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JEL - codes: M1, O3, M
Investigating the factors that diminish the barriers to university-industry collaboration

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Abstract

Although the literature on university-industry links has begun to uncover the reasons for, and types of, collaboration between universities and businesses, it offers little explanation of ways to reduce the barriers in these collaborations. This paper seeks to unpack the nature of the obstacles to collaborations between universities and industry, exploring influence of different mechanisms in lowering barriers related to the orientation of universities and to the transactions involved in work with university partners. Drawing on a large-scale survey and public records, this paper explores the effects of collaboration experience, breadth of interaction, and inter-organizational trust on lowering different types of barriers. The analysis shows that prior experience of collaborative research lowers orientation-related barriers and that greater levels of trust reduce both types of barriers studied. It also indicates that breadth of interaction diminishes the orientation-related, but increases transaction-related barriers. The paper explores the implications of these findings for policies aimed at facilitating university-industry collaboration.

Keywords: Universities, University-industry collaboration, Barriers to collaboration, Inter-organizational trust,

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Introduction

Collaboration between industry and universities faces significant challenges including the fact that these organizations are driven by different incentive systems. Universities are primarily driven to create new knowledge and to educate, whereas private firms are focused on capturing valuable knowledge that can be leveraged for competitive advantage (Dasgupta and David, 1994). In addition, universities are becoming increasingly proactive managers of their collaborations with industry, seeking to create valuable Intellectual Property (IP) for themselves. Accordingly, more and more interactions between university and industry are becoming subject to measurement and management, leading to more formal, contractual exchanges based on codified rules and regulations. This is significantly altering the nature of the interactions between universities and industry, which in the past has relied largely on informal relations.

Although both these aspects have been acknowledged in the literature on university-industry (U-I) linkages, relatively few studies have investigated the nature of the barriers and the factors that might mitigate them (see also Hall et al., 2001). Given the central importance given by policy to building and supporting U-I, the lack of research the obstacles to it is a serious hindrance to the design of effective policy.

In order to advance knowledge in this area, this paper examines two types of barriers: i) those related to differences in the orientations of industry and universities or what we describe as ‘orientation-related barriers’; and ii) barriers related to conflicts over IP, and dealing with university administration, or what we describe as ‘transaction-related barriers’. This paper explores the mechanisms can lower the degree to which firms encounter these types of barriers through an examination of three important elements that
influence the firm’s perception of these two obstacles to collaboration. First, we explore the impact of the firm’s prior experience of working on research projects with universities on the assumption that experience eases both types of barriers to collaboration. Second, we examine whether the nature of the interaction between the firm and its university partner plays a role in the perception of barriers (D’Este and Patel, 2007). In this case, we expect that in broad collaborations the barriers will be perceived as less constraining. We also investigate whether the nature of the interaction – here we contrast education-based with contract-based forms of interaction - that firms engage in with university partners positively (or negatively) influences the perception of different types of barriers. Finally, we assess how the level of trust in its university partners shapes the firm’s perception of the barriers to working with universities (Nooteboom, 2002; McEvily et al., 2003). Our approach provides a window on some of the mechanisms that may limit the depth and quality of interaction between universities and businesses.

The analysis is based on the statistical analysis of a large survey of UK firms that have collaborated on publicly funded research projects, combined with data from records of prior involvement in research collaboration with universities. The analysis shows that prior experience of collaborative research lowers orientation-related barriers and that greater levels of trust reduce both types of barriers studied. We also find that breadth of interaction diminishes the orientation-related, but increases transaction-related barriers. We explore the implications of these findings for research and policy.

**Barriers to U-I collaboration**

*Incentives and conflicts between public and private knowledge*

At the core of the obstacles to U-I collaborations are the different institutional norms
governing public and private knowledge (Dasgupta and David, 1994). The university system is rooted in Mertonian norms of science, such as communalism, universalism, disinterestedness and organized scepticism (Merton, 1973). The creation of reliable and public knowledge has been central to the growth of these organizations, leading to support from government for research to expand the pool of economically useful knowledge (Geuna et al., 2003). These institutional norms are fundamental to the way that many academics perceive and perform their work. Indeed, scientists are willing to accept lower wages in order to work within the institutions of science, indicating that many scientists are motivated by intrinsic goals as well as the social objectives of the universities (Stern, 2004; Cohen and Sauermann, 2007). The institutions of science include strong competitive mechanisms and powerful incentive regimes. The priority of establishing reputation through publication is critical to academic success and/or career sustainability. Academics often have to engage in ‘status competitions’ with their peers, based on publication records, institutional affiliations and prizes (Becher, 1989). Many of these competitions take the form of winner-takes-all, in which publishing first or winning the largest research grants precludes others from these same achievements or resources. Given this environment, much of the science system is driven by internal dynamics that are separate from market transactions (Polanyi, 1962; Dasgupta and David, 1994; Stephan, 1996). Peer esteem cannot be bought and must be created by winning favour and reputation among colleagues.

Although it might be tempting to see the science system as operating outside the confines of market transactions, it is also true that economic and social forces outside the science system itself play a powerful role in shaping scientists and science (Freeman,
1999). Much of the research supported by government is applied, or practically-oriented, and focused on solving general social, technical or economic problems using the capabilities of science (Pavitt, 2001). Scientists often hold conflicting and evolving views on the benefits of working with industry (Welsh et al., 2008). Moreover, many fields of research, such as engineering, by their nature, involve considerable interaction with industrial practice (Rosenberg and Nelson, 1994). In addition, the role of the university as an educator of professionals – doctors, engineers, accountants, lawyers, etc. – means that a large proportion of their staff is focused on fields of research that engage with practical problems. For the researchers working in such areas, practical problems provide a powerful stimulus to the development of new ideas (Rosenberg, 2002). However, although within these practical-oriented areas of research the norms of science still operate, they do so somewhat differently from the Mertonian ideal of science. Researchers in these areas are more likely to be engaged on real world problems and interacting with industry, and their status is likely to be co-determined by their reputation among their peers and their standing in industry. This is especially true in the case of engineering (Vincenti, 1990).

In contrast to the relatively open nature of the science system, the process of knowledge creation in the private sector is dominated by attempts to appropriate the economic value of what firms know in order to gain competitive advantage (Teece, 1986). This ‘private’ knowledge is largely closed, remaining hidden within the firm or disclosed in a limited way through patents filed primarily for the purposes of obtaining temporary monopolies (Allen, 1984; Dasgupta and David, 1994). This is not to say that industry knowledge is completely closed: many forms of knowledge exchange and
leakage occur between firms working in the same sector. Many firms publish academic and technical papers to signal their competencies or to defend against others’ attempts to control particular areas of technology (Hicks, 1995; Cockburn and Henderson, 1998). They may also participate in open source software projects to help lower the costs of their own development activities (von Hippel and von Krogh, 2003), and there is some evidence that firms engage in strategic trading of information with competitors (von Hippel, 1987). Despite these examples of openness, the primary motivation of firms’ knowledge creation activities is the appropriation of knowledge for private gain, and openness to external actors is used as a strategic mechanism to gain advantage over competitors (Chesbrough, 2006).

Given these two different systems of knowledge production, private firms often conflict with university researchers over the topic of research and timing and form of disclosure of research results. While researchers may be keen to disclose information to gain priority, firms may wish to keep secret or appropriate the information. To paraphrase Duguid and Brown (2000), academics wish to create ‘leaky’ knowledge so that their ideas will be acknowledged by their peers while firms want the knowledge to be ‘sticky’ so that they can control a resource that is not available to their competitors. University researchers are also likely to choose research topics that are perceived by their peers to be interesting and valuable, while firms are likely to choose topics and problems that are perceived as being valuable for the development of new products and services for their customers (Nelson, 2004). This means that the problems that each party may want to explore within a research project may be very different and the types of outputs may also diverge.
Conflicts over IP and university administration

The growth over the past 30 years of universities as economic actors in their own right, has also been important in shaping the nature of the interaction between universities and firms. The rise of the university Technology Transfer Office (TTO) and the increasing attempts of universities to capture formal IP have had a profound impact on the nature of scientific efforts (Shane, 2004). These efforts have led to an expansion in university patenting and the creation of a new commercial focus on the part of the universities to create valuable IP and exploit it for financial gain (Henderson et al., 1998; Mowery and Ziedonis, 2002). Support designed to encourage academics to engage with industrial partners can take many different forms and often varies across universities and countries. In the UK, for example, the government has launched a range of initiatives to encourage universities to capture and exploit their IP (Lambert, 2003; Chapple et al., 2005).

For some, this focus on commercialization undermines the public commons of science, weakening the institutions of open science through the imposition of private norms on public activities (Nelson, 2004). For others, the rise of the university as an economic actor creates a new motor of economic development that in the past has been rarefied and separate (Etzkowitz and Leydesdorff, 2000). Some scholars have attempted to measure the effect of engagement with industry on academic behaviour by examining the impact of patenting on individual researcher’s publication activity (Agrawal and Henderson, 2002; Calderini and Franzoni, 2004; Fabrizio and DiMinin, 2005; Azoulay et al., 2007). These studies suggest that there are complementarities between industry collaboration and scientific performance, and that those individuals that do the best research are also successful at engaging in real world problems and creating commercial
value (Rothaermel et al., 2007). Although these findings are not definitive and are liable to differ across research fields and across countries, they do suggest that academic engagement in commercial activities or with industry can have complementarities with research performance.

Apart from these results at the individual level, we know little about the effects of increasing commercial-orientation in universities on general patterns of U-I collaboration. Evidence from the US since the Bayh-Dole Act suggests that although the level of university patenting has increased since the early 1980s, the quality of these patents has declined over time (Mowery et al., 2001). Moreover, increased university patenting activity began before the Bayh-Dole Act came into force and is highly localized in a few technological fields. The pattern is similar in Europe (Geuna and Nesta, 2006). It is unclear whether the changes that have occurred in university patenting activity are a direct consequence of technological changes or of policy. Moreover, we do not know what effect these efforts at commercialization have had on the nature, frequency and types of U-I collaboration. Early research in this area by Valentin and Jensen (2007) and Fabrizio (2007) suggests that the increase in university patenting has been accompanied by a slowdown in joint research collaborations and in the pace of private knowledge exploitation across a number of technological areas. This is especially the case in areas where there was strong reliance on public science in the past. It is also clear that in some cases, attempts by universities to capture the commercial benefits from research have led to significant conflicts and disputes between universities and their industrial partners over IP and/or disclosure of results (Florida, 1999; Shane and Somaya, 2007).
For many firms, universities are too difficult to work with, and they eschew any form of university collaboration. For example, in the UK, less than 5 per cent of all the firms that have responded to recent waves of the UK innovation survey indicate that they have collaborative agreements with universities (Tether and Tajar, 2008). These low numbers are consistent across a range of European countries (European Commission, 2004) because the barriers we have identified have proved too great to enable successful collaboration. Although we know a considerable amount about the factors that lead some firms to collaborate or draw knowledge from universities (Meyer-Krahmer and Schmoch, 1998; Tether, 2002; Arundel and Geuna, 2004; Laursen and Salter, 2004), we know little about how the barriers perceived by industry to working with universities may be mitigated. Our current understanding tends to rely on information from non-collaborators, which does not provide insights into how those firms that do collaborate with universities overcome these barriers (Mohnen and Hoareau, 2003; Fontana et al., 2006).

In this paper, we focus on three potential mechanisms to reduce the obstacles to U-I collaboration experience, breadth of interaction, and inter-organizational trust. These mechanisms build on our understanding of the factors that shape successful inter-organizational as well as U-I collaboration. Our aim is to explore the mechanisms used to lower the perceived barriers to collaboration. We develop detailed arguments for each of these areas in the following section.

Factors that mitigate the barriers to interaction

Experience of collaboration

Working with universities on research projects requires not only that firms learn to work across organizational boundaries, but also that they have or can build the capabilities to
collaborate with partners operating within a different incentive system. Collaborating with a university partner requires that firms develop operating routines and practices to manage this collaboration. Establishing expectations about when and in what form the results from a joint research project will be published may be controversial, for example. However, once routines and practices have been established, they are likely to be refined and reused in subsequent collaborations. For example, problems that emerge in one project can be overcome by careful planning in subsequent projects. Thus, university collaboration is an activity in which firms learn from experience and develop richer and more refined ways of engaging with the university sector.

Not all firms are interested in this investment; they tend to fall into the categories of infrequent, intermittent or recurrent partners with universities (Hall et al., 2003; Hertzfeld et al., 2006; Bishop et al., 2008). Frequent and recurrent partners, however, are particularly likely to capitalize on their collaboration experience by transferring the information and knowledge gained through their involvement in multiple and diverse partnerships. Recurrent collaborators are also more likely to put in place the necessary routines to reconcile conflicting views on research targets (Gomes et al., 2005), dissemination of results (Hall et al., 2003), and timing of deliverables (Van Dierdonck and Debackere, 1988), among other potential sources of conflict between university and business partners, which should lower the barriers related to research orientation.

Collaboration experience should also help to lower transaction-related barriers. Research on inter-organizational alliances shows that collaboration experience is a critical determinant of the success or failure of subsequent alliances (Hagedoorn and Schakenraad, 1994). In the case of U-I links, Hertzfeld et al. (2006) find that prior
collaborative experience results in standard protocols that are used as starting points for negotiations on IP ownership, facilitating the setting up of new collaborative agreements. Also, experience is instrumental in easing negotiations on the IP for new technologies developed during collaborative projects (Hertzfeld et al., 2006; Jelinek and Markham, 2007). In addition, firms that have worked on many projects may have greater experience in negotiating IP contracts with university partners’ TTOs. They may also be more aware of differences in IP regimes across different universities, which may put them in a favourable position to negotiate with university managers compared to less experienced companies. In sum, research collaboration experience should help to lower transaction-related barriers.

**Breadth of interaction channels**

Research shows that firms draw benefits from universities via rich and varied ways (Gibbons and Johnston, 1974; Cohen et al., 2002), from joint research collaborations to consultancy work, and informal interactions in meetings and at conferences. While some links require high levels of co-ordination and sustained interaction, offering rich opportunities for knowledge exchange, others are more arm’s-length and rely on impersonal forms of exchange, such as publications. Therefore, research that accounts for only one type of linkage may miss many channels relevant to firms’ drawing knowledge from universities and, thus, may provide only a partial understanding of the overall patterns of interaction.

Involvement in a variety of channels of collaboration may contribute to better equip the firm to manage conflicts over the orientation of research for at least two reasons. First, engaging in a broad range of interaction channels creates opportunities for
organizational learning by exposing the firm to formalized and non-formalized interactions; face-to-face and arm’s length interactions; and short/targeted and long-term/open-ended interactions. There are substantial synergies between these channels: while face-to-face and frequent interactions may not require a formalized-contractual relationship, they are crucial to improving the effectiveness of formal, long-term research agreements. Second, broad engagement also contributes to strengthening the firm’s capacity to balance and align conflicting interests arising from the distinct system of incentives between academia and industry (D’Este and Patel, 2007).

However, interactions with universities facilitated by many different channels may also lead to increased transactional conflicts, as many more parts of the university are engaged in the relationship. Each channel of interaction may engage a different part of the university, leading to increased levels of engagement with the university administration and its many rules and procedures. For example, informal relationships with academic faculty on education-related matters, such as student secondments, are likely to involve very different parts of the university administration than interactions with university research services departments for joint research projects. The different university actors (TTO, research services, departmental administrators, etc.) may have conflicting agendas and diverse levels of experience of working with industry. Therefore, interacting across different channels can entangle firms in many messy and labour intensive interactions with the university, which firms used to operating along a narrow line of interaction will find problematic. In sum, it can be expected that working across different channels may raise transaction-related barriers, while at the same time the increased breadth of interaction will lower orientation-related barriers.
Inter-organizational Trust

U-I research collaboration involves high levels of uncertainty because the research process is beset with many unknowns. Given this, it is almost impossible to specify in advance the follow-on implications for the disclosure and commercialization of the research. Under such conditions, collaboration partners may seek to take advantage and act opportunistically to appropriate the benefits of the collaboration (Williamson, 1993). High levels of trust, on the other hand, help to reduce the fears that one of the partners will act opportunistically (Bradbach and Eccles, 1989). Here, trust is defined as “the expectation that a partner 1) can be relied on to fulfil obligations; 2) will behave in a predictable manner; and 3) will act and negotiate fairly when the possibility for opportunisms is present” (Zaheer et al., 1998: 142). Trust allows the partners involved in the exchange to be confident that their collaborator will treat them fairly and in a consistent way, and will help to resolve any problems that may arise jointly. Therefore, trust may help to lower perceived barriers to collaboration.

Moreover, in order to render the research collaboration effective, firms and universities will have to share knowledge and information. This knowledge and information may be proprietary and tacit, which makes its exchange difficult. If a collaboration is characterized by low levels of trust, partners are less likely to be forthcoming about the knowledge and information required to make the collaboration successful (Inkpen and Tsang, 2005). Thus, higher trust between partners stimulates rich social and information exchanges and encourages partners to exchange more and valuable knowledge and information (Ring and Van de Ven, 1992). Moreover, trust-based relationships facilitate the exchange of difficult to codify knowledge and information,
which is by definition difficult to communicate and to trade in markets (Kogut and Zander, 1992). Trust expresses the capacity of firm and university to work together to resolve problems, and demonstrates a willingness to understand and adjust behaviours to align with the needs and expectations of partners (McEvily et al., 2003). For these reasons, it can be expected that high levels of trust will be associated with lower orientation-related and transaction-related barriers.

Data, method and empirical approach

Since our study is designed to capture industry attitudes to collaboration, we conducted a survey of firms that have collaborated with universities. To construct the sampling frame for our study, we drew on the records of research projects funded by the Engineering and Physical Sciences Research Council (ESPRC). The EPSRC is the UK’s largest funding council, providing over £700 million each year to university researchers to conduct new research. The remit of the ESPRC is broad and includes areas of the engineering and physical sciences, including engineering disciplines, mathematics, chemistry and physics. Thus, our study includes a broad range of scientific areas and neutralizes the strong life-sciences bias that pervades much of the literature on U-I links. In order to ensure complete records, we surveyed all the private, for-profit organizations with formal involvement in EPSRC collaborative projects between 1999-2006. After cleaning the records for duplicates, we obtained a sample of 3,119 different organizations. The survey was addressed the person responsible for the university collaboration within the organization. In addition, to ensure that our individual level responses were representative of views of their wider organization, we included a top up sample of 312
individuals that were listed as the second contact name on the collaboration. This approach left us with a final sample of 3,431 individuals.

The sampling method in our study does not allow us to explain why firms collaborate with universities, which is a topic that has been extensively covered in prior research. Instead, we offer evidence on firms’ perceptions of the barriers to collaboration among those that have engaged in cooperation with universities. This allows us to provide information based on actual experience of collaboration rather than the perceptions of non-collaborating firms, which inevitably reflect general attitudes to universities rather than real experience of university collaboration.

The unit of analysis for our survey is the business unit which we defined as “an organizational unit producing goods or services which benefits from a degree of autonomy in decision making, especially for the allocation of its resources”. This definition is consistent with the UK innovation surveys (Stockdale, 2002). We decided to focus on the business unit because some of the firms in our sample are large, multi-site organizations. As U-I collaboration is often local in character, collaboration between business units and universities is likely to be decided locally rather than centrally (Cantwell, 1989; Criscuolo, 2005). Our analysis also distinguishes between subsidiaries and independent organizations.

In past studies, scholars have tended to focus on projects rather than business units when assessing the nature of the barriers to collaboration (Hall et al., 2001). Our choice to focus on the business unit is also because many of the organizations in our sample are involved in more than one project. For example, more than ten organizations in our sample have had involvement in more than 40 different research projects. Although
focusing on project-level interactions can uncover important issues arising from exchanges within a project, the limitation is that it captures information on only one among what may be a portfolio of projects. The barriers that emerge in one project may have been resolved in another project, even with the same university and industry partners. Also, focusing on a single research project can obscure the different relationships likely to be in place between the firm and its university partners, such as student training or contract research, and how these broad forms of interaction shape the nature of the barriers faced by firms in their engagement with universities in general. By capturing information at the level of the business unit, we go beyond the confines of a single project and explore the more general pattern of relations between the firm and its university partners.

To develop the survey questionnaire, we conducted a number of interviews with industry and with academics as well as reviewing the literature. The survey asked about the barriers to interacting with universities and the frequency of interaction by types of engagement (Cohen et al., 2002). Responses were based on an extensive list of barriers and types of engagement, described below. Factual questions, such as number of times the firm engaged in different channels of interaction, referred to the period 2005-2006. The survey also included a series of questions on respondents’ organizations: size, sector, R&D expenditure, share of staff with higher education degrees, and ownership.

Data collection was done in several stages. First, in November 2007, we wrote to 3,431 individuals in our sample with an invitation to the individual to go to a website to complete an electronic version of the survey. The invitation included a letter from Professor David Delpy, Chief Executive of the EPSRC, endorsing the study. This first
stage elicited 276 responses. To improve the response rate, we telephoned non-
respondents to encourage them to respond. This yielded another 176 responses. In the
second stage and again to improve the response rate, we conducted another postal survey
in February 2008, this time including a paper copy of the questionnaire in order that
respondents had the choice of an electronic or paper-based version. This second stage
yielded another 188 responses. In the third stage, we used the email addresses collected
from the telephone contacts with organizations to send email reminders to non-
respondents for whom we had email addresses. This yielded another 13 responses giving
us a total of 646 usable responses, representing 602 organizations (44 responses were
from individuals in the same firm and were excluded). Based on a total survey population
of 3,431, the response rate was just under 20 per cent. After removing questionnaires
with incomplete information, or from individuals in the same organization (we took the
average scores for these), we were left with a sample 503 organizations for analysis. The
sample covers a diverse range of firms, with representation from organizations of
different sizes, across all sectors, including professional services.

To check the reliability of our sample, we conducted a number of tests on the
respondent population. First, we compared early and late respondents: we found no
significant differences in terms of structural features, such as size, sector or R&D
intensity or attitudes to collaboration (Armstrong and Overton, 1977). Second, we
compared the responses from two or more respondents form the same organization and
we found that individual responses were highly correlated. This indicates that the
responses reflect general organizational practice rather than individual attitudes. Finally,
we compared between electronic and paper-based responses to the survey and found no significant differences. These tests increase confidence that the survey data are reliable.

**Measures**

**Dependent variable**

As discussed above, barriers to U-I collaboration are based on: 1) differences in incentives and orientation (orientation-related barriers); and 2) conflicts over IP and university administration procedures (transaction-related barriers). To capture the extent to which firms indicated that they faced orientation- and transaction-related barriers in working with universities, we drew on the responses to a question about the general barriers to interaction with universities. Respondents were asked to indicate their level of agreement with 12 statements concerning some likely barriers to interaction with universities. The items were developed based on interviews with industry organizations and the literature on barriers to knowledge exchange between universities and industry.

To construct our measure of *orientation-related barriers*, we focused on the three items directly related to the orientation of university research and researchers. These are: university research is extremely orientated towards pure science; long term orientation of university research (concerns over lower sense of urgency of university researchers compared to industry researchers); and mutual lack of understanding about expectations and working practices. Each item is measured on a five point likert scale from ‘strongly agree’ to ‘do not agree at all’ and is coded 1 if respondents indicate that they ‘agree’ or ‘strongly agree’ with the statement, and 0 otherwise. To calculate the variable *orientation-related barriers*, we added these scores so that each organizations scored 0
for no barriers and a score of 3 when all orientation-related barriers are perceived as high.¹

The second type of barrier is related to conflicts over IP with the TTO, and negotiation with university administrations or what we term *transaction-related barriers*. Previous research shows that there are often conflicts between industry and universities over IP ownership (Shane and Somaya, 2007) and also that universities may have unrealistic expectations about the commercial potential of university research (Clarysse et al., 2007), which can result in their overvaluing its IP. These types of conflicts with TTOs and university administration may put a significant strain on collaborations, eventually deterring firms from collaborating with university. The measurement of transaction-related barriers includes the following four items from the question on barriers: industrial liaison offices tend to oversell research or have unrealistic expectations; potential conflicts with university regarding royalty payments from patents or other intellectual property rights and concerns about confidentiality; rules and regulations imposed by universities or government funding agencies; and absence or low profile of industrial liaison offices in the university (which was reverse coded). Our transaction-related barriers measure was created using the method described for orientation-related barriers.²

*Explanatory variables*

We measured *collaboration experience* as the total length (in months and in log scale) of research experience of working on collaborative projects with universities, funded by the

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¹ As alternative measures, we used average and aggregate scores for both dependent variables. The results from this analysis are consistent with those reported below.

² In order to apply fractional response regression (see below), we normalize the variable by dividing by the highest barriers perceived, so that the resulting variable takes a minimum value of 0 and a maximum of 1.
EPSRC, that the organization had accumulated in the period 1991-2004.\(^3\) This measure offers a composite measure of experience, taking into account that firms may be involved in more than one project and that these projects may span different universities and different periods. The approach offers a more fine-grained operationalization than just taking numbers of years the organization has collaborated with universities or total number of projects.

In order to capture the *breadth of interaction* between businesses and universities, we created a variable measuring the extent to which organizations use different types of interactions with universities during the period 2005–2006. This information was taken from the survey question on channels of interaction between firm and university. Building on D’Este and Patel (2007), we examined the broad range of channels through which organizations can interact with universities. We focus on joint research projects, contract research, consultancy, training of firm employees; postgraduate training in the company; recruitment of recent graduates or postgraduates; and student placements. To construct the variable, we used a binary code for each channel of interaction, which takes the value of 1 if the firm reports having used a given interaction channel, and 0 otherwise. We then simply added up the seven interaction channels to represent the *breadth of interaction*.

Since the nature of industry-university interactions may have a distinctive effect on the barriers, we also considered two other measures for breadth of interactions: a variable that captures more informal interactions related to the educational role of universities, including the items ‘training of firm employees’, ‘postgraduate training in the company’,

\(^3\) We took account of records up to 2004 in order to avoid an overlap with the time frame of the questionnaire, which asks firms to report information for the period 2005-2006.
‘recruitment of recent graduates or postgraduates’ and ‘student placements’. We term this variable *education-based interaction*. We created another variable to capture more formal interactions between industry and universities through contractual relationships, including the items ‘joint research projects’, ‘contract research’, and ‘consultancy’. We call this variable *contract-based interaction*.

Building on Zaheer et al.’s (1998) inter-organizational trust scale, we measured level of trust through four statements measured on a five-point likert scale. The items include: our university partners may use opportunities that arise to profit at our expense (reverse coded); based on past experience, we cannot have complete confidence in our university partners to keep promises made to us (reverse coded); we trust our university partners to treat us fairly; and we trust that confidential/proprietary information shared with our university partners will be kept strictly confidential. As might be expected for such a well-established scale, the Cronbach Alpha was high at .83.

**Control variables**

We also included several other variables that may have an influence on the level of barriers that firms face when interacting with universities. First, we control for organization’s level of absorptive capacity. There are several proxies in the literature used to measure absorptive capacity (Cohen and Levinthal, 1990; Lane et al., 2006). Drawing on Rothwell and Dodgson (1991) and Schmidt (2005), we measure level of *absorptive capacity* as the percentage of staff with a higher education degree. We chose not to adopt one of the most common operationalizations of absorptive capacity - R&D intensity - because of the high number of service firms (over 35%) in our sample. R&D intensity may underestimate the absorptive capacity of service firms because these firms
typically have modest R&D budgets or do not conduct formal R&D, but they may have high levels of absorptive capacity. The variable is categorical and ranges from 1 to 5: 1 = percentage of higher education staff equal to or less than 10%; 2 = percentage of higher education staff between 11% and 20%; 3 = percentage of higher education staff between 21% and 40%; 4 = percentage of higher education staff between 41% and 60%; and 5 = percentage of higher education staff between 61% and 100%. We used a categorical approach because we wanted to reduce the burden for respondents.\footnote{We also conducted an additional analysis where we substituted R&D intensity for percentage of staff with higher education degrees. Again, the results were consistent, suggesting our main results did not change according to the control used for absorptive capacity.}

Second, we include a measure for firm size, i.e. the logarithm of the number of employees, expressed in full-time equivalents, as a control variable; large firms are likely to have more resources to work with external organizations such as universities (Tether, 2002; Mohnen and Hoareau, 2003). Third, we control for the nature of the firm’s organizational structure. This dummy variable identifies firms that are independent rather being part of a large group. We would expect organizations that belong to a group to have more resources for and more experience of working with universities and, therefore, to face lower barriers to collaborations. Fourth, since we rely on individuals to report information for the organization, it is important to account for differences among these individuals in terms of their educational backgrounds. Individuals with doctoral degrees are likely to be more familiar with university norms compared to individuals with only undergraduate degrees. We wanted to ensure that our results were not biased by the fact that surveys were addressed to named research collaborators, which might have increased the tendency for respondents to respond more positively to questions about barriers to universities than individuals not directly involved in the research. In order to control for
this, we include a dummy variable that equals 1 if the respondent has a doctoral degree and 0 otherwise. Finally, we also include eight dummy variables to account for inter-industry differences in patterns of U-I interaction.

**Method of estimation**

Our dependent variable (total barriers) takes on non-negative integer values and therefore is a count variable. A commonly used method of estimation is the Poisson regression model (or negative binomial regression in the case of overdispersion). However, since our dependent variable is restricted by an upper bound (i.e. the maximum number of barriers is four), Poisson or Negative Binomial distributions are not strictly applicable. An alternative approach is an ordered logistic model; however, this would imply a natural ordering in the level of barriers, which may not apply. Instead, we build on a technique provided by Wooldridge (2002: 661), who suggests that a dependent variable may be “obtained by dividing a count variable by an upper bound”, and that such an approach allows the application of fractional logit regression (Papke and Wooldridge, 1996). This approach, models $E(y \mid x)$ as a logistic function, where $y$ is the dependent variable and $x$ is a set of regressors: $E(y \mid x) = \exp(x\beta)/[1 + \exp(x\beta)]$. This model ensures that the predicted values of $y$ are in $(0, 1)$ and that the effect of any $x_j$ on $E(y \mid x)$ diminishes as $x\beta \to \infty$. The method is non-linear and can be estimated using quasi-maximum likelihood, and partial effects may be “evaluated at the $\hat{\beta}_j$ and interesting values of $x$”. (Wooldridge, 2002: 662).

**Results**

To understand the nature of university barriers to collaboration, we first explore the different obstacles that organizations face. Table 1 lists the seven barriers to university
interaction and the percentage of small and medium sized enterprises (SMEs) and large firms that indicated agreement with the different statements on these barriers to interaction with universities.\textsuperscript{5} Overall, we find that differences between SMEs and large companies are relatively small, with both types of firms indicating that orientation-related barriers are lower than transaction-related one. As might be expected, SMEs perceive the barriers related to the long-term orientation of universities and to the rules and regulations imposed by universities or government funding agencies as higher than larger firms.

-- Insert Table 1 here --

Table 2 presents the differences in orientation-related barriers across industry and the variation between sectors on the importance of different barriers. We find that orientation-related barriers are highest in the machinery and metals, transport, and utilities and construction industries, while firms in chemical-related industries have the lowest proportion of firms reporting a high number of orientation-related barriers. Again, this might be expected given that the chemical-related industries include many science-based firms, for example pharmaceuticals firms.

-- Insert Table 2 here --

Table 3 presents the differences in terms of transaction-related barriers across different industries. The table shows that firms operating in the chemical and transport industries report the highest number of transaction-related barriers while those in utilities and construction have the lowest proportion of firms reporting a high number of transaction-related barriers. Thus, we can see that for firms in the transport industry both

\textsuperscript{5} Following the EU definition, SMEs are organizations that are autonomous, that employ less than 250 people, and whose annual turnover does not exceed €50 million or whose annual balance sheet total does not exceed €43 million.
orientation-related and transaction-related barriers are high. Also, firms active in utilities and construction face high orientation-related barriers, but low transaction-related barriers. The high levels of the barriers in these industries may be result of lower levels of scientific activity in these sectors and thus fewer capabilities to collaborate with universities.

--- Insert Table 3 here ---

Table 4 reports the descriptive statistics and correlation matrix of the independent variables in the model. Overall, the level of correlation between the main variables is low, suggesting that multicollinearity is not a concern.

--- Insert Table 4 here ---

In the first stage of analysis (Models 1a and 1b - Table 5), we enter only the control variables. It can be seen that absorptive capacity (percentage of higher educated staff) is negatively associated with orientation-related barriers. Further, larger firms perceive higher transaction-related barriers, and individuals with doctoral degrees are more inclined to perceive higher transaction-related barriers to interactions with universities.

--- Insert Table 5 here ---

In Models 2a and 2b, we introduce our key explanatory variables. First, we suggested that organizations with more collaboration experience will perceive fewer barriers than their less experienced counterparts. The coefficient of prior collaboration experience is negatively associated with barriers related to differences in orientation (- .05; p ≤ .01), but not to barriers related to transactions-related conflicts. This suggests that routines learnt through conducting joint research with universities, lower the barriers related to the long-term nature of university research, helping to overcome differences
between the partners on time horizon. However, experience of working with universities does not lower the perceived barriers related to university administrative procedures and conflicts over IP. Therefore, experience plays only a partial role in mitigating the barriers to U-I collaboration. To complement, these results we undertook several more analyses exploring different measures of experience, such as number of projects, number of university partners and research project size. The results (which are not shown for reasons of space) are consistent with those reported above.

Next, we suggested that breadth of interaction is likely to be associated with lower orientation- and transaction-related barriers. The results show an interesting swing in the relationship between breadth of interaction and orientation-related and transaction-related barriers, respectively: while the coefficient is significant and negative in the case of orientation-related barriers (-.06; \( p \leq .01 \)), it is significant and positive for transaction-related barriers (.12; \( p \leq .001 \)). These findings cast light on how broader U-I ties can have both a positive and a negative effect on the barriers to collaboration. The fact that breadth of engagement is negatively associated to orientation-related barriers suggests that collaboration involving multiple channels allows firms to cope better with the problems associated with divergent priorities and time horizons in the research. It also indicates firms’ willingness to invest across many areas of engagement enables the building of routines for long-term and mutually beneficial exchanges. However, working with universities involving many different channels is also likely to involve negotiation with more university actors, including different administrative departments and possibly the TTO. As a result, broad patterns of engagement might mean involvement in numerous and lengthy interactions with university administrators, who are likely to be highly risk
averse and may be responding to differing agendas and mandates. Thus, broad engagement may raise greater transaction-related barriers to collaboration.

Finally, as expected, the coefficient of inter-organizational trust is negative and significant in Models 2a (-.75, p ≤ .001) and 2b (-.37, p ≤ .001), indicating that high trust in university partners is associated with lower barriers. It is interesting that trust reduces both orientation-related and transaction-related barriers. This may be because trust relies on strong bonds of mutual understanding and adjustment and, therefore, helps firms to manage their different expectations of the research and to lower the considerable transaction costs of working with university partners.

Table 6 presents the results for influence of education-based and contract-based interactions on orientation-related barriers and transaction-related barriers respectively. There is a strong negative association between education-based interactions and orientation-related barriers (-.08, p ≤ .01), but not contract-based interactions (-.03). Also, we find that both types of interaction have a strong positive influence on the number of transaction-related barriers: .11, p ≤ .05 for education-based interactions and .13, p ≤ .001 for contract-based interactions. The effects of the other explanatory and control variables do not change. These results show that those interactions that involve informal and frequent face-to-face contacts contribute significantly to attenuating the orientation-related barriers, while broader interactions (both education and contract-based) increase the extent of transaction-related barriers. These findings support the above results suggesting that the differential effect of breadth of interactions on perceived barriers increases transaction-related barriers but lowers orientation-related barriers. These
findings highlight the importance of education-based interactions for breaking down orientation-barriers.

-- Insert Table 6 here --

Conclusions and implications

Although it there has been recognition that there are substantial barriers to successful collaboration and knowledge exchange between universities and firms, few studies have attempted to measure and map these perceived barriers or investigate what may attenuate them. From our analysis it is clear that many types of barriers plague collaboration between industry and universities - from orientation of the university and its researchers, to attitudes and behavior of university administration and the TTO. Although the ‘classic’ barrier to U-I collaboration – the university’s long-term orientation – remains substantial, other factors are important in constraining collaboration, especially those related to IP and administrative procedures.

Some authors argue that IP-related barriers have become more prevalent in U-I interactions as a consequence of policies designed to encourage universities to increase the commercialization of research and to adopt a more aggressive strategy towards negotiations over IP (Siegel et al., 2003; Hertzfeld et al., 2006). While our study does not address these aspects directly, it does show that transaction-related barriers are much more difficult to mitigate than orientation-related barriers. In particular, while collaboration experience and breadth of interactions equip firms to handle (and potentially overcome) barriers related to conflicts of interest in research priorities, they do not help firms to handle IP-related barriers. In this respect, we show that transaction-related barriers are particularly sensitive to government policy and higher education
governance. For instance, changes in the system of governance of U-I collaboration in the UK to favour the involvement of an increasing number of parties both within the university (e.g. university research contracts office, TTO, the department) and the firm (e.g. the IP office, research labs and firm headquarters). This trend is likely to exacerbate IP-related barriers since multiple collaborations can increase both the costs and time required to build new collaborations. At the same time, older and more informal systems of exchange and collaboration are coming under increasing scrutiny from university administrators. Such efforts to bring exchanges and interaction ‘in from the cold’ could have the effect of raising transaction-related barriers, especially if these efforts are organized around the requirements of central university rules and regulations. Thus, increasing attention to the management of U-I links through government policy efforts and university administration could increase the barriers to such interactions. It would be unfortunate if the efforts to manage (and potentially support) these interactions results in increasing the barriers. The challenge for policy, then, is to find straightforward, simple mechanisms for management and monitoring of U-I interactions. Achieving this will require attention to the costs and benefits of management and monitoring efforts, and the weighing of the value of monitoring against negatively perceived intrusion.

An important finding from this study is that inter-organization trust is one of the strongest mechanisms for lowering the barriers to interaction between universities and industry. It suggests that the traditional system of informal reciprocity and exchange, which dominated U-I exchanges in the postwar era, should be an important part of attempts to support and build U-I collaborations. Building trust between academics and industrial practitioners requires long-term investment in interactions, based on mutual
understanding about different incentive systems and goals. It also necessitates a focus on face-to-face contacts between industry and academia, initiated through personal referrals and sustained by repeated interactions, involving a wide range of interaction channels and overlapping personal and professional relationships.

Future research and limitations

Understanding the perceived barriers to U-I collaboration is important because it uncovers the problems and challenges that have emerge in the U-I collaboration process. Much of the research on U-I links relies on secondary information on the problems and challenges involved in collaboration and very little on information from firms actually involved in these collaborations. The present study looks at the mechanisms that may mitigate the barriers to U-I collaboration, and may help to set in place programmes that will alleviate the problems before they undermine what might be rewarding sets of collaborations.

Our study focuses on one period, which makes it difficult to draw inferences about the direction of causality. Future research should explore the barriers over time, and examine the factors that lower or raise the barriers to collaboration. It may be that policy interventions, such as new university IP policies or changes in university funding regimes, will have a significant impact on the perceived barriers. Currently, we do not have the appropriate data to map the barriers to collaboration over time. Relying on secondary sources, such as patents or academic citations, may obscure important institutional changes within the collaboration process itself. New and careful efforts are required to monitor the health of U-I collaboration and should include study of collaboration across different areas of research, as opposed to a focus on only the life
sciences where patterns of collaboration may be more easily monitored through established indicators.

Future research should also examine the impact of barriers on the outcomes of collaboration. Although it is assumed that these barriers hinder effective knowledge exchange, we do not have evidence on how the perceived barriers shape subsequent collaborations. For example, it would be useful to know whether a bad experience of university collaboration deters the firm from future collaboration with a university. In this paper, we focused on a sample of firms that had been involved in formal research projects, but many firms never get this far in their interactions with universities. For most firms, U-I interaction involves a long process of learning through small steps, such as enabling student placements through to more extensive engagement. We know little about firms’ progression from informal, infrequent interactions to long-term, sustained collaboration with universities. An understanding of this progress may offer the greatest potential for effective policy measures to support U-I collaboration.
References


Allen, J.T., 1984, Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information within the R&D Organization (MIT Press, Cambridge (MA)).


Becher, T., 1989, Academic tribes and territories - intellectual enquiry and the cultures of disciplines (The Society for Research into Higher Education & The Open University, Milton Keynes).

Bishop, K., P. D’Este and A. Neely, 2008, Gaining from interactions with universities: multiple methods for nurturing absorptive capacity. (Copenhagen)


D'Este, P. and P. Patel, 2007, University–industry linkages in the UK: what are the factors underlying the variety of interactions with industry?, Research Policy 36, 1295-1313.


Fabrizio, K. and A. DiMinin, 2005, Commercializing the laboratory: faculty patenting and the open science environment,


Hicks, D., 1995, Published papers, tacit competencies and corporate management of the public/private character of knowledge, Industrial and Corporate Change 4, 401-424.


Schmidt, T., 2005, Absorptive capacity: one size fits all? A firm analysis of absorptive capacity for different kinds of knowledge, Mannheim)


Vincenti, W., 1990, What Engineers Know and How They Know It (John Hopkins Press, Baltimore).


Tables and Figures

Table 1: Type of barriers to university interaction for SMEs and large firms
(% of firms that indicated that they agree or strongly agree with the item in the questionnaire)

<table>
<thead>
<tr>
<th>Type</th>
<th>Barrier</th>
<th>SME</th>
<th>Large firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation-related</td>
<td>University research is extremely orientated towards pure science</td>
<td>31</td>
<td>36</td>
</tr>
<tr>
<td>barriers</td>
<td>Long term orientation of university research (concerns over lower sense of urgency of university researchers compared to industry researchers),</td>
<td>69</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Mutual lack of understanding about expectations and working practices</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Transaction-related</td>
<td>Industrial liaison offices tend to oversell research or have unrealistic expectations,</td>
<td>50</td>
<td>49</td>
</tr>
<tr>
<td>barriers</td>
<td>Potential conflicts with university regarding royalty payments from patents or other intellectual property rights and concerns about confidentiality,</td>
<td>57</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>Rules and regulations imposed by universities or government funding agencies,</td>
<td>58</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Absence or low profile of industrial liaison offices in the university (reverse coded)</td>
<td>27</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 2: Number of orientation-related barriers to university interaction, by sector

<table>
<thead>
<tr>
<th>Industrial sector</th>
<th>Number of firms</th>
<th>Number of Orientation-related barriers (%) of firms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Chemical</td>
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<tr>
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<tr>
<td>Machinery and Metal</td>
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<tr>
<td>Electronics and Instruments</td>
<td>70</td>
<td>27</td>
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<tr>
<td>Transport</td>
<td>15</td>
<td>27</td>
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<tr>
<td>Utilities and Construction</td>
<td>46</td>
<td>22</td>
</tr>
<tr>
<td>Business services</td>
<td>182</td>
<td>27</td>
</tr>
<tr>
<td>Other</td>
<td>77</td>
<td>29</td>
</tr>
</tbody>
</table>
Table 3: Number of transaction-related barriers to university interaction, by sector

<table>
<thead>
<tr>
<th>Industrial sector</th>
<th>Number of firms</th>
<th>Number of Transaction-related barriers (% of firms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical</td>
<td>37</td>
<td>0 1 2 3 4</td>
</tr>
<tr>
<td>Chemical-related</td>
<td>23</td>
<td>0 5 19 30 30 16</td>
</tr>
<tr>
<td>Machinery and Metal</td>
<td>53</td>
<td>9 17 21 32 25 6</td>
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<td>Electronics and Instruments</td>
<td>70</td>
<td>10 19 34 29 9</td>
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<td>0 47 13 27 13</td>
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<td>24 43 13 20 0</td>
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<tr>
<td>Business services</td>
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<td>12 25 36 22 5</td>
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<tr>
<td>Other</td>
<td>77</td>
<td>17 29 29 17 9</td>
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</table>
### Table 4. Descriptive statistics and correlation matrix of independent variables

<table>
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<tr>
<th>Variable</th>
<th>Mean</th>
<th>S.D.</th>
<th>Min</th>
<th>Max</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<tr>
<td>1. Orientation-related</td>
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<td></td>
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<td>2. Transaction-related</td>
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<td>3. Collab. Experience(^a)</td>
<td>157.60</td>
<td>491.67</td>
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<td>-.06</td>
<td>.01</td>
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<td>4. Breadth of interaction</td>
<td>3.64</td>
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<td>7</td>
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<td>.18</td>
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<td>5. Education-based</td>
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<td>6. Contract-based</td>
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<td>.40</td>
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<td>7. Inter-organizational</td>
<td>3.65</td>
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<td>1.25</td>
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<td>8. Absorptive capacity</td>
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<td>1.54</td>
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<td>5</td>
<td>-.10</td>
<td>.07</td>
<td>-.09</td>
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<td>.03</td>
<td>.08</td>
<td>.03</td>
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<td>9. Size</td>
<td>4.46</td>
<td>2.33</td>
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<td>11.51</td>
<td>-.01</td>
<td>-.03</td>
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<td>.00</td>
<td>.02</td>
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<td>-.19</td>
<td>-.15</td>
<td>.10</td>
<td>.44</td>
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<tr>
<td>11. Doctoral</td>
<td>.48</td>
<td>.50</td>
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<td>.20</td>
<td>.03</td>
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<td>.23</td>
<td>-.01</td>
<td>.16</td>
<td>.09</td>
<td>.07</td>
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</table>

Note: Coefficients with an absolute value above .09 are significant at the .05 level, two-tailed. Industry dummies are not reported. \(^a\)For prior collaboration experience, natural logarithm is used in correlations and analysis but actual values are reported in descriptive statistics.
Table 5. Fractional logit regression estimates of orientation-related and transaction-related barriers to interaction

<table>
<thead>
<tr>
<th>Control variables</th>
<th>Orientation-related barriers</th>
<th>Transaction-related barriers</th>
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<tbody>
<tr>
<td>Absorptive capacity</td>
<td>Model 1a</td>
<td>-.08*</td>
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<td>Size</td>
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<td>.01</td>
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<tr>
<td>Independent</td>
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<td>-.13+</td>
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<td>.13</td>
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<td>Industry dummies</td>
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<td>Yes</td>
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Explanatory variables

<table>
<thead>
<tr>
<th></th>
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<th>Transaction-related barriers</th>
</tr>
</thead>
<tbody>
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<td>Collaboration experience</td>
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<td>.00</td>
</tr>
<tr>
<td>Breadth of interaction</td>
<td>-.06**</td>
<td>.12***</td>
</tr>
<tr>
<td>Inter-organizational trust</td>
<td>-.75***</td>
<td>-.37***</td>
</tr>
</tbody>
</table>

Log pseudolikelihood -133.20 -101.11 -52.58 -32.60

df (residual) 491 488 491 488

No observations 503 503 503 503

*** p ≤ .001, ** p ≤ .01, * p ≤ .05, + p ≤ .10; one-tailed. Standardized coefficients are reported. Standard errors are in parentheses.
Table 6. Fractional logit regression estimates of orientation-related and transaction-related barriers to interaction involving education-based and contract-based interaction

<table>
<thead>
<tr>
<th></th>
<th>Orientation-related barriers</th>
<th>Transaction-related barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 3a</td>
<td>Model 4a</td>
</tr>
<tr>
<td>Control variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absorptive capacity</td>
<td>-.08***</td>
<td>-.08**</td>
</tr>
<tr>
<td>Size</td>
<td>-.01</td>
<td>-.01</td>
</tr>
<tr>
<td>Independent</td>
<td>-.13</td>
<td>-.12</td>
</tr>
<tr>
<td>Doctoral</td>
<td>.13</td>
<td>.11</td>
</tr>
<tr>
<td>Industry dummies</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Explanatory variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collaboration experience</td>
<td>-.05**</td>
<td>-.05**</td>
</tr>
<tr>
<td>Education-based interaction</td>
<td>-.09**</td>
<td>-.08**</td>
</tr>
<tr>
<td>Contract-based interaction</td>
<td>-.05</td>
<td>-.03</td>
</tr>
<tr>
<td>Inter-organizational trust</td>
<td>-.74***</td>
<td>-.73***</td>
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<tr>
<td>Log pseudolikelihood</td>
<td>-101.01</td>
<td>-102.27</td>
</tr>
<tr>
<td>df (residual)</td>
<td>488</td>
<td>488</td>
</tr>
<tr>
<td>No observations</td>
<td>503</td>
<td>503</td>
</tr>
</tbody>
</table>

*** p ≤ .001, ** p ≤ .01, * p ≤ .05, + p ≤ .10; one-tailed. Standardized coefficients are reported. Standard errors are in parentheses.