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Crossing the Rubicon: exploring the factors that shape academics' perceptions of the barriers to working with industry

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Although academics are under increasing pressure to engage industry in their research, they often find it difficult to do so. Conflicts with industry over the timing of disclosure and the choice of topics are common. Moreover, collaborations with industry may require academics to negotiate formal contracts about the ownership of intellectual property. To help understand the factors that might mitigate these conflicts, this paper examines how the professional and collaborative experiences of academics shape their perceptions of the barriers to industry collaboration. Using a rich dataset of UK academics, we find that perceived barriers to collaboration are lower for academics with industrial and collaborative experience and for those who trust their industry partners. However, for the transactional costs of industry engagement, we find entrepreneurial experience and the diversity of methods used to collaborate with industry increases the perceived barriers to collaboration.

Key words: Industry–university collaboration, Barriers to collaboration, Universities, Academic entrepreneurship
JEL classifications: O31, O38

1. Introduction

The prestige of universities is increasingly defined in terms of both the generation of high-quality research and the success in transferring scientific findings into commercial development (Etzkowitz *et al.*, 2000). Although the empirical literature on knowledge transfer has helped to uncover many facets of university–industry relationships, we still

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know little about the formation of scientists' perceptions of the costs (and benefits) associated with these relationships. As Owen-Smith and Powell (2001) point out, scientists' perceptions of these costs and benefits are crucial to understanding their willingness to participate in knowledge transfer activities. Indeed, without academics' willingness to participate, there would be relatively little knowledge transfer between universities and industry. So, by understanding academics' views about the barriers to industry engagement, it is possible to gain insights into the nature and drivers of university–industry collaboration.

It has long been recognised that academics and industry operate within different institutional settings, with potentially conflicting norms and incentives. In an extreme case, Polanyi (2000 [1962]) described science as a republic that was 'ex-territorial' from the rest of the society. In Merton's highly idealised account of institutional norms of science, there were seen to be strong differences between academics and industrial scientists and engineers (Merton, 1973). These conflicts stem from the nature of information disclosure, choice of research topics and long-term orientation of research. This Mertonian theme of orientation conflict between academics and industry has been widely cited as a barrier to university–industry collaboration (Dasgupta and David, 1994). Alongside these orientation-related problems, other forms of conflict can arise between academics and their industry partners. University–industry collaborations often take place under formal scrutiny and management by universities, and are subject to conflicts about the ownership of the intellectual property (IP) rights arising from academics' research efforts (Siegel *et al.*, 2004; Rhoten and Powell, 2007; Wright *et al.*, 2007). Indeed, it could be argued that university–industry collaborations increasingly resemble collaborations in the private sector, as they require prior agreements about background and foreground IP, and clear statements about the ownership of outcomes arising from the research. In the face of these changes, academics are becoming more aware of transaction costs of industry collaboration (Williamson, 1987)—the costs of dealing with the requirements governing industry and commercial engagement. Such costs can act as an important set of barriers that are somewhat distinct from conflicts about the orientation of research.

Although much has been made of the various conflicts between academics and industry, there are few, if any, studies that have examined factors that shape academics' attitudes towards barriers to engagement and which factors alleviate these negative attitudes or conflicts. When looking at industrial firms, Bruneel *et al.* (2010) found that different factors shape the perception of different types of barriers to collaboration with university, and that collaboration experience and trust were critical to breaking these down. Yet we lack understanding of the nature of the barriers faced by academics. Past research on academics' engagement decisions have tended to focus on the positive aspects of collaboration, exploring the motivations to engage in different types of collaboration (D'Este and Perkmann, 2010; Lee, 2000; Baldini *et al.*, 2007), while ignoring the negative aspects of this relationship. However, this approach says little about how academics overcome barriers and how experiences of academics can mitigate their perception of the barriers to industry collaboration. Given that the decision to engage lies with individual academics who have to weigh the costs and benefits of collaboration, the lack of attention to the negative aspects of collaboration leaves a critical gap in our understanding of university–industry links.

In order to shed light on this issue, this paper seeks to make three contributions to our understanding of the nature of academics' engagement with industry. First, we focus on

the negative aspects of engagement, the perceived barriers that confront an academic when considering working with industry. In doing so, we help to correct the strong pro-engagement bias that exists in the general literature on academic collaboration with industry. Second, we bring to the surface and contrast two different types of barriers faced by academics in working with industry: the orientation- and transaction-related barriers. The former refers to conflicts about the orientation of research with industry partners, or what we term 'Mertonian' barriers; the latter refers to the costs of dealing with the rules and regulations of the university and conflicts over IP with industry partners, or what we term 'Williamson' barriers. This approach helps us to unpack a wider range of challenges facing academics in working with industry. Third, we explore how the personal and professional experiences of academics can mitigate their perceptions of different barriers to collaboration. This approach allows us to comment on the mechanisms that can support successful and beneficial relationships between academics and industry.

The analysis is based on the knowledge exchange activities of 1,544 UK academics, drawing information from a range of datasets, including a survey, the project records of the UK's largest funding council, the results of the 2001 and 2008 Research Assessment Exercises (RAEs), and information on universities' technology transfer activities. The analysis examines the different types of barriers perceived by academics and what personal and professional experiences shape an individual academic's perception of these different barriers. Using a fractional logistic regression analysis, we find that perceived orientation barriers to collaboration are lower for academics with industrial, entrepreneurial and collaborative experience and for those who trust their industry partners. Although industry and collaborative experience can help lower transactional barriers, we find that academic entrepreneurs and broad industry collaborators perceived higher transactional barriers to collaboration.

2. The barriers to academics exchanging knowledge with industry

The literature on university–industry links has highlighted two broad cost types, as perceived by academic researchers, associated with knowledge transfer activities. The first are costs related to deviance from the norms of science (Dasgupta and David, 1994; Nelson, 2004); the second are the costs of complex technology transfer processes (Owen-Smith and Powell, 2001; Siegel *et al.*, 2004). In the following we explore our understanding of these two sets of barriers facing academic engagement with industry.

2.1 Orientation barriers to knowledge exchange

The institutional norms under which university scientists operate are characterised by open dissemination and autonomy, within a reward system based on peer recognition gained through publication priority and originality of research (Merton, 1957; Nelson, 2004). The motivation of academic researchers to collaborate with industry is largely driven by the aim to foster their own research agenda and therefore it is often complementary to the norms of science. Indeed, collaboration with industry often encourages a better understanding of the academic context of application of the fundamental research, to access resources and skills not available at universities, and to get inspiration for blue-sky research (Rosenberg, 1991; Mansfield and Lee, 1996; Siegel *et al.*, 2004; Breschi *et al.*, 2007; D'Este and Perkmann, 2010).

However, there are two types of costs associated with interaction with industry that might be perceived by academics as strong barriers to engagement in knowledge transfer:

secrecy and *subject skewing* (Tartari and Breschi, 2009; Gulbrandsen and Smeby, 2005). The secrecy problem refers to the extent to which collaboration with industry could be associated with restrictions on the disclosures of research findings and, more generally, on the dissemination of research results, which constitute a threat to the norms of open science and priority. For instance, several authors have shown that collaboration with industry is associated with both delays in publication and refusal to disseminate research results (Blumenthal *et al.*, 1996; Campbell *et al.*, 2000, 2002; Louis *et al.*, 2001). Whilst, the skewing problem refers to the fear that collaboration with industry could impose constraints on the university scientists' autonomy to establish their research agenda. Industry interests could lead to an epistemic drift in the research agenda towards a profile characterised by short-term and target-driven research, at the expense of curiosity-driven, basic-oriented and long-term research (Elzinga, 1997; Gulbrandsen and Smeby, 2005).

In short, academic scientists may find it difficult to reach agreements with their industrial partners on the focus of research projects, working priorities and expectations about research, as well as on the timing of the dissemination of research findings. The lack of agreement about these fundamental issues creates significant barriers to university–industry collaboration, creating what we have described as 'Mertonian' barriers to collaboration.

2.2 Transactional barriers to knowledge exchange

As argued by Owen-Smith and Powell (2001), the incentives perceived by academics to engage in knowledge transfer activities are magnified or weakened by the ease of the technology transfer process at the university. For instance, dissatisfaction with the local patent process available at the university may lead faculty inventors to abandon the decision to disclose inventions or to circumvent technology transfer offices (TTOs) by engaging directly with industry partners (Siegel *et al.*, 2004).

The academics' perception of the costs associated with pursuing collaboration with industry through their respective university depends on three features of the local university infrastructure for commercialisation of university research. First, the perceived profile of the university TTOs and, particularly, the resources available and the skills of the staff working at the TTOs may shape academics' attitudes to collaboration. If the TTO is underfunded and understaffed, it may produce long delays, inconvenient schedules, lax reporting and minimal responsiveness to the concerns of scientists in the collaboration process (Owen-Smith and Powell, 2001). Second, the availability of information about established procedures for collaboration with industry, in general, and for invention disclosures and patenting, in particular, may also contribute to shaping academics' perceptions of barriers. The formation of a supportive entrepreneurial climate at the university is largely dependent on the widespread awareness of technology transfer procedures and publicity for success stories among faculty (Owen-Smith and Powell, 2001; Moutinho *et al.*, 2007). Clear and well-disseminated procedures for engagement in knowledge transfer activities would alleviate the informational and cultural barriers faced by potential entrepreneurial academics. Indeed, scientists' favourable disposition to commercialisation activities are strongly associated with awareness of IP rights' policy at the research organisation (Moutinho *et al.*, 2007). Third, the degree of flexibility on rules and regulations put in place by universities for technology transfer activities are also likely to influence researchers' perceptions. Lack of flexible policies on IP ownership and technology transfer are often deemed by academic scientists as important hampering

factors in shaping their attitudes towards commercialisation activities. As reported by Siegel *et al.* (2004), scientists often describe university TTOs as an obstacle rather than a facilitator, because university bureaucracy imposes procedures that are too rigid to match the nuances of particular technology transfer processes. All of these factors can create significant transactional costs to industry collaboration, requiring academics to develop new contractual relationships with their external partners and to deal with their university's TTO and legal department, or what we have called 'Williamson' barriers.

3. Factors shaping academics' perceptions of barriers to knowledge exchange

Drawing upon the literature on university–industry collaboration, we suggest a number of factors that often influence scientists' perceptions about barriers to collaboration with industry. In particular, we focus on three main factors that are likely to shape scientists' perceptions of barriers towards collaborating with industry: their professional experience; their collaborative experience working with commercial organizations; and the level of trust between the academic and their industrial partners arising from past engagement efforts. We explore the arguments for each factor in turn below.

3.1 Professional experience

The career trajectories of university scientists are epitomised by long-term investments in the knowledge, skills and know-how necessary to achieve extrinsic rewards of recognition and prestige among peers, including promotion, and intrinsic rewards of puzzle solving (Stephan and Levin, 1992). This has generally led to career trajectories dominated by relatively uninterrupted periods of employment in academia, since researchers who remain in university settings are likely to be more productive over a career span (Reskin, 1977; Long, 1978). That said, it is also true that many academics have work experience in industry. These experiences may have come at early stages of their career, such as after their master's degree, or may be taken during breaks in their academic career. It is also not uncommon in some fields of research for industrial scientists to transfer from working in the private sector to the university system. This suggests that many academics have had hybrid careers, comprising periods of public and private sector employment.

The implications of researchers' work experience in industry can be profound, as it can provide them with insights into a broader range of research problems. Indeed, there is some evidence that this movement in and out from academia is often a beneficial means of coupling scientific discovery and technological innovation. For example, Dietz and Bozeman (2005) found that scholars who have spent a larger proportion of their careers working in industry are much more likely to be involved in patenting than scholars who had very little or no experience working in industry. A diverse work experience—spanning academic and industrial settings—may also contribute to the formation of richer non-academic networks, enhancing the social capital of the academic (Lam, 2005).

Given this context there are three reasons to expect that a greater experience of industry will lower academics' perception of barriers to engagement. First, through their work experience, hybrid academics' research practices are more closely aligned to the cultural norms of industry. They are aware of the challenges and operating conditions faced by their industrial partners, and consequently will be more able to develop research topics that fit the mutual needs of both parties. Second, these hybrid academics will have more relevant

social networks than their academic careerist colleagues for such industry collaboration. Accordingly, they will be more easily able to call upon these networks to help start, develop and deliver their research. Indeed, they may even be able to call on colleagues with whom they worked in their previous industrial career to join them in their research efforts. Third, they will be better able to manage the transactional barriers to collaboration since, as past members of the private sector, they are likely to have been exposed to formal requirements of IP and contractual relationships with external parties. In contrast, their academic colleagues with little or no industrial experience may lack sufficient understanding of the transactional nature of exchanges in the market for technology (Arora *et al.*, 2001).

A second element of industrial work experience that is likely to shape the perceived barriers to collaboration is personal involvement in an entrepreneurial start-up or academic entrepreneurship (Shane, 2004). It is clear that significant numbers of academics are or have been entrepreneurs. For example, Stuart and Ding (2006) found that 12% of life scientists had been involved in setting up a private firm. Many of these new firms are not based on formal university IP, but rather offer a range of consulting services (Fini *et al.*, 2010). Fundamentally, the involvement of an academic in a new venture is tangible evidence that they seek to capture private returns from their skills and know-how. However, the value of entrepreneurial experience in shaping perceived transactional barriers to industry engagement is less clear. Of course, venture experience will educate the academic about the commercial requirements of industry, but it also may provoke conflicts with the university over the IP developed by the new venture, the commercial terms and rules in force in their local university environment. Indeed, it is not uncommon for academics to find themselves in conflict with their university about the terms under which their private firms may operate. These clashes may stem from conflicts of interest, the access terms of university resources to support the new firm or the balance of an academic's time between the new firm and their academic responsibilities (Campbell and Slaughter, 1999; Crespo and Dridi, 2007). These conflicts may be mitigated by joint ownership of the new firm by an academic and the university, but even here conflicts may emerge about the path and direction of the firm and its relationship to the university that spawned it (Debackere and Veugelers, 2005; Shane, 2004). Given these factors, it is unclear what role academic entrepreneurship will play in shaping Williamson barriers to collaboration.

3.2 Research collaborative experience with industrial partners

Prior research collaboration experience with industry has often been identified as having a favourable influence on the disposition of academics towards technology transfer. Several authors show that the relational capital of academic researchers with industry partners is positively and significantly associated with the extent to which the academic researcher engages in knowledge transfer activities (Landry *et al.*, 2007; Ponomariov and Boardman, 2008). Also, as Shane (2000) shows, the knowledge about markets, technologies and consumer needs that strongly contribute to forming positive attitudes and skills towards entrepreneurship are fundamentally gained by close interaction with industry partners. The formation of a favourable perception of collaborations with industry is also likely to be shaped by the environment in which the individual scientist works. Academics in universities and departments with an established tradition of collaborative research with firms are indeed more likely to recognise the commercial opportunities of their research activities and more willing to initiate interactions with industry partners in the context of

their research activities (Owen-Smith and Powell, 2001; Feldman and Desrochers, 2004; Jong, 2006).

In line with this discussion, we would expect that academics with past experience of collaborative research are less likely to perceive orientation and transactional barriers to industry collaboration. This is because that experience provides an opportunity for an academic to learn how to recruit industry partners to their research and to frame research questions in ways that appeal to industry. Skilled collaborators have developed operating routines to work with their industrial collaborators, learning to speak the language of practice and developing research outputs that have value to their industrial partners as well as their academic peers. Thus, collaborative experience helps academics overcome the skewing of research to short-term, less academically valuable outcomes that can be a consequence of industry engagement. It may also be evidence of an academic's willingness to have their research focused on more short-term, tangible outcomes. Moreover, building research collaborations with industry teaches academics how to find mutually acceptable ways of disclosing results, helping overcome concerns of secrecy. Past collaborations can also enable an academic to establish a track record with the business community, showing their ability to deliver high-quality research as well as industry-relevant knowledge, allowing them to successfully negotiate future collaborations and overcome the associated barriers (Landry *et al.*, 2007).

Formal research collaboration experience is not the only approach to enable an academic to lower perceived barriers. Indeed, many academics draw on a wide range of mechanisms with industry, including consultancy, joint educational efforts, contract research and training (D'Este and Patel, 2007). Working across these different channels of industry engagement allows an academic to draw upon formal and informal mechanisms to support their engagement efforts. Informal means can help the academic manage formal collaborations, as understanding and experience developed in one informal channel be used to overcome barriers in more formal channels of collaboration. However, drawing upon a wide range of mechanisms for engaging with industry may subject the academic to interaction with different parts of the university and this could raise transaction barriers. For example, joint research contracts are usually managed by the research services unit of the university, consultancy may be delivered through a university-owned and university-operated consulting unit, and teaching programme developments may be managed at the department level. Each of these units of the university may have different rules and reporting requirements. For these reasons, engagement in a broader range of collaboration mechanisms can be expected to lower the academic's perception of the orientation barriers; whereas it might increase the academic's perception of transactional barriers to collaboration with industry partners.

3.3 Trust between academic researchers and their industrial partners

Personal and trust-based relationships between university scientists and industrial partners are crucial for the effectiveness of knowledge transfer activities. Interactions between university scientists and industry partners often involve turning embryonic research into marketable technologies, where the commitment of both sides is instrumental for the success of the endeavour (Jensen and Thursby, 2001; Dechenaux *et al.*, 2009). In this context, trust-based relationships are particularly important to facilitate the exchange of difficult-to-codify knowledge and information (Kogut and Zander, 1992). Trust enables both parties to make mutual commitments to the project and helps to ensure that each

party feels that they will be treated fairly if problems arise (McEvily *et al.*, 2003; Dodgson, 1992; Bachman and Lane, 1996). In this sense, trust helps to alleviate opportunistic behaviour and enables richer and more integrated collaborations between academics and their industry partners (Santoro and Saparito, 2003).

In the case of Mertonian barriers, if academics trust their industry partners, it means that they believe those partners will try to ensure that their needs from a project, such as for the generation of publications, are met. In addition, trust can help to overcome the timescale problem of collaboration, as many research projects are undertaken on the basis of uncertain future payoff (Nooteboom, 2002). If the two parties trust one another it is easier for them to work together for long-term gain, with an understanding that neither will 'cut and run' from the collaboration.

In terms of Williamson barriers, trust can help the formation of an understanding of the nature of the project—its scope and intended outcomes. Building a new research project may require considerable negotiation between the academic and their industry partners to determine the nature of the project and its deliverables. An attempt to codify the roles, responsibilities and outcomes arising from a research project can be a major burden for both parties. Where trust is present it is possible to work without complex or highly detailed contracts or agreements, and consequently to start projects more quickly, at a lower transactional cost (Sako and Helper, 1998; Gulati and Nickerson, 2008). Thus, trust in industrial partners is critical for shaping the perceptions of academics towards the transactional costs of industry collaboration.

4. Data and methods

For the analysis in this paper we draw information from a unique dataset covering approximately 6,200 academics in the UK, using a range of sources to construct our database. First, we obtained information on all the academic researchers holding a grant (principal investigators and co-investigators) from the UK Engineering and Physical Sciences Research Council (EPSRC) from 1992 to 2006. The EPSRC is the largest funding body for research in the UK and all funds are allocated on the basis of peer review. From these records we extracted information about the funding profile of the researchers, including amount of funds received and length of projects undertaken.

Second, we used information obtained through a survey of the academics in the EPSRC records, listed as active researchers on their universities' web sites in 2008. The survey was designed to collect information about several aspects of researchers' engagement with industry, such as types of engagement, attitudes towards collaboration and perceived barriers. The questionnaire built on previous work, allowing comparability of results. In particular, we build upon survey items employed by D'Este and Patel (2007) and the Research Value mapping Program conducted at Georgia Tech (Bozeman and Gaughan, 2007; Link *et al.*, 2007). The survey was administered between March and September 2009 and we obtained a total of 2,194 completed questionnaires, corresponding to a response rate of 36%.

Third, we matched the sample of researchers who answered the questionnaire with the population of the RAE conducted in 2008 and covering the years from 2001 to 2007 (HEFCE *et al.*, 2008). The RAE was a government programme assessing the research quality of higher education institutions in the UK. It includes rich data about the scientific profile of all departments in the UK, along with information on their funding sources.

Fourth, we matched the universities included in our sample with the data from the government's higher education and business interaction surveys, which cover the years

from 2005 to 2007 (HEFCE, 2008). This annual survey collects financial and output information on the activities universities conduct with businesses and society at large.

Lastly, we collected data for the regions (NUTS2 level) in which the universities are located, including gross domestic product (GDP), business research and development (R&D) expenditures, and patent applications (Eurostat, 2003).

After having completed the entire matching process and excluded the researchers for whom we do not have complete demographic characteristics (such as age, gender and academic rank), we were left with 1,544 individuals, across 70 different UK universities.

In order to check the reliability of our final sample we undertook some tests for sources of bias. First, we compared response rates to our survey of academics from different types of UK universities and found no significant differences in our sample and the wider population of EPSRC-funded academics. Second, we compared the responses of early and late responders to our survey and found no significant differences. Third, we compared the survey responses from the individuals whom we were unable to collect full information about to our complete sample and found no differences in the pattern of each group's responses to our main variables.

4.1 Dependent variables

In our analysis we specify two models: one focuses on orientation barriers and the other on transactional barriers. To capture these two different kinds of perceived barriers, we draw information from a survey question about the barriers academics have faced when engaging with industry. In particular, respondents were asked to rate the extent to which a set of 11 items acted as a constraint to their involvement in interactions with industry on a five-point Likert scale from 'not at all' to 'very much'.

To construct our measure of orientation barriers, we focused on six items, which are directly related to the differences in timing, research choice and speed of the research process between industry and academic researchers (the full list of items is shown in Table 1). Each item is coded '1' if the respondents indicate that the item is acting 'quite a lot' or 'very much' as a constraint to their involvement in interactions with industry. To calculate the variable *orientation barriers*, we added these scores so that each individual scores 0 for no barriers and scores 6 when all orientation-related barriers are perceived as being present.

To construct our measure of transactional barriers we focused on the other five items in the questionnaire, which are related to the potential conflicts between university and industry over IP and university regulations (see Table 1). Our transaction barriers measure was created using the method described above for orientation barriers.

In order to explore the reliability and validity of these composite indexes in capturing two distinct sets of the barriers facing researchers, we performed a principle component analysis using orthogonal varimax rotation, including all of the 11 items on the survey. The resulting factors directly correspond to the aggregation individual items used above (not reported for reasons of space). Moreover, although these are new scales, the Cronbach alpha is high (0.7) for both measures, indicating a good degree of internal consistency.

4.2 Explanatory variables

The first group of explanatory variables describes the researcher's professional experience in industry and with commercialisation. We begin by measuring the number of years of experience that an individual has working in industry (*industry experience*): this variable captures the researcher's professional experience in the same context as their industrial

Table 1. *Descriptive statistics of items describing perceived barriers*

Barriers		Mean	SD	Respondents perceiving this item as of high importance (%)
Mertonian barriers				
1M	Short-term orientation of industry research	3.2	1.3	44
2M	Difficulty in finding companies with appropriate profile (e.g. highly innovative partners)	3.0	1.3	40
3M	High personnel turnover and lack of continuity in companies' research strategies	2.5	1.3	23
4M	The nature of my research is not linked with industry interests or needs	2.2	1.3	20
5M	Mutual lack of understanding about expectations and working priorities	2.4	1.2	19
6M	Industry imposes delays in dissemination of research outcomes and publications	2.2	1.1	14
Williamson barriers				
1T	Rules and regulations imposed by university or government funding agencies	2.4	1.3	21
2T	Policies adopted by the university's technology transfer office	1.9	1.2	13
3T	Potential conflicts with industry regarding intellectual property rights	2.1	1.1	13
4T	Absence of established procedures for collaboration with industry	2.0	1.1	13
5T	University's technology transfer offices have a low profile	1.9	1.1	10

partners. We also introduce a variable describing the researcher's experience with start-ups (*academic entrepreneur*). This variable is a dummy that takes value 1 if the researcher has been involved in the creation of a start-up at any point in their career. Although all of these questions are drawn from survey data, both measures cover the entire career of the respondent.

The second group of variables describe the researcher's collaborative experience with industry. We include in the model the number of the academic's unique *industrial collaborators*: this variable reflects the extent of experience with industrial partners and also the variety of their collaborations. This variable is taken from the EPSRC records and focuses on the number of different companies that the researcher has partnered. To reflect the breadth of an academic's engagement with industry, we construct a variable capturing the researcher's *breadth of collaboration*. This variable measures the total number of different channels of collaboration in which the academic has been involved in the two years prior to

our survey. This information has been collected from a survey question on the channels of interaction: each channel has been coded '1' if the academic has engaged at least once in that kind of interaction and '0' otherwise. Therefore, the variable can take values from 0 (no collaboration) to 8 (all channels). The full list of channels and their frequency of use is reported in Appendix 1.

We also measure the level of trust that academic researchers have in industrial partners. This measure builds on Zaheer *et al.*'s (1998) interorganisational trust scale, but focuses on the levels of personal trust between the researcher and their industry partners. The level of trust is garnered through five statements, measured on a five-point Likert scale (see Appendix 1 for the items used). The variable is obtained through a factor analysis (principal component factors, orthogonal varimax rotation) and has a Cronbach alpha of 0.8, indicating a high degree of reliability.

4.3 Control variables

To control for other factors that may shape the level of barriers beyond professional and collaborative experience, we include a range of other variables in the model. A first group of variables is related to the individual characteristics of the respondent. We have included the researchers' *academic age* (years elapsed from the PhD) and their position in the university system (*professor*). We also include the *gender* of the researcher: previous research has shown that male researchers are more likely to collaborate with industry than female researchers. The variable *UK PhD* is coded 1 if the researcher holds a PhD degree awarded by a British institution. People trained in the same country in which they work should be more aware of rules and regulations concerning collaborative activities and will also be culturally closer to their industrial partners. To control for differences between disciplines we use a set of four dummies to characterise the scientific disciplines—*life sciences*, *physical sciences*, *engineering* (including computer science), and *social sciences and humanities*—of each academic. This information is taken from the RAE.

A second group of control variables refers to the organisational environment surrounding the academic. Here we include a variable capturing *department industry funds*, which measures the amount of money received by the department of the researcher from industrial sources in the academic year 2006/07 divided by the number of full-time researchers in the department. Departments with high levels of industrial collaborations are likely to value knowledge exchange more highly. We also capture the general environment around collaboration at the university level, introducing the variable *university industry funds*. This variable describes the amount of money received by the researcher's university from research contract and consultancies (with commercial organisations) in the academic year 2006/07 divided by the number of full-time researchers in the university. Universities that are active in collaborating with industry will be better equipped to deal with the transactional aspects of these collaborations. Lastly, we control for the regional environment by introducing the percentage of GDP spent in R&D (*regional R&D*) in 2003 at the NUTS2 region level: these data allow us to understand the regional economic context in which an academic operates, as some local environments may offer greater opportunities for industrial engagement than others.

4.4 Estimation

The two dependent variables are count variables, as they take on non-negative integer values. Count variables are usually estimated using Poisson or negative binomial regression

models. However, since our dependent variables are restricted by an upper bound (e.g. the maximum number of orientation barriers is six), Poisson or negative binomial distributions are not appropriate. An alternative approach is to employ a technique provided by Wooldridge (2002), 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 logistic regression (Papke, 1996). This method is non-linear and can be estimated using quasi-maximum likelihood techniques. To address the possible problem of heteroskedasticity, we use robust standard errors. Moreover, as the respondents in our sample come from different disciplines, we can expect that there is some group correlation we are not able to observe; therefore we cluster errors by scientific discipline.

5. Results

To understand the determinants of barriers towards interaction with industry, we first explore the different obstacles that academics face in their collaboration activities with private companies. Table 1 reports the importance of different barriers for the total sample of respondents. The results indicate that, in general, orientation barriers are more strongly perceived by academics than transaction barriers. Of the orientation barriers, the 'short-term time horizons of industry partners' as well as the 'lack of suitable partners' are the most frequently cited. Both of these items relate to the problem of agenda skewing. Conflicts about disclosure appear to be the least common barrier, indicating the timing and nature of disclosure are not major problems for many academics when dealing with industry. This result contrasts with the strong emphasis on disclosure problems discussed in Dasgupta and David's (1994) new economics of science. When considering transactional barriers, conflicts over the rules and regulations are also frequent. However, IP conflicts appear to affect only a modest share of academics. What is clear from the factor analysis is that these different forms of barriers capture bundles of interrelated problems faced by academics. However, variation within and across these bundles of barriers provides insights in the nature of the conflicts that separate academics from their collaboration with industry.

Table 2 reports the descriptive statistics, while Table 3 presents the correlation matrix of the explanatory variables and the control variables in the model. Overall, the level of correlation between variables is low, suggesting that multicollinearity is not a concern.

In the first stage of the analysis (Model 1a and 1b in Table 4) we introduce only control variables. Gender is associated with greater transaction barriers, with women reporting higher perceived transaction barriers to knowledge exchange. This result is consistent with the fact that there are relatively few women in engineering positions in UK universities and therefore women confront a very male-dominated working environment. Holding a British doctorate is negatively related to orientation barriers: again, locally trained scientists appear to be culturally closer to their industrial partners. Funds from industry at the university level are negatively related to orientation barriers. This suggests that researchers in universities active in collaboration feel more encouraged to participate in these kinds of activities and they may also perceive them as institutionalised and therefore more pertinent to their academic role.

In Models 2a and 2b we explore the effect of an individual's professional experience. The number of years of work experience in industry is negatively correlated with orientation barriers, suggesting that the more a researcher has worked with industry, the more able he/she will be to understand their industrial partners. It appears that private sector experience can

Table 2. *Descriptive statistics of explanatory and control variables*

Variable	Mean	SD	Minimum	Maximum
Academic age (years)	21.27	9.98	1	60
Professor	0.56	0.50	0	1
Gender (female = 1)	0.12	0.32	0	1
UK PhD	0.84	0.37	0	1
Life sciences	0.05	0.22	0	1
Physical sciences	0.33	0.47	0	1
Engineering	0.56	0.50	0	1
Social sciences and humanities	0.06	0.23	0	1
Department's industry funds (£000)	10824.08	11985.26	0	82197.66
University's industry funds (£000)	12.22	11.62	0.19	72.49
Regional R&D	1.78	0.96	0.93	4.29
Academic entrepreneur	0.26	0.44	0	1
Industry experience	2.82	5.37	0	45
Industrial collaborators	2.34	4.12	0	45
Breadth of interaction	4.12	2.14	0	8
Trust	0.03	0.99	−4.05	2.21

enable the individual to have a richer understanding of work practices in the private sector. However, this variable has no statistically significant effect on transaction-related barriers.

The experience as an academic entrepreneur is negatively related to orientation barriers, while it is positively related to transaction barriers. As we suggested, the involvement of academics in the creation of a venture is clear evidence of the intention of commercialising their research. These academics conform to a private sector ethos and they are therefore less likely to perceive orientation relation barriers than academics with little or no entrepreneurial experience. On the other hand, creating a start-up company may provoke conflicts both with the university and the potential industrial collaborators over the IP developed by the new venture. Because of these possible conflicts of interests, academic entrepreneurs seem to perceive a higher level of transaction barriers to industry collaboration.

In Models 3a and 3b we analyse the impact of collaborative research experience on the perceived barriers. The number of unique industrial partners contributes to a decrease in the perception of orientation-related barriers: engaging in a large variety of collaborative activities can lift some of the problems related to the 'cultural clash' between university and industry, as both partners learn how the other operates and what its priorities are. This result does not hold, however, when we introduce our measure of trust into the regression. Transactional barriers are also negatively related to the number of industrial partners: researchers working with a wide variety of partners seem to be able to leverage the experience they have acquired in a particular collaboration to solve issues arising with a different partner.

When we examine the influence of multiple collaboration channels used by an academic to engage with industry, we find that greater breadth is positively related to transaction barriers. This indicates that problems related to the drafting of contracts, negotiating IP rights and making sense of regulations are peculiar to different kinds of interaction. By using different mechanisms to engage with industry, researchers may find themselves increasing the time necessary to gain approval and support for these engagements from

Table 3. *Correlation matrix*

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]
[1] Orientation barriers	1.00																	
[2] Transaction barriers	0.30	1.00																
[3] Academic age	−0.06	−0.06	1.00															
[4] Professor	−0.05	−0.04	0.52	1.00														
[5] Gender (female = 1)	0.06	0.07	−0.15	−0.13	1.00													
[6] UK PhD	−0.11	−0.03	0.15	0.08	−0.04	1.00												
[7] Life sciences	0.00	0.02	0.00	−0.03	0.03	0.05	1.00											
[8] Physical sciences	0.06	−0.04	0.10	0.06	−0.04	−0.07	−0.17	1.00										
[9] Engineering	−0.05	0.04	−0.06	−0.05	−0.02	0.02	−0.27	−0.79	1.00									
[10] Social sciences and humanities	−0.03	−0.03	−0.06	0.03	0.08	0.04	−0.06	−0.17	−0.28	1.00								
[11] Department's industry funds	−0.11	−0.02	0.04	−0.02	0.00	0.07	0.02	−0.31	0.35	−0.15	1.00							
[12] University's industry funds	−0.09	−0.02	0.02	0.03	0.03	0.04	−0.01	−0.07	0.11	−0.08	0.33	1.00						
[13] Regional R&D	−0.06	−0.02	0.00	0.00	−0.01	0.01	−0.02	−0.02	0.04	−0.02	0.06	0.29	1.00					
[14] Academic entrepreneur	−0.12	0.05	0.15	0.16	−0.11	0.07	0.02	−0.09	0.08	−0.02	0.06	0.09	0.03	1.00				
[15] Industry experience	−0.10	0.02	0.14	0.10	−0.07	0.10	−0.01	−0.10	0.09	0.02	0.08	0.07	0.04	0.23	1.00			
[16] Industrial collaborators	−0.11	−0.05	0.16	0.21	−0.04	0.13	−0.10	−0.16	0.16	0.06	0.14	0.05	0.02	0.17	0.11	1.00		
[17] Breadth of interaction	−0.20	0.11	0.04	0.17	−0.05	0.15	0.00	−0.21	0.22	−0.03	0.26	0.13	0.03	0.29	0.16	0.26	1.00	
[18] Trust	−0.36	−0.12	0.12	0.12	−0.04	0.13	−0.06	−0.01	0.04	0.00	0.08	0.03	−0.01	0.10	0.12	0.15	0.29	1.00

Table 4. *Fractional logistic regression estimates of orientation and transaction barriers to interaction*

	Orientation-related barriers				Transaction-related barriers			
Variables	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
Academic age	−0.005	−0.004	−0.005	−0.002	−0.009⋆	−0.010⋆	−0.007	−0.006
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
Professor	−0.024	0.004	0.089	0.083	−0.072	−0.099	−0.120	−0.101
	(0.073)	(0.067)	(0.070)	(0.073)	(0.072)	(0.075)	(0.081)	(0.078)
Gender	0.176^{+}	0.140	0.138	0.146	0.250⋆	0.280⋆	0.286⋆⋆	0.313⋆⋆
	(0.090)	(0.090)	(0.096)	(0.109)	(0.109)	(0.112)	(0.109)	(0.111)
UK PhD	−0.284⋆⋆⋆	−0.263⋆⋆⋆	−0.191⋆	−0.115	−0.093	−0.103	−0.120	−0.067
	(0.074)	(0.074)	(0.084)	(0.083)	(0.073)	(0.076)	(0.074)	(0.081)
Life sciences	0.272⋆	0.272⋆	0.251⋆	0.126	0.547⋆⋆	0.535⋆⋆	0.419^{+}	0.401^{+}
	(0.125)	(0.129)	(0.123)	(0.110)	(0.195)	(0.200)	(0.218)	(0.212)
Physical sciences	0.310⋆⋆⋆	0.271⋆⋆	0.228^{+}	0.256⋆	0.094^{+}	0.115^{+}	0.071	0.173⋆⋆
	(0.082)	(0.100)	(0.120)	(0.117)	(0.056)	(0.063)	(0.053)	(0.063)
Engineering	0.242⋆	0.246⋆	0.279⋆⋆	0.251⋆⋆	0.324⋆⋆	0.316⋆⋆	0.262⋆⋆	0.293⋆⋆
	(0.095)	(0.110)	(0.093)	(0.096)	(0.102)	(0.096)	(0.099)	(0.093)
Department's industry funds	−0.000^{+}	−0.000^{+}	−0.000	−0.000	−0.000	−0.000	−0.000⋆	−0.000⋆
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
University's ndustry funds	−0.006⋆	−0.005^{+}	−0.005^{+}	−0.006⋆⋆	−0.003	−0.004	−0.004	−0.004
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)
Regional R&D	−0.063⋆	−0.062^{+}	−0.065⋆	−0.068⋆	−0.048	−0.049	−0.048	−0.040
	(0.032)	(0.032)	(0.030)	(0.031)	(0.055)	(0.053)	(0.052)	(0.059)
Industry experience		−0.015⋆	−0.012^{+}	−0.006		0.002	0.001	0.005
		(0.006)	(0.006)	(0.007)		(0.012)	(0.012)	(0.012)
Academic entrepreneur		−0.229⋆⋆	−0.114⋆	−0.138⋆⋆⋆		0.233⋆⋆	0.171⋆	0.161⋆

Table 4. *Continued*

	Orientation-related barriers				Transaction-related barriers			
Variables	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
		(0.071)	(0.058)	(0.036)		(0.074)	(0.078)	(0.072)
Industrial collaborators			−0.017*	−0.011			−0.041**	−0.035**
			(0.008)	(0.007)			(0.013)	(0.012)
Breadth of collaboration			−0.086***	−0.040*			0.088***	0.115***
			(0.014)	(0.018)			(0.026)	(0.020)
Trust				−0.432***				−0.267***
				(0.043)				(0.074)
Constant	−0.663***	−0.632***	−0.399*	−0.747***	−1.590***	−1.612***	−1.839***	−2.123***
	(0.137)	(0.151)	(0.179)	(0.205)	(0.094)	(0.097)	(0.114)	(0.139)
Observations	1,544	1,544	1,544	1,498	1,544	1,544	1,544	1,498

Notes: Robust standard errors in parentheses.
Two-tailed tests: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, +$p < 0.1$.

their department or wider university. It is also clear, however, that the breadth of interaction affects an individual's engagement with industry by reducing orientation barriers. This indicates that researchers engaging in a wide variety of activities with industrial partners may have higher possibilities of extracting value for themselves from relationships with their industrial partners. They may also be able to use informal channels to solve problems arising from formal channels of interaction.

Last, as expected, trust is negatively related to both orientation- and transaction-related barriers (Models 4a and 4b). Trust rests on mutual understanding and shared experiences, and therefore its presence in the mind of the researchers helps to lower the perception of all types of barriers to collaboration.

In order to verify the robustness of our specification, we undertook several rounds of additional analysis. First, we performed the same econometric analysis by using dependent variables obtained through the factor analysis. The results of this analysis are consistent with what is reported here. Second, we ran the analysis with only a subset of the items related to transaction barriers (items 1T, 2T and 3T in Table 1), providing a narrower definition of Williamson barriers. The results remain unchanged. Third, we measured past experience in academic entrepreneurship by introducing the number of start-ups in which they have been involved; the results are comparable to the main specification. Last, to measure past collaboration experience, we estimated the models using only grants received by the individual since 2001, as some of respondents may have no recent experience of collaboration as our data on collaborative grants go back to 1996. Again, the results are unchanged. This is evidence that our results are not a product of the particular features of the sample, which includes only EPSRC grant-winning academics.

6. Conclusions

In this paper we have sought to increase our understanding of the barriers faced by academics in their interactions with industry and the factors that could mitigate these barriers. Drawing on the wider literature, we suggested that there are two main sets of barriers facing academics: Mertonian barriers, relating to the orientation of research, and Williamson barriers, relating to the transactional costs of working with industry. By bringing these two barriers to the surface, our approach provides insights into the drivers of academics' attitudes to engagement and helps to enrich our understanding of how personal and professional experience can help alleviate these barriers.

In our analysis it is clear that many academics still perceive considerable barriers to working with industry and this suggests that external engagement is not a frictionless process. Indeed, academics will carefully weigh the costs against the benefits of collaboration before embarking on it. When we look at the different barriers themselves, the most important one is differences in timescales (i.e. short-term orientation of industry research). Conflicts with industry over the timing of disclosure and topics of research are also perceived to be important. In contrast, conflicts over IP and the rules and regulations only seem to afflict a minority of academics.

Probing the information from our survey more deeply, we uncovered two distinct interrelated sets of barriers, which aligned to the concepts of Mertonian and Williamson barriers that we developed in our review of the literature. We then considered how personal and professional experience shaped academics' perceptions of these different barrier bundles. In terms of Mertonian barriers it was clear that experience plays a critical

role in shaping the mindset of academics towards the differences in orientation between themselves and their industry partners. Industrial work experience and collaborative experience with different partners all lowered Mertonian barriers. In addition, the wider the range of an academic's engagement with industry, the less likely they were to perceive Mertonian barriers. Given these results, it is clear that Mertonian barriers to collaboration, although common, can be overcome by experience. Our results provide evidence that academics can learn to deal with orientation differences when collaborating with industry.

The case of transactional barriers is a more complex and challenging one. For transactional barriers, the diminution of barriers depends on the nature of an academic's experience with industry. Academic entrepreneurship and broad patterns of engagement with industry are associated with higher transactional barriers, whereas collaborative experience on research projects is associated with lower transactional barriers. We suggest that the heightening of perceived transactional barriers by academic entrepreneurs could be because these individuals come up against the rules and regulations of their university, and also run into conflicts with their TTO. Academics with a diverse portfolio of collaborations might have to negotiate with different parties of the university's administration. In the process they may confront different rules and regulations (such as those concerning contract research or consultancy), which involve different parts of the university administration, and be subject to varying reporting requirements. The lack of flexibility and the low profile of TTOs may therefore make the whole process cumbersome for academics involved in many different activities, and discourage them from collaborating. These results suggest that transactional barriers are particularly sensitive to the characteristics of the operating environment in which academics work.

The results show that the level of trust of an academic in their industrial partners is important in confronting both types of barriers. In this case our measure of trust provided us with an understanding of the quality of past collaborative experiences of the academic with their industrial partners. In many cases it can be expected that collaboration by itself with an industry partner does not necessarily lead to academics trusting their industry partners. However, the importance of trust for both types of barriers is suggestive of the importance of face-to-face, personal relationships in creating and sustaining links between industry and academia. These relationships, however, do not necessarily act as substitutes for more formal and organised collaboration mediated by university's structures, but they should help academics in dealing with partners outside the boundaries of their organisation.

The research has several important implications for policy and for our understanding of the changing role of universities in society. First, the considerable policy effort to encourage academics to engage with industry must be aligned to the individual incentives and motivations of researchers. For our population of academics, experience provides valuable lessons in overcoming barriers to collaboration, and therefore it may be possible to develop policies to entice academics into new collaboration and to build up their collaborative experience with industry. Critically, these experiences will need to be relatively 'transaction-lite', as they need to encourage academics with limited experience and knowledge of industry practices to build up their 'engagement capacity'. Essential to the formation of this 'engagement capacity' is to provide mechanisms for academics to develop one-to-one relationships with industry that are meaningful and useful for their research and to provide them with high-quality, efficient structures dedicated to technology transfer inside the university. Second, it is clear from the analysis that

transactional barriers are more 'sticky' than orientation barriers in that prior industry experience does not always lead to lower perceived barriers. In fact, it is clear that the most commercially minded of our population of academics—the academic entrepreneurs—had the highest levels of transactional barriers. Of course, these high barriers could be the result of individuals engaging in commercial enterprises that may have goals that conflict with those of the wider university or their industry partners. Regardless, it remains striking that these individuals are the ones who face the biggest barriers to negotiating the terms for collaboration. This result suggests that more effort is needed by universities to support their academic entrepreneurs, providing clear, well-articulated and flexible rules and regulations about what these individuals can and cannot do with university resources and under their employment contracts. Moreover, it may be necessary to provide more high-quality service support to these individuals to help guide them through the university's systems and support them after they created their firm. Joint ownership of the new venture between the academic and the university may help mitigate some of these inherent conflicts, as it ensures better alignment of incentives between the parties.

Third, the value of trust in shaping both orientation and transaction barriers may have an important policy implication. Past patterns of university–industry engagement tended to rely on informal, personal-based relationships, often using non-contractual obligations (Lee, 1996; Van Dierdonck *et al.*, 1990). These informal mechanisms of exchange—often unreported and unmeasured—provide a great deal of flexibility for individual academics (and their industrial partners) to shape their engagement efforts in ways that were well tuned to their needs and ambitions. Yet the preponderance of informal mechanisms of knowledge transfer meant that researchers with less diverse networks were mostly excluded a priori from collaborating with industry. Moreover, the lack of formal requirements and regulations in university–industry relations often put researchers in a weakened position when negotiating the terms of research agreements, especially in regard to the ownership of results. The growth in the 'engagement infrastructure' in the university—as described above—has supported academics in this process, but it has also led to the imposition of new rules, regulations and procedures for engagement. It is clear that these efforts have made the activities of academic engagement more transparent and may have helped professionalise the management of some forms of exchange, such as the writing of formal research contracts with external parties. Yet, such transparency and professionalisation may have come at the cost of flexibility for some of the most engaged academics.

There are several important limitations and future research questions that arise from our study. First, although one of our measures of experience comes from different sources and covers periods outside the survey responses on the barriers to collaboration, it is difficult for us to make statements about the causal structure of these relationships. Indeed, for some of our measures, such as trust and the breadth of collaboration, there is a significant danger of reverse causality. Of course, with cross-sectional information, it is difficult to resolve these issues with any clarity. However, we have sought to suggest associations rather than any causal structure and we have used, where possible, measures that capture information about the experiences of academics in the years prior to our survey. Moreover, we have tried to treat collaboration experience in all its many different facets, including joint research, industry work experience and engagement across multiple channels. This approach helps us to probe different types of experience and to capture how the quality and depth of these collaborations shapes perceived barriers.

Second, it is clear from our research that engagement decisions of academics are complex and multifaceted, requiring judgements about both the costs and benefits of engagement. Although our study unpacks different barriers to engagement, we still do not know how these different barriers may shape future engagement choices of the academics. Last, the attitudes of academics towards engagement are useful in the sense that the observable behaviour of academics may not be a one-to-one match to their attitudes. Indeed, Bercovitz and Feldman (2008) suggested that many academics engage in entrepreneurship for largely symbolic reasons. By probing the attitudes of academics and seeing how these attitudes are associated with more observable forms of engagement, it is possible to get under the surface of academics' industrial engagement and to better understand the 'why' and the 'how' of their engagement with industry.

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Appendix 1

Trust

(1) During collaborative projects, my industrial partners usually treated my problems constructively and with care.

(2) My industrial partners may use opportunities that arise to profit at my expense or at the expense of the university.

(3) Based on past experience, I cannot have complete confidence in my industrial partners to keep promises made to me.

(4) I trust my industrial partners to treat me fairly.

(5) I trust that confidential information shared with my industrial partners about my research results will be kept strictly private.

Table A1 *: Channels of interaction between academics and industry*

Channels of interaction	Respondents having used this channel at least once in 2007/08 (%)
Attendance at conferences with industry and university participation	83
Attendance at industry-sponsored meetings	64
A new contract research agreement	58
A new joint research agreement	57
A new consultancy agreement	47
Training of company employees	47
Postgraduate training with a company	30
Creation of new physical facilities with industry funding	17