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INTELLECTUAL ARBITRAGE ACROSS INSTITUTIONAL DOMAINS: EFFECTS ON INNOVATION

Markus PERKMANN

Wolfson School of Mechanical and Manufacturing Engineering
Loughborough University
Loughborough LE11 3TU (UK)
m.perkmann@lboro.ac.uk
phone +44 1509 22 76 74
fax +44 1509 22 76 71

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Abstract: I address the question how innovation results from boundary spanning between commercial and non-commercial domains. Through an inductive study of university-industry projects at an engineering faculty, I show that exchange transactions are shaped by systematic differentials prevailing between different domains. I identify value differentials, knowledge differentials and interest differentials. I further formulate a model of intellectual arbitrage that postulates specific effects of these differentials on innovation outcome. I distinguish between effects on exploration, experimentation and the governance of innovation-oriented collaboration. The results have implications for the study of user innovation, open source software programming, university-industry relations and other instances where commercial innovators benefit from inputs by non-commercial individuals and organizations.

Keywords: innovation - exchange relationships – intellectual arbitrage – university-industry relations

INTRODUCTION

Innovation often occurs when boundaries are spanned. Boundaries may cut across teams, organizations or technologies. Teams are more innovative if they communicate more with their external environment (Ancona, and Caldwell, 1992). Firms seek to innovate by entering into R&D alliances with other organizations (Kotabe, and Swan, 1995). Reaching out into different technological domains is likely to generate more radical innovations compared to when technological search remains local (Rosenkopf, and Nerkar, 2001).

In this paper, I address a type of boundary that has received less attention: institutional boundaries. By this I mean boundaries that separate domains characterized by different institutional logics. Universities, for instance, belong to an organizational field that differs from commercial firms with respect to their aims, the rules they follow and the markets they serve. Examples of other non-commercial domains are open source communities, user communities and third sector organizations. Previous research has shown that these domains often provide sources of innovation for commercial innovators (Louis, et al., 1989; Cohen, Nelson, and Walsh, 2002; von Krogh, and von Hippel, 2006). At the same time, it has remained unexplored how exactly institutional boundaries are spanned and what effects this has.

I address these questions using an inductive study of innovation-oriented collaboration between university researchers and industrial firms. My analysis builds on the idea of "intellectual arbitrage" (Harrison, 1998). The concept was previously used to explain knowledge production at the interstices between theory and practice (Van De Ven, and Johnson, 2006) – these are also domains governed by different logics. I use this sensitizing concept to develop a model of institutional boundary spanning and its effects on innovation outcomes. This enables me to uncover two essential moments of innovation-oriented transactions across institutional boundaries. First, transactions take the general form of exchange (Blau, 1964). This means individuals positioned in different domains "trade" various assets with each other, based on the value these assets have in their respective domains. Second, exchange transactions are enabled by the presence of differentials. According to the Cambridge Dictionary, a differential is an "amount of difference between things which are compared". For instance, exchange might occur when there is a sufficient difference in terms of the knowledge held by the exchange partners. The idea of exchange, facilitated by differentials across institutional domains, forms the cornerstone of the model I develop in this article.

I begin by outlining in detail the theoretical problematique I intend to address. I review existing research on boundary spanning and then discuss in more detail the instances where institutional boundary spanning has been found to matter for innovation. These are open-source innovation, user innovation and university-industry collaboration. I then discuss the two main approaches that have been used to explain these instances, "commercialism" and "communalism". While acknowledging their merits, I identify their limitations in informing a model of institutional boundary spanning. In the second section I describe the data and methodology used in this study.

The subsequent sections contain the findings whereby I move from the presentation of "raw" evidence to increasingly theorized statements. Hence, I first provide an overview of the relationships that I found to prevail between academics and their industrial partners. Having established that nature of these relationships as exchange relationships, I then explore *what* was being exchanged. This allows me to identify three types of differentials that provide the conditions for these exchanges to take place: value differentials, knowledge differentials, and interest differentials. I then proceed to theorize the effects of these differentials on processes of innovation. I conclude with a discussion of the results in light of the wider literature.

THEORY BACKGROUND

Innovation tends to occur when knowledge from different contexts is combined (Kogut, and Zander, 1992). Novel products and processes therefore often arise from the interstices between firms, universities, research laboratories, suppliers, and customers (Powell, Koput, and Smith-Doerr, 1996). Technological opportunities often develop in different industry sectors or in the realm of academic research (Scherer, 1965; Klevorick, et al., 1995). This demonstrates the relevance of boundaries for the study of innovation (Tushman, 1977). When boundaries are successfully overcome or bridged, innovations are more likely to be generated (Hargadon, and Sutton, 1997; Carlile, 2002). By spanning boundaries, organizations can break away from the shortcomings of local search and access a wider range of knowledge than would otherwise be available (March, and Simon, 1958).

Previous research has explored various types of boundaries relevant to innovation processes. Organizational boundaries are spanned when firms collaborate with external organizations to exploit complementary competencies or to engage in mutual learning (Larsson, et al., 1998; Hagedoorn, Link, and Vonortas, 2000). Firms that span organizational boundaries achieve better innovation results even when they collaborate with firms with similar technological competences (Rosenkopf, and Nerkar, 2001). Technological boundaries are spanned when firms or firm units collaborate with partners that have different technological competencies. Rosenkopf and Nerkar (2001) found in a study of the disk industry that technological boundary spanning allows firms to innovate in areas other than their immediate core technology.

In this paper I focus on institutional boundaries. These exist between domains characterized by different institutional logics (Friedland, and Alford, 1991). Institutional domains can be organizational fields that are populated by organizations that are similar to each other and pursue similar goals (DiMaggio, and Powell, 1983). Organizations belonging to different fields therefore often have different sets of goals, authority relations, technologies, and seek to serve different markets (Hannan, and Freeman, 1984). Institutional domains may also be constituted by life world realms, organized or otherwise, such as social movements (Benford, and Snow, 2000), community-based entrepreneurship (Peredo, and Chrisman, 2006), communities of practice (Brown, and Duguid, 1991) and communities of practitioners in sports, leisure or consumption (Franke, and Shah, 2003). Within different domains, organizations and individuals act under different assumptions as to what constitutes legitimate behavior (Selsky, and Parker, 2005).

In the same way it has been suggested for organizational and technological boundaries, boundary spanning between institutional domains equally appears of relevance for innovation. For instance, individual creative action is influenced by multiple social domains as this creates situations when individuals choose between creative and routine actions (Ford, 1996). Previous research has identified several non-commercial domains as sources of innovation for firms. For instance, user innovation is based on ideas and work originating in users' life worlds or professional contexts (von Hippel, 1987). Similarly, open source software innovation takes place in communities of technology-savvy developers who make their creations available to other users and producers for free (von Krogh, and von Hippel, 2006). This can benefit commercial innovators in various ways, for instance via "firm-hosted" communities (Dahlander, and Magnusson, 2005; Jeppesen, and Frederiksen, 2006). Finally, academic researchers are often enlisted to collaborate on industry innovatory activities (Cohen, Nelson, and Walsh, 2002). All these instances have in common that innovation-relevant contributions are provided by individuals, organizations and communities situated in non-commercial domains.

How does this work? Research suggests that non-commercial innovators are rarely driven by strict commercial motivations. Rather, they tend to get involved based on the incentives and norms prevailing in their home domains. Reasons for engaging range from intrinsic motivators, such as fun, enjoyment and learning, to extrinsic motivators, including within-community reputation building and competence-signaling to prospective employers (Lerner, and Tirole, 2002; von Hippel, and von Krogh, 2003; Lakhani, and Wolf, 2005). In the Apache project many developers were paid to take part in the project (Roberts, Hann, and Slaughter, 2006). Even so, these developers were more strongly motivated by achieving high status in the community, rather than the commercial value of their creations (Roberts, Hann, and Slaughter, 2006).

A special case of open source software programming prevails when open source communities participate more directly in innovation activity pursued by firms. Firms can pursue various strategies to take commercial advantage of results generated by user communities (Dahlander, and Magnusson, 2005). Yet participants in such firm-hosted communities tend to be hobbyists motivated by intrinsic motivation, rather than professionals who are less likely to engage in activities where little extrinsic rewards are offered (Jeppesen, and Frederiksen, 2006).

Furthermore, interactions between users and commercial firms have been noted in diverse sectors such as medical devices, scientific instruments and sports equipment (von Hippel, 1976; Shaw, 1998; Franke, and Shah, 2003). For instance, companies can obtain ideas for new products or product improvements by adopting concepts and prototypes already developed by users (von Hippel, 1986). By involving lead users in testing and improving prototypes and beta-versions, companies explicitly seek to exploit users' knowledge (von Hippel, 2001b).

Most commonly perhaps, interactions with universities have long been noted as a source of innovation for firms (Rosenberg, 1994). Academic researchers work with industry in a variety of ways, ranging from academic entrepreneurship to collaborative research and consulting (Louis, et al., 1989; Cohen, Nelson, and Walsh, 2002). A significant number of innovations in the commercial sector draw on knowledge from the academic realm (Mansfield, 1991). At the same time, the production of knowledge in the academic domain is typically "open", meaning that it does not traditionally link direct financial remuneration to knowledge creation (Dasgupta, and David, 1994).

The extant literature offers two main avenues of explanation for this general phenomenon. The first view is *commercialism*. From this perspective, academics, users and open-source programmers work with firms because they "go commercial". For instance, some academics choose to become entrepreneurs, and set up university spin-off companies (Louis, et al., 1989; Shane, 2005). In the majority of these cases, these individuals are commercially motivated and hence adopt the norms, expectations and practices prevailing in the commercial sector. According to some observers, increasing commercialism by academics indicates a process of institutional change that sees the academic sector increasingly adopting the organizational goals and norms of the commercial sector (Owen-Smith, 2005). Most notably, this involves growing importance attributed to proprietary approaches to the dissemination and commercial exploitation of science and engineering research (Owen-Smith, 2005; Colyvas, 2007). On the micro-level, this manifests itself as organizational change compelling individual academics to act more entrepreneurially (Bercovitz, and Feldman, 2008).

However, most instances of university-industry relations do not involve the set-up of commercial entities by academics. More commonly, academics choose to work with industry from within their academic institutions, deploying various forms of collaboration (Perkmann, and Walsh, 2007). Instead of taking direct commercial responsibility, academics choose the “assistant mode” in their dealings with industry (Stankiewicz, 1986). Their objectives and behaviors remain consistent with the world of open science where career progress is linked to the accumulation of peer reputation through publications (Merton, 1973; Dasgupta, and David, 1994). Previous research has shown that academics interact and collaborate with industry mainly to further their own career goals within the science system (Mansfield, 1995; Lee, 1996). This could for instance include the desire to secure funds for graduate students, access laboratory equipment, gain insights applicable to their own research, test practical applications, and supplement research funds. For similar reasons, if academics are encouraged to act entrepreneurially by their departments, compliance is often merely symbolic as their motivations are oriented to towards academic goals (Bercovitz, and Feldman, 2007). For these reasons, the commercialism perspective has serious limitations for describing the phenomenon as a whole. In similar ways, it has been argued that users or open-source programmers do not typically get involved with commercial players under commercial terms (von Krogh, and von Hippel, 2006). A participant-observer even described open source development as a special case of applied academic research, because academics, similarly to open source programmers, are “not in it for the money” (Bezroukov, 1999).

The second view proposed for explaining institutional boundary spanning is *communalism*. Some have suggested that informal relations, embedded in community ties, facilitate transactions between commercial and non-commercial domains. For instance, Powell et al (1996: 120) argue that, in the case of high-tech industries, " … beneath most formal ties, then, lies a sea of informal relations". They find that firms are embedded in multiple ties with university researchers that enable them to acquire new knowledge through largely informal collaborative activities that "represent more than just formal contractual exchange" (Powell, Koput, and Smith-Doerr, 1996: 120). A similar argument is advanced by Liebeskind et al. (1996) who find that social networks with university scientists constitute the most effective way of sourcing knowledge for biotechnology firms. Kreiner and Schultz (1993: 193) find that in relationships between Danish biotechnology firms and universities "… participants show very little concern for the immediate terms of exchange and few take special precautions to ensure reciprocation". Related arguments have been applied to the interaction of firms with users (von Hippel, 2001a), and open-source programmers (Lakhani, and Wolf, 2005). More generally, Allen found that many production techniques in the 19th century were developed via "collective invention", involving free revealing by inventors (Allen, 1979).

Communalist accounts assume that institutional boundaries are spanned by informal networks, such as communities of practice, within which innovation-relevant knowledge is freely shared (Rosenkopf, and Tushman, 1998; Wenger, 1999). Yet, the communalist argument also suffers from shortcomings. First, while its proponents tend to emphasize the positive effects of social networks on innovativeness, less is known about how exactly and under what conditions interaction occurs within these networks. Second, it is not clear whether it makes a difference if networks cross the boundaries between organizations belonging to different organizational fields. Are the combinative opportunities merely linked to technological and organizational boundaries, or is there something more specific about institutional boundaries? Other authors have emphasized that it can be challenging to integrate the logics of different domains, as Cockburn, Henderson, and Stern (1999) highlighted with the example of science-based drug discovery. In this instance, drug companies faced major challenges in designing appropriate incentive schemes, because of the very different ways in which commercial and scientific activities are performed and measured.

In sum, while the commercialism argument does not appear to be widely applicable, the communalism argument lacks precision and does not offer a satisfactory account of inter-institutional boundary spanning. Here is where my work intends to contribute with a study of university-industry collaboration. I inductively explore the circumstances in which academic researchers engage with industrial partners. I focus on three objectives. The first objective refers to the structural context in which these transactions occur. If there is something special about inter-institutional boundary spanning, then one should be able to articulate this in analytical terms. The sensitizing concept I used was the concept of “intellectual arbitrage” (Harrison, 1998). The concept was elaborated and used by van de Ven and Johnson (2006: 803) to characterize the structural conditions prevailing when practitioners and scholars collaborate. They define intellectual arbitrage as “… a strategy of exploiting differences in the kinds of knowledge that scholars and practitioners can contribute on a problem of interest”. They use the concept to illustrate how academics and practitioners can fruitfully resolve problems by confronting divergent theses and antitheses that arise from their different viewpoints. While they argue that arbitrage is not a method for addressing narrow problems where experts agree how they are to be resolved, it provides a strategy for “triangulating” between judgments exerted from different viewpoints (Van De Ven, and Johnson, 2006). A related concept is “information arbitrage”, often used by network brokers, which consists in exploiting informational differences between two network nodes (Burt, 2004). However, “information arbitrage” is a narrower concept, and I therefore prefer to use “intellectual arbitrage”.

The second objective refers to the nature of the interactions occurring across institutional boundaries. If neither a fully-fledged commercial logic nor a community logic applies, what are the ways in which non-commercial innovators get involved with commercial firms? The analysis should contribute to open up the black box that prevails in the literature with respect to the drivers underlying these transactions. Heuristically extrapolating from the trading metaphor of intellectual arbitrage, I view the transactions as exchanges in a general sense. Exchange is a much broader concept than implied in a narrow view of monetary market transactions (Biggart, and Delbridge, 2004). Exchange and cooperation often have a social dimension (intrinsic utility) as well as an economic dimension (extrinsic utility) (Nooteboom, Berger, and Noorderhaven, 1997).

Exchange is a particular type of interaction between actors based on their voluntary agreement to accept one type of asset in return for another (Blau, 1964). As a social process, exchange enables the movement of valued things (resources) across persons (Emerson, 1976). Through this lens, even gift giving can be seen as a particular type of exchange (Mauss, 1954). Underlying exchange is a notion of equivalence even though this might not be expressed in quantitative, monetary form (Simmel, 1978). The exchange can take the form of barter, i.e. a transaction in which unlike objects are exchanged directly for one another without the use of money (Strathern, 1992).

This notion of exchange is sufficiently general not to compromise my inductive exploration. Exchange relationships are very common, and include transactions between teachers and students, employers and employees and others (Takahashi, 2000). Particularly within innovation studies, informal exchange of know-how has for instance been found to occur within industries, even among competitors (Hippel, 1987; Schrader, 1990). Implicit trading has been found to occur in industry-university co-authoring (Hicks, 1995).

The third objective, finally, is to generate insights as to whether institutional boundary spanning has specific effects on innovation. Here the question is whether this type of boundary spanning is more likely to generate certain innovation outcomes at the expense of others. If institutional boundary spanning has specific characteristics as a social relationship, then one might be able to theorize its effects on innovation processes. This might then be used for explaining why, for instance, user innovation applies only to a narrow set of circumstances (Christensen, 1997) or the structural limits to university-industry collaboration (Mansfield, 1991). In the next section, I describe the data and methodology used to pursue these objectives.

DATA AND METHODOLOGY

As my objectives are exploratory in character, I adopted a qualitative research methodology. Such an approach is suitable for areas where existing theory is unable to fully explain empirical phenomena (Eisenhardt, and Graebner, 2007). I adhered to the principles of analytic induction to make sense of my qualitative data. This involves developing working hypotheses on the basis of specific instances and then comparing the emerging hypotheses with the remaining instances in an iterative process (Znaniecki, 1934). Analytic induction is primarily deployed for generative research and uses external observer categories to interpret and understand the raw data (Goetz, and LeCompte, 1981). Simultaneously, it also acknowledges existing theory, rather than necessarily starting from a theoretical tabula rasa. In this way, I was able to “elaborate theory” (Lee, 1999) by using categories provided by extant theory as prompts while at the same time generating new relationships between concepts (Bacharach, 1989).

Study setting and sample

I chose a UK university setting as case site for studying innovation-oriented institutional boundary spanning. University-industry collaboration is a widely acknowledged source for commercial innovation (Mansfield, 1991; Grossman, Reid, and Morgan, 2001; Salter, and Martin, 2001). Joint research, consulting or contract research are seen as highly relevant by industry and academics alike (Meyer-Krahmer, and Schmoch, 1998; Cohen, Nelson, and Walsh, 2002).

Within this setting, my site choice was informed by three considerations. Firstly, I focused on highly research-productive academics because they could be expected to more strongly adhere to the norms and values prevailing in academia as an institutional field. For instance, adhering to the norm of priority will produce the highest payoff for the best scientists, meaning that they will be less inclined to privatize their knowledge (Dasgupta, and David, 1994). This ensured I was actually selecting a setting where institutional boundaries were crossed.

Secondly, I chose engineering because it constitutes a discipline with a high level of university-industry collaboration (Meyer-Krahmer, and Reger, 1999; Schartinger, et al., 2002). My inquiry therefore promised to provide a view on a range of different ways in which such collaboration was pursued. Engineering combines a set of disciplines that are guided by perceptions of technical problems and deploys findings derived from the more “basic” sciences to this purpose (Klevorick, et al., 1995). This implies a relative affinity between academic engineers and industrial users and developers of technology. At the same time, engineering is an academic discipline with rules for novelty, priority and reputation similar to other academic disciplines (Merton, 1973). Thirdly, I chose to carry out my study at one university because I wanted to control for university-specific influences that were not at the centre of my inquiry.

These considerations led me to select interviewees at a research-intensive university via a theoretical sampling strategy (Eisenhardt, 1989). The departments were rated as “internationally excellent” within the UK research assessment exercise. The selection criterion for interviewees was that they were participating at the time or within the previous year in a project involving a university and a (usually private sector) corporation. They were identified in several steps. Firstly, I approached members of the engineering faculty who were involved in facilitating commercialization and technology transfer and asked them to refer me to members of the department who were working with industry. Secondly, I talked to the head of academic consulting at the university’s technology transfer office and requested access to a list of academics across different departments who had pursued consulting engagements with outside organizations. Respondents selected to be interviewed were primarily located in engineering, with the remaining being scientists or human scientists. I ensured that respondents affiliated with other faculties had technical interests comparable with those of engineers. Finally, I asked my academic interviewees for contact details of industrial partners they had worked with on joint projects. This allowed me to generate pairs of collaborating academics and industry staff, although in some cases academics declined to nominate their partners for confidentiality and relationship-related reasons.

Data collection

I held 46 interviews in 2006-2007. They lasted above an hour on average and were all recorded and transcribed. Interviews are referenced using interview codes (e.g. i21, listed in Table 5). I used the literature, and initial pilot interviews (i1-i6) to design the interview protocol. The questions asked during pilot interviews revolved around themes extracted from the literature. I solicited information on the types of activity pursued within university-industry collaboration, the motives for getting involved on both academic and industrial sides, outputs and benefits as well as types of inter-organizational arrangements deployed. The results of the pilot interviews enabled me to iteratively revise the interview protocol, by narrowing down the questions and removing those that were too general to yield meaningful results.

The resulting final interview protocol contained a list of themes that were addressed during the interviews in a semi-structured way. I used two different versions for academics and industry staff to account for different organizational settings and task characteristics. After asking the respondents to summarize their background, career trajectory and primary motivational drivers, I encouraged them to reflectively step back and consider the whole range of ways in which they interacted with industry (for academics) or with academia (for industry staff). I suggested they distinguish between different types of projects and then provide a few examples of their current or recent projects for each of the types they identified.

I then asked them to expand on one specific example for each type in more detail. I asked them to describe how each project was initiated, what its objectives were and who the partners were. Then I enquired about the precise nature of activities involved at various phases of the project, and how they were organized. I also asked respondents to describe how relationships with the partners were established, how they viewed the relationships they had developed and whether there were any problems and barriers they had experienced. Importantly, I then enquired in more detail about the rationales that informed their decision to work with industrial/academic partners for each project, what the benefits were from their viewpoint and what exactly they thought made their work valuable to the partners. Finally, I asked about various aspects surrounding the specific collaboration instances, including whether any patenting was being pursued or other intellectual property provisions were made and (for academics) whether the outputs lent themselves to publishing in peer-reviewed journals.

An additional source of information was provided by archival records relating to collaborative projects my informants referred to. Whenever possible, I asked my informants to provide written documentation on these projects. This included grant proposals, contract notes and outcome reports. In some cases, I looked up information on the projects on the Internet, notably on the websites of various funding councils and bodies my informants were funded by. I also consulted bibliographic databases, such as Google Scholar, to obtain a picture of my informants' academic publication track record and contrasted this information with their interview statements. Consulting these sources allowed me to triangulate some of the information provided, helping me to compile the initial narratives for each project instance.

I adopted various measures to improve validity. I prompted the interviewees for facts rather than opinion to reduce cognitive biases and alleviate impression management (Miller, Cardinal, and Glick, 1997). For instance, I asked about how precisely projects had been initiated, the number of partners and people involved, and the concrete outcomes achieved. Confidentiality was promised to respondents in order to further improve the accuracy of the details given (Miller, Cardinal, and Glick, 1997). My effort to interview several informants (academics and industry staff), where possible, was designed to alleviate subject bias. To reduce retrospective bias, I consulted individuals only about activities they were involved in at the time of interview or in the immediate past.

Data analysis

From the interview transcripts, I extracted information on 57 collaboration instances ("projects") in which interviewees were involved. These projects formed the primary unit of analysis. I then pooled the information on these projects to devise generalizable statements about them, similar to previous studies (Miner, Bassoff, and Moorman, 2001; Elsbach, and Kramer, 2003).

I initially generated a narrative summary for each of the projects. I recorded project characteristics within several dimensions: type of industrial partners involved, type of interaction, the rationale for the academic researcher to collaborate, the type of activities pursued, and outputs generated. This data reduction resulted in an unordered "mega matrix", maintained as a spreadsheet, that formed the basis for the further analysis of the data (Miles, and Huberman, 1994). An immediate output was a project typology which I was able to use to select project instances relevant for my study. I present illustrative examples of projects in Table 1.

Table 1 about here

I then went back to the interview texts and coded them using the sensitizing concept of “exchange”. I identified those statements where respondents referred to explicit and implicit trades they engaged in. Such references were often made when respondents talked about benefits they had accrued while engaging in a certain transaction, or compromises they had agreed to. This was often linked to implicit references to trades, such as: “ … in return for collaborating on this project, I was able to use their fan blade data”. This coding exercise allowed me to generate a list of different “objects” that were exchanged, ranging from material resources (such as data) to intangible resources (such as legitimacy). I then went back to the data, and in a subsequent round of coding, I isolated the structural conditions enabling the exchange transactions my interviewees had engaged in. The result was a typology of “differentials”, i.e. degrees of differences between the various types of assets my respondents controlled or aspired to, compared to their industrial partners.

In a final step, I identified the effects on innovation outcomes that the presence of these differentials induced. I did this in two interrelated ways. On one hand, I went back and forward between what I found, and provisional concepts that were emerging from the evidence, in “grounded-theory” style (Glaser, and Strauss, 1967), to describe the effects. On the other, I attempted to approximate those provisional concepts with concepts known in the literature, as I wanted to link my findings with generally accepted categories describing antecedents of innovation outcomes.

CHARACTERISTICS OF COLLABORATIVE PROJECTS

The first focus of my fieldwork was to establish the purposes that brought universities and industry to work together on collaborative projects. This allowed me to compile a typology of such projects. A first project type was focused on *solving problems*. Firms approached academics to assist them with a specific problem they had encountered within their R&D, engineering or manufacturing operations. For instance, a manufacturer of electronic circuit boards for commercial aircraft approached a university research group to resolve difficult-to-spot quality flaws inherent in the design and manufacturing of such boards. Secondly, academics were approached to help firms *develop technology*. Such projects focused more directly on improving or developing specific technologies relevant to commercial users. An example is provided by a project aimed at developing flexible printed circuit boards to replace wire harnesses in cars. A third type of project I labeled as *providing advice*. Such projects were aimed at mobilizing the expertise of academics by soliciting advice, without necessarily requesting any ready-to-use outputs. For instance, an engineering professor specializing in risk modeling was asked by a multinational energy company to provide a risk assessment for a planned oil platform refurbishment.

Fourth, some projects entailed what I refer to as *testing ideas*. Firms approached academics to explore specific ideas they had generated within their R&D or manufacturing units. These were seen as “high-risk” ideas with commercial potential if successfully translated into a concrete concept, prototype or technology. For instance, a multinational automotive manufacturer asked a mechanical engineering professor to experiment with a novel, microwave-based device to see whether it could be used to as a particle filter for diesel engines.

A fifth type of projects was represented by what were essentially academic research projects with industrial participation – I label them as *generating knowledge*. Such projects were removed from any immediate commercial application, and were usually initiated and controlled by academics, with industrial partners playing advisory or observer roles. For instance, a project was aimed at advancing “zero-breakdown” machines by equipping them with intelligent electronic monitoring systems. Industrial partners often contributed “in kind”, i.e. by committing management time, materials and occasionally access to prototypes and experimental set-ups within their laboratories.

Table 2 about here

Summarizing, I identified five types of goals of university-industry collaboration projects (Table 2). Among these, projects focusing on problem solving, developing technology and providing advice and, to a large degree, idea testing, were explicitly aimed at assisting industrial firms achieve certain R&D or innovation objectives. This conclusion is supported by the fact the overwhelming majority of these projects was initiated by firms, providing a strong indicator of perceived use value. In the same vein, for most of these projects, firms provided all or at least the majority of the required funding.

In the remainder of this article, I restrict my analysis to those 40 project instances that were explicitly aimed at assisting firms achieve R&D or innovation objectives (i.e. type 1 to 4). By excluding the project instances aiming at “generating knowledge”, I ensure that my analysis only covers instances of extra-commercial innovation. In other words, I focus on instances where firms clearly followed a commercial purpose when sourcing knowledge from universities. This is a conservative assumption aimed at improving the validity of my analysis as some knowledge generating projects doubtlessly also provided some degree of opportunity for gaining innovatory inputs from the academic realm.

"NOT IN FOR THE MONEY": WHAT IS BEING EXCHANGED?

The next step was to explore why academics engaged in collaboration with industrial partners. Most of the academic researchers I interviewed confirmed that working with industry was not primarily motivated by personal income considerations. The following statement reflects a typical answer to the question why interviewees accepted consulting projects:

"You know, I certainly do it primarily for interest rather than money. You know, because I'm fairly busy anyway. I'm a professor; academics are not on high salaries, but we're comfortable, at least. And so I don't want to give myself more hassle unless I think it's interesting." (i23)

Other respondents echoed this attitude by stating that the monetary aspect was admittedly a "nice-to-have" but not a determining factor for participating in industrial projects. This relative disinterest in pecuniary remuneration also led many respondents to generally refrain from actively soliciting "business" that was explicitly aimed at generating personal income. The following attitude was typical: "I don't go out looking for consulting; I just react to requests" (i9). Equally, many interviewees chose to pay their consulting fees into university accounts instead of taking the money personally. This provided them with a slush fund for discretionary, research-related expenses for themselves or their PhD-Students (i28).

While being relatively disinterested in money, interviewees mentioned a series of reasons as to why they engaged in industrial work. Many pointed to the fact that working with industry was “interesting”. For instance, a professor stated:

“I find consulting interesting. I think interesting is a project where I have something to offer to help these people at [Telecom Corp]. Can I definitely help these people? Can I really do a good job? In which case, that’s interesting in its own right, because it’s quite satisfying personally. The other aspect is, well, I’ve probably got something to learn. So I think a combination of those two aspects is what I mean by interesting.” (i29)

Similarly, a renewable energy researcher stated:

“I’m very research driven. The thing that has always attracted me to [Aerospace Corp] was that they have tremendous technical problems. They provide a ready source of absolutely really challenging technical problems.” (i16)

More so than personal income, intrinsic motivators (Deci, and Ryan, 1985) such as “interest” and “learning” were generally a necessary factor for engaging in industrial collaboration. Primarily, the reasons given reflect “enjoyment-related intrinsic motivation”, i.e. the individuals’ personal satisfaction they drew from these projects, as opposed to obligation/community-based motivation (Lindenberg, 2001).

However, this again appeared not to be a sufficient condition. In the overwhelming majority of cases, respondents explained that other factors were at play. Academics were expecting more in return. Respondents indicated a wide variety of resources they attempted to obtain – and often obtained – via university-industry collaboration. I provide instances of specific exchange objects in Table 3.

Table 3 about here

A first type of resource academics were attempting to obtain, against providing their expertise, was access to data, or equipment, that they could use for their research. They pointed out that, within certain fields, such "real-life" information was an important yet scarce material resource that could ensure research relevance and quality. A second type of resource academics wanted to access was legitimacy. Particularly working with large, well-known corporations was seen as providing kudos for their research by adding to its credibility. Equally, some industry executives pointed out that legitimacy provided by university partners was an important element of exchange that was not explicitly contracted for. Thirdly, respondents pointed out that they worked with industry in order to acquire new knowledge. For instance, collaborative projects sometimes provided them with new insights and ideas that would lead to new research proposals. Alternatively, gathering insights into industry problems was frequently pointed out as a major benefit for their teaching activity.

These non-pecuniary resources were usually not explicitly contracted for, yet they were often seen as implicit part of the "deal" with industrial partners. Although money almost always changed hands, either into university accounts or more rarely directly into academics' personal bank accounts, the non-pecuniary side of the transactions was usually presented as a necessary ingredient. All these resources were ultimately instrumental for enabling and improving an academics' research activity, and were therefore intrinsically related to their situatedness in the domain of science.

Summarizing, I found that exchanges within university-industry relationships were noticeably informed by the fact that the exchange partners belonged to different institutional domains, i.e. industry and science. This led me to hypothesize that differences between the domains to which the exchange partners belonged might systematically inform the benefits arising from the relationships. Going back to the raw evidence, I re-coded my interview material with a view to capture these differences in more detail.

DIFFERENTIALS WITHIN EXCHANGE RELATIONSHIPS

I used the arbitrage concept as a heuristic device for identifying those differences that appeared to form the basis of the exchange relationships I observed. I refer to these as "differentials". My analysis of exchange objects above provided me with pointers to these differentials. My coding revealed a host of such possibly relevant differentials which I then grouped into categories of intermediate generality. I report the results below.

Value differentials

When resources are exchanged across institutional boundaries, it is likely that the value of what is being exchanged will be measured differently by actors operating in different institutional systems. Value in exchange is dependent on the exchange relationship, and can therefore not be independent from the situatedness of exchange partners in their respective contexts (Emerson, 1976). In other words, what represents "equivalence" depends on the situatedness of the partners within their respective settings. This means resource A can be highly valued in system A while it is of less value in system B. If there is a resource B that is highly valued in system B and less valued in system A, then there is a case for exchange that serves the interest of the resource holders in their respective systems.

Such a situation prevailed in many of the collaboration instances I studied. For instance, the value of academic publications was generally high for an academic while it was of moderate value for industry executives and R&D personnel. Some projects did not allow academics to pursue publication, either because of IP restrictions imposed by the commercial partners, or the mere lack of novelty of project outputs. However, in a number of occasions the academic partners succeeded in circumventing both hurdles and were able to exploit project outputs via publications in academic journals. Typically, this was enabled by some concession by the industrial partners whereby the cost of these concessions was usually low and hence the concession amounted to a goodwill gesture. Concessions were offered both with respect to IP considerations and academic novelty of projects.

One academic, who had used "real-life" data on fan blade experiments provided by a turbine manufacturer, explained how the company allowed her to publish academic papers using the data that were slightly modified to preserve commercial confidentiality. This was the case even though the company engineers had no interest in publishing themselves:

"It's a trade, and you've got to work with the people [industrial partners] at a level of understanding that they appreciate what we need to do. We would not be able to publish the actual data, but we were able to use relative values. We modified the baseline in a way that was not going to make any difference whatsoever. As long as you do this, then publishing is no problem to them [our corporate partners] at all." (i13)

It was common for the respondents to describe their commercial partners as being very lenient when it came to allow for academic publications even though formally in almost all cases restrictions were in place.

“[Publishing] has not really been a problem so far. I've only ever had one time where we wanted to publish something and the partner wasn't happy with us to go ahead. I think we're normally aware enough to know what is sensitive and what isn't; so we tend not to want to immediately publish something because we know there's sensitivity there.” (i12)

Another respondent described the explicit trade in which he engaged with his industrial partners over academic publishing of project results. The trade stipulated if companies wanted to prevent publishing then they had to pay 100% of research projects. By contrast, if they chose to accept any proportion of public funding, then publishing was to be allowed.

“[Publishing] is one big difficulty with working in this field. Sometimes, especially when the project is product oriented, they [industrial partners] are unwilling to allow you to publish. Sometimes we’re negotiating: ‘If you are not going to let us publish, then we’re going to have to turn around and say, well, you pay then.’ Then maybe we get out of it some PhD graduations and stuff like that.” (i18)

The general pattern was that industrial partners would have no objection to academic publishing – a resource highly prized in the academic context – as long as the cost of doing so was low. In most cases this meant that as long no confidential commercial information was disclosed, publication approval could be given at a low cost.

Similar value differentials prevailed with respect to other resources, such as research materials, access to equipment or data access. Corporate partners often were able to provide these assets for little cost to them although it might have been costly or, in case of unique data, impossible for academics to mobilize them otherwise. Likewise, industrial partners were sometimes prepared to provide sponsorship for future "pure" academic research projects led by their collaborators. In many cases, such sponsorship deals did not involve cash but rather payment "in kind", i.e. management time, product samples or access to equipment. This meant providing such support generated little cost, yet enabled an academic researcher to win a grant from the government research council because they demonstrated industrial support.

In the same way, academics would make concessions on intellectual property. My respondents indicated that industrial partners would often insist on owning, or at least being able to exploit, any intellectual property generated during collaborative projects. In this situation, academics were often prepared to make this concession to industry, in return for assets that were valuable to them. For instance, an automotive engineering professor stated:

"Some companies absolutely won't engage in anything where they don't hold the IP. And sometimes I think, well, why would I want to work with them then. But then, we've got PhD's going through the system. We've got a lot of openings with publications." (i10)

Generally, the described exchange transactions were facilitated by differentials between the value attributed to specific resources within the industrial and academic contexts. What might be of relatively low value in an industrial context, might be of high value in the academic context, and vice-a-versa. Such conditions are less likely to prevail *within* each domain. For instance, firms will be less inclined to provide access to specific data or information to other commercial entities. On one hand, other companies will have less interest in exploiting such access for generating academic publications. On the other, sharing such information might be counterproductive because of competitive threats. Such differences in attributed value therefore help explain the "liberal information sharing" observed in earlier analysis of university-industry interactions (Kreiner, and Schultz, 1993), in addition to the more general presence of embeddedness.

Knowledge differentials

A second set of differentials characterizing the exchange relationships I studied were related to the nature of knowledge held by the partners.

Substantive knowledge differentials. A first type of knowledge differentials was based on criss-crossing knowledge domains. This is illustrated by the following case. Development engineers at a large aerospace company approached an academic specializing in electronic control systems with a problem they had encountered on a novel type of low-noise bearings they were developing for submarines. While their existing expertise was in conventional ball bearings, the new technology used actively controlled magnets to enable rotation without physical contact. Their existing expertise was in mechanical engineering while the newly required expertise was much closer to electrical engineering. When a problem occurred with the active magnetic bearings – high-frequency resonance – internal expertise was unable to identify the reason for the failure. Engaging an academic provided a way of compensating for this lack of internal expertise, and building expertise in a new knowledge domain. As the professor recalls:

“Although I did not know anything about ball bearings, I was useful to them because I knew about electromagnetic phenomena (…). I had no idea what the problem was when they described the problem. But we did some measurements, and I said, after maybe half a day: ‘I think actually what’s happening is the structure is resonating’. We had to do some extra measurements to prove it. I also went away and did a little bit of modeling to show them the difference between internal and external resonance.” (i23)

It was not always the case that different knowledge domains were brought together. On other occasions, the partners operated in similar domains yet with different outlooks. The following example illustrates a paradigm clash between industrial and academics partners with respect to the design of jet engines. An aerodynamics professor experimented with a new design principle for a jet engine component within the context of a formal organizational relationship with an aerospace company. This design principle was contrary to conventional engineering wisdom according to which certain air flows within jet engines should be minimized. The professor suggested that the engine should be built by intentionally creating such “secondary flows”, thereby improving efficiency and emissions. The aerospace company rejected this proposal due to its controversial nature: “… we were treading on holy water here; they said, no, you can’t do that!” (i16). This incident illustrates how the industry partners believed in one paradigm while the academic group had moved on to a new paradigm. In this case, the company refused to fund a research project but the academic succeeded in attracting public research funding, with the company loosely enlisted as an industrial partner. As the outcome was positive, the company supported a follow-on research project, again funded publicly, to investigate the implications of these findings and generate design specifications.

In a similar vein, an R&D executive at an automotive company stated:

"One of the benefits of working with the university as opposed to suppliers is that it's a fresh perspective. We tend to work on our own channel here within this organization; we recognize our suppliers are going to do the same in their organization. This [university collaboration] gets a completely different perspective, and universities tend to have much broader knowledge of different areas. For instance, they they're probably working within aerospace as well as the rail industry as well as our industry [automobiles]." (i32).

These statements illustrate how academics can provide industry with rapid access to different ways of thinking. By contrast, working with suppliers or commercial consultancies might mean that the resulting knowledge combinations might be less novel, due to previous relationships between the players or the existence of industry-wide template solutions.

Procedural knowledge differentials. A second type of knowledge differential was based on differences in the way industry and academics approached problems and developed solutions. Procedural knowledge consists in learned repertoires of specific behaviors that are adopted by individuals in response to specific situations or challenges (Singley, and Anderson, 1989). Differences in norms and training across industry and academia are responsible for different styles used to deploy disciplinary bodies of knowledge. This means that even though both partners might be engineers, the industrial engineers would adopt a different approach to a problem compared to academic engineers, similar to differences between occupational communities (Van Maanen, and Barley, 1984).

For instance, an aerodynamics professor described the way in which his team was able to "add value" during a collaborative project on jet engine design:

"What we contributed was expertise in using experimental techniques, in a very short time, with very few measurements, to eliminate certain things and then once we'd narrowed it down, to gather a much better guess of what was happening than would otherwise be the case. I think it was our experimental skills – the fact that we could put a rig together very quickly and that we could then use traditional instrumentation to carry out high time resolve measurements – it takes some skill to make the measurement – and then analyze that data with an insight in how combustors work." (i16)

Similarly, a problem solving project involving a construction engineering professor and the air force was aimed at creating a concrete mix for landing pads for vertical takeoff aircraft. The heat generated by the aircraft turbines had caused small concrete particles to detach from the concrete landing pads, threatening "foreign object damage" to the engines. While the air force personnel believed the problem could be resolved with steel fiber reinforcements, the academic research group experimented with different types of concrete in their laboratory, and shipped them to the airbase for testing them under a scaled jet engine.

"We had to theorize the mechanisms that were causing the spoiling. We used the evidence from the thermal imaging to do that, and we saw that fiber reinforcement did not stop the spoiling. We ended up developing a number of possible alternative concrete mix designs and materials." (i27)

These examples illustrate how the exploitation of procedural knowledge differentials enabled problem-solving in novel and imaginative ways. Academics and industry appeared to adopt different styles in approaching specific technical problems. Industrial staff adopted a relatively resource-intensive “experimental” style that essentially consisted in a trial-and-error approach to a problem. By contrast, academics used a more analytical approach that involved the heavier use of theories and simulation models before any experimentation would be carried out.

Contextual knowledge differentials. For developing a product or resolving a problem, often different types of knowledge need to be combined. Von Hippel (2005) distinguishes between two types of information that are required by product developers: need and context-of-use information, and generic solution information. Each type of knowledge tends to be “sticky”, implying that there are barriers to transferring knowledge from the holders of one knowledge type to the holders of the other one. Because of this cost, knowledge users therefore tend to privilege the use of the knowledge they have. A similar distinction between different knowledge types is proposed by Garud (1997). He distinguishes between “know-what”, “know-how” and “know-why”. Know-what represents knowledge about requirements to be fulfilled and objectives to be achieved. Know-how refers to knowledge about how to resolve problems. Know-why, finally, is knowledge deployed to investigate cause-effect relationships.

I found systematic differences as to where different knowledge types were located – I refer to these as contextual knowledge differentials. Within many projects, firms determined *what* needed to be developed. By contrast, academic researchers would provide the know-how, and if necessary, the know-why. For instance, during a project aimed at equipping an industrial oven with automating technology, the research reacted to the needs expressed by the commissioning firm by mobilizing their existing know-how:

"We essentially turned a simple oven into a system, by using some materials hardware, some control architecture, and insights from business modeling (…); On the basis of our analysis we then technically put together the control architecture." (i9).

In other words, industrial partners often defined the direction of effort, while the academic partners deployed their specialist expertise towards the desired direction. Another example was provided by a large manufacturer of gas turbines. The firm turned to its academic collaborators when it experienced critical vibration problems with a development engine that lead to its self-destruction. As the company engineers were unable to identify the problem cause, it was thought the academic research group who specialized in turbine aerodynamics would be able to provide the lacking expertise. The research group identified the cause of the problem as auto-ignition, i.e. the uncontrolled explosion of fuel within the engine. Subsequently, the company persuaded the researchers to assist them in resolving the problem by experimenting with various designs. This example illustrates how the firm mobilized the researchers' know-why and know-how by providing performance parameters for the development engine in question.

Such interactions are akin to user-producer relationships where the industrial partners perform as users and academic partners as producers (Lundvall, 1988). From the viewpoint of the academics, interaction with their industrial partners provided information equivalent to information generated by users, i.e. feedback on existing and desired functionality (von Hippel, 1976). This gave the academics with basic parameters as to where and how to direct their efforts in product and process innovation.

Summarizing, I identified three knowledge differentials within the exchange relationships I studied: differences in substantive knowledge, differences in procedural knowledge, and differences in contextual knowledge with respect to required inputs into the product development process. Though knowledge differentials are common when boundaries are crossed, procedural and contextual knowledge differentials may be more pronounced when institutional boundaries are crossed. This may assume particular relevance in mature industries, such as aerospace and automobiles, where oligopolistic industry structures generate technological path-dependencies that are enshrined in training and recruitment practices, common world views and supplier relationships. Working with extra-commercial knowledge providers, whose domains are only loosely coupled with industry structures, can therefore result in novel know-how.

Interest differentials

I found a final type of differential which related to differing interests among the exchange partners. I refer here to the material interests of exchange partners as social actors which inform how they behave in their social environment. Interests are often determined by the institutional environment in which actors are operating (Friedland, and Alford, 1991). This means firms operating in a competitive context are institutionally conditioned to pursue “commercial” interests while academics are typically more interested in objectives that further their advancement within the science system, mainly by accumulating reputation (Merton, 1973).

My evidence suggests that the fact that academic researchers had a relative commercial dis-interest facilitated the emergence and pursuit of university-industry collaboration. The following examples illustrate this. An electrical engineering professor was approached by a railway operator to help resolve a problem with a railway vehicle. A relay belonging to the vehicles control system was systematically malfunctioning. Several groups of "problem stakeholders" had different views as to how the problem should be resolved. The professor recalled:

"Now I actually didn't know much about relays. But I understood the nature of the system application that they were trying to do. And I first of all said to them: 'Well, maybe you need a relay specialist.' And they said, 'Well, we're looking for somebody who has got a bit of an independent view. We've got lots of relay specialists, but they're all strongly linked to industrial organizations, vendors of relays, and we're not getting objective information from them.' So they wanted somebody to come in with, if you like, this sort of unbiased view. And I would say on balance that this is something that I do get approached for quite a lot: 'This person from university; they've got no axe to grind.'" (i23)

Similarly, an R&D engineer at a large automobiles manufacturer explained how working with academics differed from working with suppliers. A project involved running a 600-hour test series on a new engine prototype to gain knowledge on how the engine worked as a "system". The engineer stated:

"We could theoretically ask a supplier to do that. The reason why a university might be better is because we can actually work much more closely with the university than with a supplier. The supplier has a much stronger commercial interest in reaching their own solutions than an independent university would. And their interest is much more in gaining knowledge that they can publish. They're fundamentally looking to try and get the best possible leading edge research, get their star rating up [measure used to rank UK universities]. Five star if possible. So we recognize that's their primary interest, and on that basis, it doesn't become compromised by commercial considerations." (i32)

Similar value of working with a university was described by a professor who was asked by a firm to provide an independent assessment of a software application. The software vendor withdrew from this potential sales opportunity as it did not wish to have its product assessed by an academic institution (i15). These examples illustrate how the fact that academics' interests were seen as not or at least less commercially influenced was seen as being of value by industrial partners.

My analysis uncovered several ways in which the exchange relationships between academics and industry were based on domain-specific differences (Table 4). In other words, intellectual arbitrage was enabled by the differentials I identified: value differentials, knowledge differentials, and interest differentials. The fact that these differentials were at the root of the innovation-oriented exchanges I observed, suggests they might be causally related to specific innovation outcomes. I turn to exploring this question in the next section.

Table 4 about here

EFFECTS OF INTELLECTUAL ARBITRAGE ON INNOVATION OUTCOMES

I found that the presence of specific differentials allows for intellectual arbitrage across institutional boundaries. My evidence allows me to take the analysis further and discuss how exactly this arbitrage situation impacts on innovation-related outcomes. By going back and forwards between the categories emerging from the evidence and categories accepted in the literature, I identified three types of effects. First, the presence of differentials is conducive to situations where unexpected and unplanned novelty occurs. Second, differentials are likely to provide organizational spaces of informality where experimental activities are more easily conducted compared to organized corporate contexts. Third, the presence of differentials has distinctive effects on how innovation-oriented collaboration is governed, with specific impacts on opportunism and commitment. I discuss these effects in the discussion below.

Facilitating exploration

Innovation derives from the combination of previously disparate elements (Schumpeter, 1934). Therefore, research into the determinants of innovation has focused on the mechanisms facilitating such combination. Research in the tradition of Allen's (1977) study has emphasized the importance of communication flows between different contexts in the context of product development (Brown, and Eisenhardt, 1995). This research has explored how the need of participants to "make sense" of ambiguous, conflicting and incommensurable information present in different contexts can actually contribute to generate new problems and solutions. Dougherty found that different thought worlds prevailed in different departments, leading to varying interpretation of certain information (Dougherty, 1990). She also found that successful projects were those in which cross-functional personnel were able to integrate different perspectives in an interactive, iterative way.

Piore et al. (2002) proposed the concept of “interpretation” to refer to such communicative interaction, in contrast to “analytical” activities that consist of planned, sequential problem solving within product development. They view “interpretation” as a collective process that facilitates the emergence of new combinations and ideas, often through “conversations” across organizational and institutional boundaries. They argue that while analytical approaches are useful when problem definitions, technological capabilities and user needs are clearly defined, they fail in situations where problems have not yet been defined. Here, interpretation occurring in the context of ongoing conversations between different communities, can contribute to generating new problems and pathways for design and product development (Lester, and Piore, 2004).

In the language of organizational learning, this activity of generating new combinations is known as exploration (March, 1991). Exploration, as opposed to exploitation, occurs when the organization learns from individuals who deviate from the mainstream “code” held by most other individuals in the organization. In other words, within March's (1991) account, exploration involves maintaining cognitive diversity for longer than in exploitation mode.

My findings indicate that the presence of exchange differentials facilitated the adoption of an interpretive interaction mode by the participants in university-industry collaboration, resulting in exploratory learning. I found that it was particularly knowledge-related differentials that generated the conditions for novelty-inducing interpretive activity. For instance, the automotive R&D executive quoted above explained that when looking at engine lubrication, his engine development team had benefited from the experience of university-based engineers who had participated in the development of artificial human joints:

“Some [university partners] have even worked on biomedical solutions for hip joints, having good lubrication of hip joints, and although it’s not directly relevant, it brings a fresh perspective on how to lubricate engines. And we might be thinking that an engine is an extremely highly loaded system, and they say, ‘Well, it’s not that highly loaded. In hip joints, if you jump off a three-foot wall this will be ten times the load.’ But then we say, ‘Ah, but we’re going to do it hundred times a second, whereas you can only pop down a three foot wall every now and then.” (i32).

Another example was provided by a research group who had acquired a motion capture suit to electronically capture body movements for research purposes. Soon the research group was in constant contact with the manufacturer about the characteristics and limitations of the device. These contacts led to a formal collaborative project aimed at improving the existing product. The outcome was that the research group eventually abandoned the design principle – “exo-skeleton motion” capture – that was underlying the firm’s original product because of its inherent limitations. In collaboration with the company’s designers, a prototype of a product on the basis of a new design principle – based on “optical capture” – was developed. This example illustrates how knowledge differentials underpinned the unplanned and emerging logic in which some of the projects developed, facilitated by ongoing communication between the different parties. In other words, cross-boundary interaction generated numerous opportunities for participants for deviating from participants’ organizational code (March, 1991). This can be expected to result in new project opportunities (Cohen, Nelson, and Walsh, 2002). I can therefore postulate:

Proposition 1: The presence of knowledge differentials within innovation-oriented collaboration has a positive impact on the generation of novel product and process concepts.

Enabling experimentation

Innovation processes are constrained and facilitated by the organizational structures within which they take place. One aspect emphasized by previous research relates to the ability of specific projects to break free from the managerial mainstream prevailing in an organization. This allows staff to pursue activities that are relatively unconstrained by structured, pre-determined organizational activities (Ahuja, and Lampert, 2001). Corporate venturing has been described as an example for such break-away innovation (Burgelman, 1983). Alternatively, staff might pursue independent small-scale projects at the margins of mainstream project management. Such “skunk works” or “bootleg research” have been singled out as mechanisms allowing established companies to engage in radical innovation (Quinn, 1985; Burgelman, and Sayles, 1986; Kreiner, and Schultz, 1993). In some companies, R&D staff are encouraged to spend some of their time on projects unrelated to their work (von Hippel, Thomke, and Sonnack, 1999). Similarly, increased slack within the organization may generate the conditions for employees to engage in such non-mainstream projects (Nohria, and Gulati, 1996). Purposive generation of diversity and variation is used by some organizations, via encouraging social networking and exposure to differing expertise contexts, to facilitate the pursuit of new ideas (Fleming, 2001).

I refer to these activities as “experimentation”. This is different from “exploration” in that it refers to actual resourcing and pursuit of alternative projects, once novel ideas and product concepts have taken hold. A common characteristic of experimentation activities is that they allow for projects that are not or only loosely connected to the primary exploitation activities pursued by a firm. Because these activities have not entered the official planning agenda, in many organizations there might be no explicit budgets for individual staff members to pursue them even in the case of promising ideas. In the same way experimentation is more likely in organizations that have some degree of slack, i.e. the availability of unabsorbed internal resources (Nohria, and Gulati, 1996), externally available resources will therefore equally provide opportunities for increased experimentation.

Arguably, the presence of value differentials within an exchange relationship facilitates such a situation. Certain resources that are of high value to one partner might be provided by the other partner at relatively low cost because of additional benefits accruing in the process. My data provides various examples for such a situation. For instance, a mechanical engineering professor had been working for several years on a novel type of emissions control system for diesel engines. He proposed to eliminate soot particles from the emissions by using a microwave device, an idea previously unexplored by industry. The idea originated from previous work the group had been carrying out. The professor decided to take the idea to a large diesel engine manufacturer which whom he had a relationship. He recounted:

“I went to them and said: ‘This is a concept we’ve got. We don’t know if it will work. Don’t give us a large grant. Just give us a small amount of money to try it out.’ So they gave us twenty-five thousand pounds and we did a very short project – eight weeks. We just played around in the lab and basically made the thing work. We did a feasibility study and went back to [the engine manufacturer] and said, ‘It works!’ And I think they were quite surprised that it worked as well as it did” (i10).

The example illustrates a situation where a firm was able to engage in what would the external equivalent of “skunk-works” by expending relatively little resource. This was enabled by the fact that the professor had already entertained this as an academic idea – providing value in itself in the academic domain, independently from the commercial pay-off. Summarizing, I postulate:

Proposition 2: The presence of value differentials within innovation-oriented collaboration has a positive impact on the volume of experimentation activities pursued.

Impacts on governance

Effects of exchange differentials can also be expected in terms of the governance of relationships. Interorganizational collaboration for innovation has potential benefits but it also poses risks of conflict. Free sharing of knowledge might be curtailed by fears the cooperation partner might exploit gained information for their own advantage. These agency-related risks of technology-oriented collaboration have been emphasized by research on strategic alliances. Opportunistic behavior constitutes a major threat to the success of such alliances (Williamson, 1991). Of particular relevance in R&D-related contexts are “spill-over” risks (Teece, 1986; Nooteboom, Berger, and Noorderhaven, 1997). Firms in strategic alliances may therefore choose to exhibit low transparency in order to prevent their partners from opportunistically exploiting their knowledge (Hamel, 1991). This, in turn, is likely to result in lower degrees of inter-organizational learning than would otherwise be the case (Larsson, et al., 1998).

Similarly, opportunistic behavior leads to suboptimal outcomes when highly interdependent tasks need to be accomplished by the partners. Competitive economic behavior provides for an appropriate allocation mechanism when the activities to be coordinated are relatively independent. However, in highly interdependent activities, competitive behavior can detract from achieving a better outcome (Parkhe, 1993). Cooperation related to R&D and technology is generally characterized by high degrees of interdependence among the participating parties (Gulati, and Singh, 1998).

To engage in cooperation, an actor must believe that the prospective partner will not misuse the dependencies created through the cooperation (Nooteboom, Berger, and Noorderhaven, 1997). This belief, in turn, depends on the opportunities for misuse perceived by the partner, the partners' incentives for misuse, and the partners' propensity to exploit any available opportunities (Nooteboom, 1996). Only the latter point is linked to trust and the presence of norms; here structural embeddedness provides one possible safeguard to overcome the problem of opportunism (Granovetter, 1985; Uzzi, 1997). Within embedded relationships, participants trust each other that obligations are honored and goodwill is applied if necessary to improve integrative outcomes (Ring, and Van De Ven, 1992).

However, the two former aspects, the presence of opportunities and incentives for misuse, are a function of the stakes each partner has in the collaboration, and are not affected by the presence of trust, or otherwise, in the relationship. Two points are of importance here. Firstly, ceteris paribus, the presence of opportunities and incentives for opportunism will have an impact on prospective partners' decision to engage in inter-organizational collaboration. Secondly, ceteris paribus, the presence of opportunities and incentives for opportunism will inform the level of transparency exhibited by the partners, i.e. their willingness to let their partners partake in their knowledge.

My evidence suggests that the existence of exchange differentials can reduce both the opportunities and incentives for opportunism in an exchange relationship. This effect is generated by value differentials. For instance, because academics prized intellectual property less than their industrial partners, the latter adopted a less strict approach to data protection and confidentiality compared to a relationship with a commercial partner. An information scientist described how her industrial partner, a multinational aerospace company, justified providing her with access to confidential data gained from turbine fan blade experiments with a prototype:

“The academic potential for using these data is huge. It’s about finding a situation where the data is readily available in a form that it’s not too expensive for them [aerospace company] to extract, and that is not be too sensitive [confidential] for them not to be able to release it to a third party. We do try very hard to protect the real data and the results, but inevitably that’s not the same as being in their own organization. But then, they trust us more because we are academics (i15)”.

It can be argued that because value differentials exist in this exchange relationship, there are reduced incentives for the partners to behave opportunistically. If for ego the value of a highly prized asset is judged of lesser importance by alter, then ego has less reason to fear alter’s opportunism. This in turn allows ego to be more transparent towards their partners (Hamel, 1991; Larsson, et al., 1998), thereby enhancing the prospects for integrative innovation outcomes.

An additional effect on governance is exerted by the presence of interest differentials. If partners pursue substantially different interests, this may reduce the likelihood of conflict over contested resources. At the same time, however, it may also reduce the commitment by the partners to achieving the goals of collaborative project. In other words, while distributional conflict might be alleviated, integrative (positive-sum) outcomes might be affected. As technology and innovation-related collaboration will usually rely on positive-sum solutions, rather then mere distribution, reduced commitment might lead to less optimal outcomes.

I came across examples of such an effect especially in projects that were academically led. When my respondents referred to problems during their collaborative projects, they often pointed to situations where interest differentials had turned out to be too pronounced. A technical director of an opto-electronics manufacturer remarked:

“We funded one of our academic collaborators’ students. We funded the guy to do a PhD, which he did. We didn’t think he was very good. He didn’t come and talk to us as much as he should have. He tended to be too stuck in the university, thinking this was the way to go, and he was therefore not that good.”

Similarly an electronics researcher explained that commitment on the part of industrial collaborators could suffer if projects took a direction that was “too academic”:

“Projects seem to go through phases. There’s an initial enthusiastic phase when we’re discussing what it is we’re going to do. Then you do the actual work in the lab and things slow down very much. At that point, meetings can become far more spaced out”.

Summarizing these insights, I postulate:

Proposition 3a: The presence of value differentials has a positive impact on achieving integrative innovation outcomes in exchange relationships.

Proposition 3b: The presence of interest differentials reduces the level of commitment by partners towards achieving integrative outcomes.

Figure 1 shows a graphical representation of the model of intellectual arbitrage.

Figure 1 about here

DISCUSSION AND CONCLUSION

In many instances, sources of commercial innovation reside at the outside of the commercial domain. The article addresses the spanning of institutional boundaries in these instances. I sought to identify the nature of the transactions occurring across such boundaries, the structural circumstances in which they are occurring and effects on innovation outcomes.

In devising a model of intellectual arbitrage, my contribution can be summarized in three points. First, I typify interactions occurring across institutional boundaries as instances of exchange transactions embedded in exchange relationships (Emerson, 1976). The results qualify the models of commercialism and communalism that have previously been used to explain institutional boundary spanning. On one hand, individuals in non-commercial domains do not necessarily have to turn “commercial” – indeed my results suggest that their orientation towards their own institutional realm can be conducive to establishing the structural conditions for an exchange to take place. On the other, individuals do not have to engage in “communal” free sharing for the transaction to take place. My inductive study suggests that individuals engage in exchange transactions whereby particularly the non-contractual elements often generate benefits valued by partners in different domains.

Second, these exchange transactions are facilitated by what I call exchange differentials: degrees of differences between various types of assets the exchange partners have access to and aspire to, depending on their situatedness in specific institutional domains. Here I distinguish between three types of differentials: value differentials, indicating that in different institutional domains the same assets might be valued in different terms; knowledge differentials, referring to differences in substantial, procedural and contextual knowledge; and interest differentials, indicating that individuals in different institutional contexts are likely to pursue different interests.

Third, I analyse the effects of specific differentials on innovation outcomes. Knowledge differentials facilitate explorative activities and hence the generation of new ideas and concepts, while value differentials have a positive impact on providing organizational spaces where such novelty leads to the initiation of actual projects. Interest differentials can be instrumental for preventing opportunism within inter-organizational relationships but they might lower the degree of commitment exhibited by the partners involved.

The intellectual arbitrage model enables a better understanding of innovation processes that cross institutional boundaries. User innovation, open-source communities, and academic participation in innovation have been widely discussed in the literature. Yet compared to other boundaries, such as organizational and technological boundaries, institutional boundaries have been subject to little theoretical scrutiny. The model explicates the specificities of innovation processes when such boundaries are crossed, contributing to the literature in several respects.

While in much of the debate on boundary spanning the main focus is represented by cognitive distance between collaborating parties involved in innovatory projects, my model points to other differences that are of relevance for innovation outcomes. Implicitly, most existing accounts take for granted that the limitations of local search are sufficient to explain the contribution of boundary spanning to innovation processes (Rosenkopf, and Nerkar, 2001). In other words, the conceptual emphasis is on aspects of information and knowledge re-combination and its effects on novelty generation (Tushman, and Scanlan, 1981). Ethnographic studies such as Carlile's (2002) also emphasize the knowledge dimension of cross-boundary innovation projects. Vis-à-vis this cognitivist view on boundary spanning, my analysis suggests, whilst confirming the relevance of knowledge differentials, that additional dimensions play a systematic role. In particular, I isolated value differentials, pointing to the resource dimension, and interest differentials, pointing to the governance dimension, as additional factors inducing specific outcomes.

The relevance of these dimensions arises from the fact that boundary spanning is in many cases set in a context of *collaboration.* Ranging from R&D alliances to low-profile informal contacts between individual scientists, boundary spanning might in many cases only bear fruit during some sort of collaborative activity, as opposed to pure 'informational' contacts (Tushman, 1977). For any collaboration, it not only matters what the partners know but also how the collaboration is organized and in what structural setting it is situated (Gulati, and Singh, 1998). For instance, networks between firms require rules that establish how the surplus from collaboration is attributed to the various participants (Kogut, 2000). Further work might exploit what role the differentials I identified play in collaborative settings that do not involve institutional boundary crossing.

My work has also implications for the debate on the role of inter-organizational networks for innovation. For instance, authors have frequently pointed to the informality of the networks occurring between academia and the biotechnology sector (Kreiner, and Schultz, 1993; Liebeskind, et al., 1996; Powell, Koput, and Smith-Doerr, 1996). My results shed some light on the mechanisms that are at work to sustain these seemingly informal and communalist relationships where knowledge is freely shared. In fact, the degree of formalization might not be the main determinant as to how relationships play out. Liebeskind el al (1996) argue that “markets are not good mechanisms for transferring knowledge”, and hence social networks are used for that purpose. In their case study of two biotechnology firms, they define as “markets” relationships that are formalized by contracts, as opposed to “social networks” that allow for exchange between individuals without any formalized contracts being in place. Yet, the majority of informal relationships the scientists at the two biotechnology firms maintained – as measured via co-authored papers – were with university researchers and not firms. Therefore, in light of my framework one might speculate that the determining causal variable was not be the actual governance mechanism (social network, market or hierarchy) as claimed by the authors. Rather, the results might have been due to the fact that firm scientists were exploiting differentials across domains functioning according to different logics. This might be independent from whether formal agreements are in place. In fact, many relationships between university scientists and companies do actually involve some formal contract but this does not necessarily prejudice as to how exchanges are facilitated by the non-contractual elements I described in this paper.

There are similar implications for what we know about the barriers that make it difficult to share knowledge across boundaries. Specifically, one might postulate contingent effects of some differentials on others. For instance, boundary spanning might be easier across teams specializing in related knowledge domains (Hansen, 2002) but simultaneously knowledge sharing might be affected by inter-team competition (Tsai, 2002). In this circumstance, the presence of interest differentials can be expected to moderate the willingness to 'trade' knowledge among the partners. Specific governance mechanisms for structuring network relationships might have to be put in place in a high-competition scenario, while in a low-competition scenario interaction will be more spontaneous and require less monitoring or sanctioning (Dyer, and Nobeoka, 2000). My analysis suggests that the prevailing conditions for exchanges to occur have to be taken into consideration when assessing the potential for boundary spanning in specific situations.

The findings also have implications for the debate on the relationship between theory and practice. The essential question raised in this debate relates to the possibility of boundary spanning between two institutional domains following different logics (Gulati, 2007). Put very simply, "theory" or scholarship is oriented toward rigor, and "practice" is oriented towards relevance and applicability (Vermeulen, 2005). Van de Ven and Johnson (Van De Ven, and Johnson, 2006) list various ways in which knowledge production can occur at the interstices between theory and practice. They use the concept of intellectual arbitrage as a heuristic for deriving prescriptive advice as to how such knowledge production should occur. Here, my research provides insight into how intellectual arbitrage can be understood in sociological terms, hence shedding light on the conditions on which this process relies upon.

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Table 1: Examples of university-industry collaboration projects

Project goal	Type of partner	Outputs
Identify quality flaws in the manufacturing of avionics circuit boards	Component manufacturers in aerospace industry, plus some suppliers	Modeling of manufacturing process – formal characterizing of a process, resulting in alternative options and risks
Identify causes of vibration problems with prototype jet engine	Large multinational (aerospace)	Identification of root problem, and options to resolve it
Deploy infrared sensors to predict breakdown in automatic mail sorting machines	Small technology company; large logistics company	Prototype; software
Use polymer sealing connectors on semi-conductor devices	Several firms	Experimental prototypes, reports
Carry out risk assessment of oil platform process designs, and improvement of the latter	Oil major	Assessment and feedback on design options
Explore feasibility of new emissions control system for diesel engines	Large automotive manufacturer	Feasibility study – academic publications held back to prevent dissemination of unprotected ideas
Reduce unplanned breakdown by using intelligent machines	Large Multinationals	Reports and academic papers

Table 2: Types of university-industry projects

Goal	Description	Initiation
Solving problems	Seek a solution to a technical problem arising within a firm's R&D, manufacturing or other operations	Firms
Developing technology	Develop design specifications or prototypes for new or improved products or processes	Firms
Providing advice	Provide advice on R&D projects and development projects pursued within firms	Firms
Testing ideas	Explore a high-risk concept on behalf of a firm – outside the firm's mainstream activities	Firms, academics
Generating knowledge	Carry out research on topics of broad interest to a firm	Academics

Table 3: Objects of exchange in university-industry projects

Object of exchange	Who benefits	Illustration from data	Type of resource
Access to data	Academic	"For a lot of what we do, we need output data from wind farms or data from what we call the 'scarlet systems' from the wind farms; so to do that, you need to have good relations with these companies" (i24)	Scarce material resource
Credibility for research	Academic	"You can imagine it makes a difference for the presentation at the conference whether this is just academic rubbish and or whether it was done with companies, you may have heard of them, multibillion dollar companies. They [give you] quite a lot of credibility" (i9)	Legitimacy
Raises success rate for grant applications	Academic	"If you have industrial partners, it indicates that this [a project] is of relevance and it has uses (…) it gets hard to demonstrate industrial relevance, if you don't have someone who's prepared to support it." (i12)	Legitimacy
Credibility of a company's research programme	Industry	"[collaborating with a university] is actually a marketing tool for our company [an engineering consultancy]. Just imagine you're designing engines for the Ford Motor Company. Do you think the Ford Motor Company will let you tell the world that you designed their engine? Not a chance. So when you go to another customer and they say, 'what can you do, then?' You think, 'I can design engines really well, but I can't tell them because they're all top secret.' So it's really good to have some stuff that is in the public domain, and university research, as you know, can be very, very public indeed." (i26).	Legitimacy
Generate ideas for application of techniques	Academic	"The project we did with [aerospace company] got us interested in the statistics of rare events. This opened up a whole new research area for our group."	Knowledge
Enable better teaching	Academic	"[Collaborating with industry] definitely impacts my teaching. I taught a second-year course this semester and I am very proud to say that the reviews that came from the course are better than I have ever had before, in eighteen years of teaching. I think the reason is that I try to read into each and every one of my lectures what this means practically. The only reason that I can do that is because I have these experiences of working with industry." (i47)	Knowledge

Table 4: Exchange differentials in university-industry relationships

Concept	Definition	Illustration
Value differentials	Value of assets is measured differently across domains	Academic publications are valued higher in academia
Knowledge differentials	Substantive: Actors specialize in different knowledge areas	Mechanical engineering vs. electronic control systems
	Procedural: Different approaches to tasks and problems differs across domains	Deductive reasoning style vs. trial-and-error
	Contextual: Actors have access to different, context-related types of knowledge needed to resolve a problem or develop a product	Know-how vs. know-what vs. know-why
Interest differentials	Actors have different interests depending on their situatedness in different domains	Commercial interests vs. reputation in science

APPENDIX

Table 5: Interviews

Interview codes, interviewee roles and affiliations in chronological order (May 2006 - Dec 2007)

Code	Interviewee Role	Affiliation
i1	Technology Transfer Co-ordinator	Academic
i2	Head of Technology Transfer	Academic
i3	Head of Academic Consulting	Academic (administrative)
i4	Head of University Relations	Industrial (aerospace)
i5	Head of University Relations	Industrial (pharmaceutical)
i6	Head of University Relations	Industrial (aerospace)
i7	Professor of Manufacturing Management	Academic
i8	Professor of Photonics	Academic
i9	Professor of Manufacturing Processes	Academic
i10	Professor of Applied Thermodynamics	Academic
i11	Automotive Engineering Fellow	Academic
i12	Senior Lecturer in Electronics Manufacturing	Academic
i13	Senior Lecturer in Automotive Engineering	Academic
i14	Professor of Healthcare Engineering	Academic
i15	Senior Lecturer in Software Design and Information Modelling	Academic
i16	Professor of Combustion Aerodynamics	Academic
i17	Senior Research Fellow in Electronics Manufacturing	Academic
i18	Professor of Risk and Reliability	Academic
i19	Professor of Chemical Engineering	Academic
i20	Senior Lecturer in Electronics Manufacturing	Academic
i21	Researcher in Ergonomics	Academic
i22	Researcher in Materials Characterization	Academic
i23	Professor of Control Systems Engineering	Academic
i24	Senior Lecturer in Alternative Energies	Academic
i25	Professor of Ceramic Materials	Academic
i26	Director of Engineering	Industrial (automotive consultancy)
i27	Professor of Structural Engineering	Academic
i28	Senior Lecturer in Sports Physiology	Academic
i29	Professor of Wireless Communications	Academic
i30	Professor of Electronics Manufacturing	Academic
i31	Director of Business Development	Industrial (fuel cells)
i32	Advanced Power Train Engineering Manager	Industrial (automotive)
i33	Technical Specialist Signal Processing	Industrial (automotive)
i34	Head of Mobile and Telecoms Ergonomics	Academic
i35	Senior Lecturer in Human Sciences	Academic
i36	Research scientist	Industrial (fuel cells)
i37	Professor of Analytical Chemistry	Academic
i38	Professor of Mechatronics	Academic
i39	Professor of Moving Image	Academic
i40	Professor in Music	Academic

i41	Technical Director	Industrial (opto-electronics)
i42	Senior Lecturer in Alternative Energies	Academic
i43	Manufacturing Technology Consultant	Industrial (consultancy)
i44	Medical director	Industrial (financial-health)
i45	Head of Powertrain Research	Industrial (automotive)
i46	Senior R&D scientist	Industrial (chemical)
i47	Professor in medical engineering	Academic

Figure 1: A model of intellectual arbitrage