

THE MICROFOUNDATIONS OF UNIVERSITY-INDUSTRY INTERACTIONS

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DECLARATION

This is to certify that:

- i. The thesis comprises only my original work towards the PhD except where indicated;
- ii. Due acknowledgement has been made in the text to all other material used;
- iii. Due acknowledgement has been made in the text to my co-authors with whom I have worked on research manuscripts;
- iv. The thesis is less than 100,000 words in length, inclusive of table, figures, bibliographies, appendices and footnotes.

Valentina Tartari

ABSTRACT

In the last three decades universities have experienced major changes, which have affected both their research objectives and their sources of funding. Universities are increasingly asked to contribute to economic growth by increasing their commercialization and technology transfer efforts. The relationship between university and industry has attracted a great deal of interest because of both the opportunities that can be generated by collaboration and the controversy surrounding universities' commercial activities. Previous research has analysed in depth these issue at the level of institutions and universities. Collaborating with industry, however, constitute discretionary behaviour for academics: while literature has examined the role of individual characteristics such as demographics and productivity, aspects related to psychological traits, perceptions and social influence are poorly understood. To address this gap, I employ an interdisciplinary approach to investigate the drivers of university-industry interactions at the level of the individuals.

The analysis draws upon data on the characteristics and activities of a sample of academic scientists in different scientific disciplines in Italy and in the UK. The datasets integrate information collected through surveys, as well as data on scientists, department and universities gathered through several secondary sources.

Results show that researchers' evaluation of potential benefits and costs of collaboration with industry are a major driver of academic engagement. Moreover, this thesis highlights the crucial role of scientists' personality in determining academic engagement and entrepreneurship, while putting back into perspective the role of organizational support mechanisms. The role of the academics' immediate social context is also assessed, showing that individuals look to their immediate peers for their orientation, both collaboratively via learning as well as competitively via social comparison. Finally, this research informs policy on how to devise more effective strategies to promote university-industry interactions.

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Writing the acknowledgments for one's own PhD thesis is, I believe, a very exciting moment for a student. It marks the end of an intense journey, and the beginning of a brand new one. In the journey through my PhD, I have been fortunate enough to be accompanied and supported by an amazing group of people.

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CHAPTER 1 - INTRODUCTION

Only by taking infinitesimally small units for observation (the differential of history, that is, the individual tendencies of men) and attaining to the art of integrating them (that is, finding the sum of these infinitesimals) can we hope to arrive at the laws of history

L. Tolstoj, War and Peace

A BRIEF HISTORICAL OVERVIEW OF UNIVERSITY-INDUSTRY COLLABORATION

Interest, among both policy-makers and academics, in universities' engagement with industry partners has grown considerably in recent years. The university-industry relationship is attracting interest because of the opportunities generated by collaboration, and the controversy surrounding universities' commercial efforts.

The history of the relationship between the university and industry worlds is linked inextricably to the evolution of the industrial research system and public support for scientific research. Since the development of the chemical industry in the 19th century up to the Second World War, universities and industry have collaborated intensely. Academic engagement in industry has a long tradition: in the US it benefited from the unusual and varied structure of the higher education system, for example, universities that emphasized practical and technical relevance, such as land grant universities whose mission was to provide practical education in agriculture, science and engineering whilst also assisting local firms (Mowery and Nelson 2004). Similar links existed in Europe, and connections developed especially through the efforts of key scientists, such as the collaboration in the 1950s between Nobel Prize laureate Giulio Natta and Montecatini, which eventually led to the discovery of isotactic polypropylene. In this period, several large industrial firms had advanced in-house research facilities and were also very active in the markets for technology and ideas, acquiring technologies developed externally by independent research and development (R&D) laboratories and universities.

After World War II, new industries, such as those based on innovations in Information and Communication Technologies (ICT) and biomedicine, emerged and started to grow consistently (Mowery 2009). In the US and in Western Europe, government support for research increased from the 1950s, for several reasons. First, public R&D spending in

defence-related areas and biomedical research increased dramatically. Large scale scientific efforts were focused on areas that derived from wartime military projects: nuclear energy (spurred by the creation of nuclear weapons in the UK in 1952 and in France in 1960, and followed by civilian applications such as the Calder Hall power station in 1956), aerospace (growing out of military rocketry programmes in Germany), astronomy and meteorology (Mowery 2009). The changing social and economic conditions meant that chronic disorders and degenerative diseases rather than bacterial infections became the major causes of death, spurring medical research in areas such as oncology.

Second, policymakers showed explicit commitment to financing basic research, based on the conclusions from the linear model of innovation (Bush 1945), which suggested that upstream (basic) research (conducted mainly by public institutions) proceeds independently of technological developments, but acts as the initiator of ideas that lead to industrial innovation. If the knowledge is public and discoveries are unpredictable, upstream research without immediate applicability is unlikely to be directly addressed by the private system of research, resulting in underinvestment in basic research (Nelson 1959; Arrow 1962).

The university and public research systems became the principal examples of patronage (Dasgupta and David 1994): governments finance research conducted by scientists working in organizations, such as universities and public research centres, and encourage the disclosure of the results to society. In the 1950s and 1960s, the main source of funding for university research was government grants (Bok 1982). While in Europe the industrial research structure was dominated by large national champions (Chandler and Hikino 1997), the US post-war industrial research system was undergoing radical changes. The introduction of a very stringent antitrust policy meant that large firms focused more on internal discovery than accessing technologies from outside (Fligstein 1990). At the same time, a large number of small firms emerged in areas of new technology, as spin offs from basic research conducted in universities and public laboratories (Chandler and Hikino 1997). It should be noted also that in several European countries, a number of institutions undertaking research (and sometimes teaching) at levels comparable to universities, started to gain importance. They included the CNRS laboratories in France, the Max Planck Institutes and Fraunhofer Institutes in Germany, and the Research Council Laboratories in the UK. These organizations were mainly government funded and became increasingly relevant in the European public research environment (Porter 1990).

From the late 1970s, large firms started to dismantle or downsize their internal R&D facilities, becoming more reliant on externally acquired knowledge. Knowledge-intensive

industries, especially ICT and biotechnology, became increasingly vertically specialized: small firms occupied narrow segments of the value chain (especially in the upstream part), rendering reliance on market mechanisms for transferring technology critical for incumbents and entrants alike (Mowery 2009). Overall, although no longer concentrated in a few large companies, industry R&D increased considerably during the 1970s, in both scope and quality (Mowery 2009). Simultaneously, fiscal budgetary constraints forced policy makers in many developed as well as developing countries to encourage universities to move towards competitive funding sources (Geuna and Nesta 2006), to devote more effort to commercialization of technology through patenting and licensing (Cohen, Nelson et al. 2002), and to develop a so-called ‘third mission’ by fostering links with knowledge users outside of academia (Florida and Cohen 1999; Etzkowitz, Webster et al. 2000; Gulbrandsen and Slipersæter 2007).

Changes in the structure of university funding were often accompanied by changes in the range of incentives offered to researchers to complement their traditional activities with technology transfer activities. In several OECD countries, it was assumed by legislators that university inventions were mostly proofs, concepts or prototypes and that since neither the universities nor the scientists would have the necessary financial resources and commercial competencies to develop these inventions, it was necessary to establish clear and negotiable intellectual property rights (IPRs) to create the economic incentives for private firms to invest in their development (Mowery, Nelson et al. 2001). The earliest example of legislation in that direction is the well-known US Bayh-Dole Patent and Trademark Amendments Act of 1980, which assigned to US universities all property rights on results stemming from research financed by federal funds. Before the Bayh-Dole Act was passed, different funding agencies had different policies regarding the assignment of IPRs, creating uncertainty for the future commercialization of inventions (Mowery 2009). After the Act, the number of patents assigned to US universities has risen from 0.3% in 1963 to around 5% of total US patents in 1999 (Mowery and Sampat 2005), and the number of academic institutions owning patents has gone from 65 in 1965, to 150 in 1991 and 400 in 1997 (Mowery and Sampat 2005). The UK was among the first countries in Europe to adapt its legislation to mirror the US example, by abolishing the exclusivity of the BTG (British Technology Group) on university inventions and giving universities the rights to own the patents on inventions made by their researchers and to license them.

In continental Europe, the intellectual property deriving from university research traditionally was owned directly by the researcher. This norm was first introduced in

Germany in the 19th century (Lissoni, Llerena et al. 2008). Since 2000, several European countries, such as Germany, Austria and Denmark (OECD 2003), have abolished the professor's privilege, the main reason being the extremely high administrative costs associated with patenting procedures, and the transaction costs linked to the commercialization of inventions. Following a somewhat opposite reasoning, some other countries in Europe (such as Italy) have established professor's privilege in an attempt to shift the economic incentive to commercialize inventions from a bureaucratic and inefficient actor (the university) to the individual researcher, who it was believed would be more flexible and more susceptible to monetary incentives (Lissoni, Llerena et al. 2008).

This increasingly 'commercial' behaviour of universities (which can be considered a second, more institutionalized wave in the history of university-industry collaboration) may be seen as an effective way to raise additional funds, fostering new research areas and improving education opportunities. However, it is impossible to ignore the drawbacks that underlie academic involvement in industry and the possible unintended effects on the advancement of science (Mowery, Nelson et al. 2001; Murray and Stern 2007; Larsen 2011). In particular it seems that increased collaboration between universities and private companies could skew public research agendas towards marketable research at the expenses of fundamental research (Lee 1996; Nelson 2001), threaten the freedom of public institutions (Henderson, Jaffe et al. 1998) and, ultimately, upset the efficiency of the division of labour between private and public science (Dasgupta and David 1994; Rosenberg and Nelson 1994; Nelson 2004). In addition, concerns about secrecy are particularly relevant to the debate on university-industry interactions, since private research sponsors may require publication delays (Thursby and Thursby 2002) or demand secrecy for at least part of the research results. Empirical evidence shows that the strong push in favour of academic patenting constrains communication among scientists (Blumenthal, Campbell et al. 1996), limits or delays publication of scientific papers (Calderini, Franzoni et al. 2007) and in some cases results in the withholding of data (Campbell, Clarridge et al. 2002).

PREVIOUS RESEARCH ON UNIVERSITY-INDUSTRY COLLABORATION

In this thesis, I focus on the university side of university-industry collaboration. My reasons for this focus are theoretical and pragmatic. From a theoretical perspective, I am interested in analysing how individuals operating in a professional bureaucracy (such as a university) where they enjoy relatively high levels of autonomy, engage in discretionary behaviour which puts them in contact with actors operating under different logics and values.

While it would be interesting also to understand how and why firms engage in collaboration with industry, since my focus is on individuals, the industry setting is less attractive since industry employees enjoy much lower levels of autonomy compared to academics (as shown by Stern (2004), researchers are willing to lower their salary in order to increase their research freedom). From a practical point of view, data on academic activities are more readily available to researchers. Universities are required to publish large amounts of information on their activities. Given the nature of their work, academics also release information on themselves, primarily through their publications. This does not apply in industry: many firms are not required to report on any of their activities and decisions tend to be attributed to the firm not to particular employees. Therefore, the brief overview of the literature in this section deals only with the perspectives of universities and academic researchers in this collaboration.

Given the focus of the research presented in this thesis, I cannot however ignore the growing literature on firms' engagement in collaborative activities with industry. Firms collaborate with universities in order to access new knowledge which will be useful for innovation, and to recruit highly-skilled and competent personnel (Lee 2000). They tend to look for partners located geographically close to them which are good scientific performers (Mansfield and Lee 1996). University research is seen largely as complementing the research performed in-house: firms need to possess adequate absorptive capacity to be able to incorporate the knowledge obtained from universities into their own innovation processes (Cohen and Levinthal 1989). Firms also face considerable barriers in collaborating with universities. Research shows that the increased importance given by university administrators to research commercialization is blocking rather than facilitating collaboration (Siegel, Waldman et al. 2003; Fabrizio 2007; Valentin and Jensen 2007). Nelson (2001) argues that a good share of the technology transfer that has occurred in the US would have occurred had there been no claiming of IPRs by universities and, in some cases, it seems possible that access to IPRs - rather than facilitating the process - has made technology transfer more costly and time consuming for the firms involved. Bruneel and colleagues (2010) show that firms perceive numerous barriers to collaboration with academic institutions and, while issues related to university's long-term orientation remain substantial, other factors, such as those related to IP and administrative procedures, are important in constraining cooperative activities.

On the academic side, research on university-industry interaction can be categorized according to three levels: *system*, *university* and *individual* (Grimaldi, Kenney et al. 2011).

Several scholars have analysed system-level specificities such as the legal frameworks and public policies (Mowery, Nelson et al. 2001; Powers and McDougall 2005), the institutional characteristics of countries (Geuna and Nesta 2006; Verspagen 2006), and the role of the external environment, for example, industry and regions (Friedman and Silberman 2003; Gulbrandsen and Smeby 2005). These analyses build on the wider observation that academic entrepreneurship is both a demand pull and a technology push phenomenon (Rothaermel, Agung et al. 2007). On the one side, as demand for technological innovations increased, universities became a key source for innovation (von Hippel 1988), especially in biotechnology (Zucker, Darby et al. 1998) and nanotechnology (Darby and Zucker 2005). On the other side, universities over time started proactively transferring technology to industry, partly because of reductions in their public funding (Thursby and Thursby 2002).

Most contributions on academic collaboration focus on the level of the university. There is a clear trend in the published literature with a rapid increase in the number of contributions starting in the late 1990s corresponding to increasing levels of entrepreneurship and technology transfer in universities, in most developed countries. While it is important to recognize that academic researchers have been involved in collaboration activities for a very long time – frequent instances of university-industry interactions can be traced back to the development of the chemical industry in the 19th century (Meyer-Thurow 1982), it is since the early 1990s that there has been an *institutionalization* of the linkages between university and industry (Geuna and Muscio 2009). Early entrepreneurial activities by academics took place outside formal university structures and were based primarily on individuals' initiatives and networks of contacts (Van Dierdonck, Debackere et al. 1990; Lee 1996). Supported by policy changes, such as the Bayh-Dole Act, universities began to professionalize technology transfer, promoting the proliferation and expansion of technology transfer offices (TTOs) and revising existing incentive mechanisms to encourage faculty to engage in collaboration activities with industry. Researchers began to focus on different aspects at the university-level of analysis: specific characteristics of the universities, such as history, culture, internal values and organizational identity (Owen-Smith and Powell 2001; Thursby, Jensen et al. 2001); characteristics and performance of technology transfer offices (Bercovitz, Feldman et al. 2001; Siegel, Waldman et al. 2003; Jain and George 2007); incentive mechanisms and regulations in place (Lach and Schankerman 2008; Sauermann, Cohen et al. 2010).

Finally, collaborating with industry constitutes discretionary behaviour for academics, who decide to engage (or not) in technology transfer activities for a multiplicity of reasons. In analysing university-industry interactions it is crucial to recognize that at the core of every

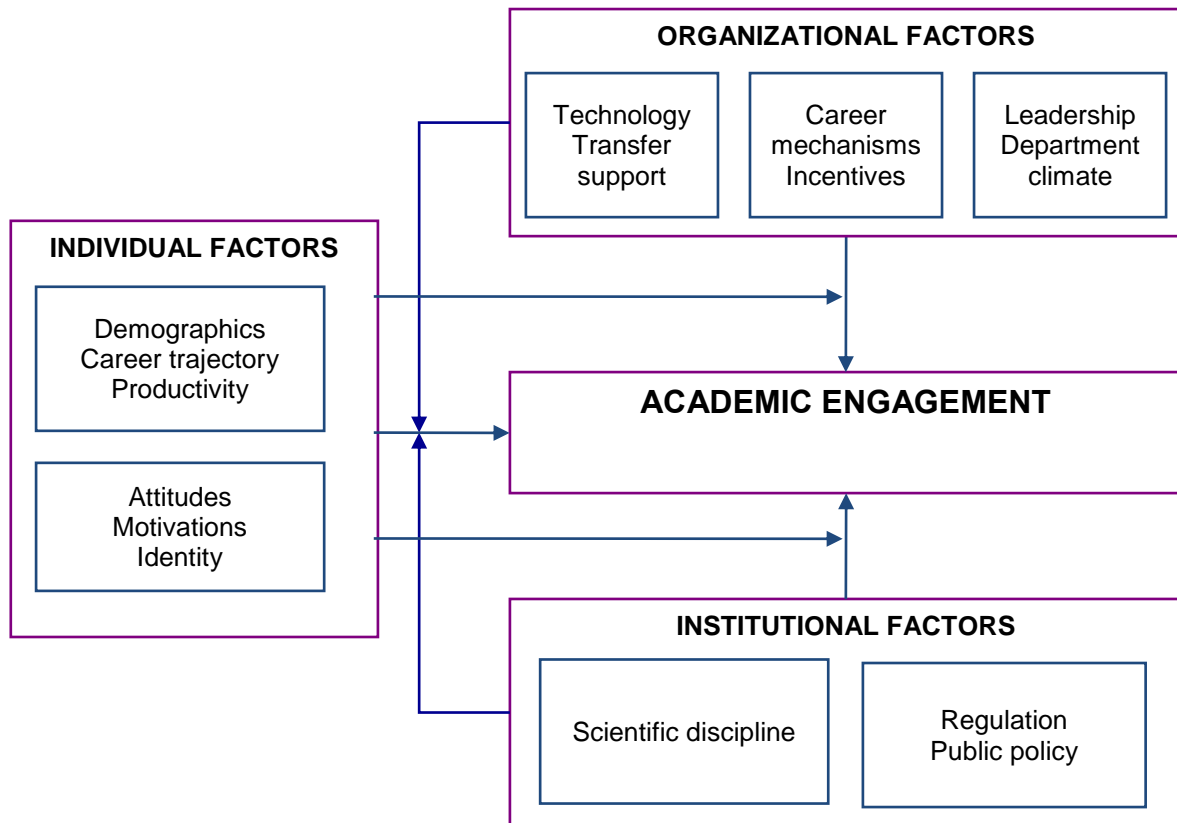
collaboration there are individuals, from both the university and the firm. Academic engagement represents inter-organizational collaboration which involve ‘person-to-person interactions’ (Cohen, Nelson et al. 2002). Since universities are ‘professional bureaucracies’ (Mintzberg 1979) that rely on the independent initiative of autonomous, highly skilled professionals to achieve their organizational goals, academic engagement tends to be individually driven and pursued on a discretionary basis.

While scholars recognize that researchers’ involvement in collaborative activities with industry is affected by institutional and organizational contingencies, the influence of academics’ individual characteristics, such as age (Bercovitz and Feldman 2008; D’Este and Perkmann 2011; Haeussler and Colyvas 2011), gender (Link, Siegel et al. 2007; Göktepe-Hulten and Mahagaonkar 2009; Giuliani, Morrison et al. 2010), tenure (Boardman and Ponomariov 2007; Link, Siegel et al. 2007), number and quality of publications (Blumenthal, Causino et al. 1996; Gulbrandsen and Smeby 2005; Azoulay, Ding et al. 2007; Breschi, Lissoni et al. 2007; Fabrizio and Di Minin 2008), ability to attract public funding (Lee and Bozeman 2005; Bozeman and Gaughan 2007; Link, Siegel et al. 2007; Boardman 2009; Boardman and Ponomariov 2009), research orientation (Blumenthal, Causino et al. 1996; Azoulay, Ding et al. 2007), field of research (Owen-Smith and Powell 2001; Kenney and Goe 2004) is also very important.

Another critical aspect is related to researchers’ perceptions of the potential benefits and costs deriving from collaboration. Scientists’ perceptions are crucial because they reflect a subjective understanding of the issues related to university-industry collaboration and, more importantly, because they influence the willingness to participate in collaborative activities with the private sector, thereby affecting the success or failure of university technology transfer policies (Davis, Larsen et al. 2009). The adherence to the traditional academic norms of openness (Renault 2006; Boardman and Ponomariov 2009; Krabel and Mueller 2009), the belief that working with industry can restrict communication within the scientific community (Welsh, Glenna et al. 2008), and the perceived benefits to be obtained from collaboration (D’Este and Perkmann 2011) significantly influence researchers’ willingness to engage in commercialization or entrepreneurial activities.

The insights gained from previous published contributions can be represented in a stylized model, outlining the antecedents of university-industry interaction at the individual, organizational and institutional levels (Figure 1). The work presented in dissertation seeks to make a contribution to the several areas that so far are relatively underexplored.

Figure 1: Antecedents to academic engagement with industry



OVERVIEW OF THE CHAPTERS

My aim in this thesis is to theoretically and empirically investigate the following research questions:

1. What is the role of scientists' evaluation of the benefits and costs of collaboration with industry on their engagement with firms? (*Chapter 4*)
2. What is the role of personality traits in determining scientists' engagement with industry, and which factors moderate this relationship? (*Chapter 5, Chapter 6*)
3. What is the role of peer effects on researchers' engagement with industry, and what are the mechanisms underlying this effect? (*Chapter 7*)

Chapter 2 presents a brief overview of the Italian and UK institutional contexts for university-industry interaction. Chapter 3 describes the construction of the databases used and the information they contain.

Chapters 4, 5 and 6 focus on the effects of differences among individuals' traits and perceptions on their industry engagement and entrepreneurship activities; Chapter 7 deals with the effect of social context on academics' collaboration activities.

Chapter 8 summarizes the main contributions of this thesis research and the policy implications that can be derived, and highlights some possible limitations.

Chapter 4 analyses the impact of scientists' evaluation of the benefits and costs of collaboration on the intensity of their engagement with industry. I exploit information derived from a survey questionnaire administered to 2,163 researchers active in different scientific fields in three large Italian universities. To analyse the intensity and frequency of their research collaboration with industry partners, I use information derived from the questionnaire on the benefits and costs of collaboration as perceived by researchers. The analysis shows that access to financial and non-financial resources are the most important factors spurring academic researchers to increase collaboration with industry. The perception that collaboration will limit a researcher's freedom is one of the main factors hindering it. At the same time, and somewhat surprisingly, it appears that the possibility that private sponsors might claim ownership and limit the diffusion of research results does not significantly deter researchers' engagement in collaboration activities.

This chapter seeks to make two contributions to the literature. First, the analysis explicitly includes researchers with and without experience in collaboration and patenting activities. Recent work on academics' motivations tends to focus on two forms of collaboration, namely academic entrepreneurship (Jain, George et al. 2009; Krabel and Mueller 2009) and academic patenting (Baldini, Grimaldi et al. 2007; Davis, Larsen et al. 2009). Since university patenting represents only a small fraction of the total knowledge transfer from academia to the private sector (Agrawal and Henderson 2002), a focus on academic entrepreneurs or inventors may provide incomplete descriptions of researchers' attitudes towards engagement with industry. Second, many existing analyses of university-industry collaboration are qualitative; chapter 4 provides direct quantitative evidence that individual preferences shape researchers' choices about industry collaboration.

Chapter 5 analyses the impact of a personality trait, namely self-monitoring, on academics' engagement activities with industry. Self-monitoring is the individual's active construction of the public self to achieve social ends: according to this theory, individuals differ in the extent to which they are willing and able to monitor and control their self-expression in social situations. Using data from a survey administered to 6,000 academics in

physical sciences faculties in UK universities, I suggest that high self-monitoring individuals collaborate more with industry than their low self-monitoring colleagues, across a variety of channels of interaction. Furthermore, the influence of self-monitoring on researchers' collaboration activities is moderated by both individual and environmental characteristics. For high-status researchers who have already achieved high levels of visibility outside academia, the influence of their self-monitoring score is less pronounced. This applies also to academics who are extrinsically motivated in their jobs and who value tangible benefits. Individuals who operate in an environment that is very supportive of industrial engagement need to rely less on their self-monitoring profiles since opportunities are readily available to everyone.

Chapter 5 contributes to current debate on the need to pay greater attention to the microfoundations of university-industry collaboration (Rothaermel, Agung et al. 2007). While my findings confirm the role played by some key demographic characteristics, in particular academic rank, industry experience, gender and academic age, by analysing the effect of self-monitoring on academics' engagement with industry, I provide novel insights into the individual determinants of engagement activity, and especially the effect of researchers' personality.

Chapter 6 focuses on a specific form of academic engagement with industry, namely academic entrepreneurship, and the relationship between individual and organizational attributes. Using a large-scale panel of academics from a variety of UK universities from 2001-2009, this chapter shows that individual level attributes and experience are the most important predictors of academic entrepreneurship. I find also that the academic's social environment plays an influential, but less prominent role than individual level factors. Finally, I demonstrate that the activities of the TTO play only a marginal and indirect role in driving academics to start new ventures.

The contribution of this chapter is to enrich understanding of the nature of academic entrepreneurship by incorporating individual attributes (such as entrepreneurial orientation and experience) which the wider entrepreneurship literature emphasizes as being central determinants of both entrepreneurial activity and success. Moreover, this study offers the possibility to gauge the role of TTOs as facilitators (or blockers) of individual-level predispositions towards new venture creation.

Chapter 7 analyses the role of social context on academics' industry engagement activities. I develop hypotheses to test the idea that peer effects are generated by two distinct mechanisms. The first mechanism is social learning, indicating that individuals reduce

uncertainty by following the behaviour of their peers (Bandura 1977; Nanda and Sorensen 2010). The second is social comparison whereby individuals choose local peers to act as a reference group (Hyman 1942; Ibarra and Andrews 1993). I test my hypotheses using multi-source data on 1,500 academic scientists in a range of disciplines, in UK universities. I make particular efforts to address the so-called reflection problem common to econometric studies of peer effects on individual behaviour (Manski 1993), which can result in spurious correlation. This chapter shows that individuals look to their immediate peers for their orientation, both collaboratively via learning as well as more competitively via social comparison.

While recognizing the importance of individual (demographic and psychological) factors for explaining an individual's behaviour, this chapter contributes to the literature on university-industry relations and commercialization of university technologies in two ways. First, it highlights the importance of the local social environment in influencing an individual to depart from the routines prevailing in the organization. Second, it identifies the precise mechanism by which this local context influence occurs.

CONTRIBUTIONS

First, the research described in this thesis seeks to contribute to the debate on the individual determinants of academics' industry engagement. Several studies highlight the central role of academic scientists in the commercialization of universities' inventions (Zucker and Darby 1996). On the one hand, academics operate in professional bureaucracies (Mintzberg 1979) and enjoy considerable autonomy in their work, retaining decision rights over the projects they take on and the methods they use to tackle them. On the other hand, they are bound by their universities' policies and regulations regarding tenure decisions and royalty agreements, for example. Technology commercialization and collaboration with industry are activities that are usually not formalized in researchers' contracts: research has therefore tried to understand which are the characteristics of the researchers who engage in this kind of activities. Previous literature has mainly explored correlations between certain observable characteristics and academic engagement: this may be problematic because without really opening the black box of academics' individual volition we cannot gauge the actual importance of agency compared to the role of organizational incentives and pressures. The analysis presented in this thesis offers the opportunity to study jointly the effect of individual-level and organizational-level variables. Through an investigation of the elements

related to researchers' personality and perceptions on one side, and of organizational features on the other side, I can assess the relative role of individual volition in academic engagement, enriching our theoretical understating of this phenomenon.

Second, I contribute to the literature which proposes that academic scientists look to reference groups to guide their professional behaviour (Stuart and Ding 2006; Bercovitz and Feldman 2008; Haas and Park 2010) by analysing the mechanisms by which peer effects influence researchers' collaboration activities with industry. Literature on scientists' behaviour tends to polarize between two contrasting perspectives regarding academics' choice of behaviours. One side presents an over-socialized view of this issue, emphasizing the role of fundamental Mertonian norms in guiding scientists' conduct, and largely ignoring the exercise of individual agency by scientists (Merton 1973). The other side, by focusing on individual activities and attributes, implies that academics' behaviours are determined solely by their individual interests, resulting in an under-socialized account of researchers' decision making processes. A recent stream of research offers a meso-level perspective, by focusing on the social context in which academics operate and how this context interacts with both individual and structural characteristics. I contribute to this literature by decomposing the effect of the social context into two mechanisms: this is relevant because different mechanisms may be driving different behaviours and may require different incentive systems.

Third, it is important to recognize that whilst commercialization clearly represents an important way for academic research to contribute to economy and society, there are multiple other ways in which university research is transferred (Salter and Martin 2001). In this thesis I focus not just on academic entrepreneurship in the strict sense, meaning the creation of commercial ventures, but also on what I call *academic engagement with industry*, defined as knowledge-related collaborations between academic researchers and commercial organizations. These interactions include formal activities, such as collaborative research, contract research and consulting, as well as informal activities, such as provision of ad-hoc advice and networking with practitioners (Van Dierdonck, Debackere et al. 1990; Bonaccorsi and Piccaluga 1994; Meyer-Krahmer and Schmoch 1998; D'Este and Patel 2007; Perkmann and Walsh 2008). Although commercialization is considered a prime way to achieve academic impact, it is only the tip of the iceberg of university-industry interactions since many companies consider academic engagement to be significantly more valuable than licensing university patents (Cohen, Nelson et al. 2002).

Finally, from an empirical perspective, I consider a large population of academic researchers, spanning different scientific disciplines. Previous studies on academics'

involvement with industry have focused on relatively narrow fields, notably the life sciences or medical disciplines. However, scientific disciplines tend to define the extent of researchers' engagement in collaborative activities with industry: in more applied fields of science, such as engineering, collaboration is more likely (Rosenberg and Nelson 1994). For researchers working within the so-called Pasteur's Quadrant (Stokes 1997), practical problems provide a powerful stimulus for the development of new ideas (Rosenberg 2002). By considering a wide range of scientific disciplines, I increase the generalizability of my results to the whole population of academics.

CHAPTER 2 – INSTITUTIONAL CONTEXTS

This chapter presents a brief analysis of the institutional context of university-industry interactions in Italy and in the UK. This analysis is useful to better understand the institutional setting in which the academics surveyed operate. As several scholars observed, the characteristics of countries and of their industrial and innovation systems are important in explaining the phenomenon of university-industry interactions (Friedman and Silberman 2003; Mowery and Sampat 2005; Geuna and Nesta 2006).

ITALY

Italy is a late industrialized country (Graziani 1979): modern industry developed from the 1950s and national support focused on traditional sectors. Except for some centres of excellence (such as Montecatini), Italian firms spent very little on R&D until the second half on the 20th century. R&D started to increase in the 1980s, pushed by a rapid increase in research performed in national public laboratories, such as those affiliated to the *Consiglio Nazionale delle Ricerche* (CNR). Nowadays, the Italian industrial system is characterized by a dualistic structure (Malerba 1993) in which two innovation systems with different capabilities, organizations and performances, coexist.

On one side there is a network of small and medium size firms (SMEs), highly specialized and often concentrated in clusters supported by local institutions (such as banks and professional schools). These firms interact intensively between them (also thanks to high labour mobility in clusters) and are able to rapidly adopt technologies that are generated externally. They innovate incrementally, through learning by doing, adaption and improvement of existing technologies. On the other side there is the core R&D system, composed by large firms with R&D laboratories, small high-technology firms, universities, and public laboratories, linked through a complex organizational system at the national level. This part of the innovation system is quite recent and it is not as technologically advanced as in the rest of Western Europe. The core R&D system is flawed by both endogenous and exogenous problems. The industrial structure is dominated by few large oligopolistic firms (Malerba 1988), often originated directly from monopolistic public enterprises, and a very limited number of small high-tech firms (Raffa and Zollo 1988). Demand for technology and innovation is also weak, and the role of public procurement and military demand has been much smaller in Italy than in other European countries (Pontarollo 1986). In terms of the

generation of advanced scientific and technological opportunities, Italy presents a high fragmentation of efforts and a high variance in terms of scientific output. The quality of basic research conducted in universities is highly variable, and except for some pockets of excellence in specific disciplines (such as particle physics and lasers), it tends to lag behind other developed countries (Dosi 1989).

The Italian university system has a long tradition of a highly centralized governance structure and very low level of autonomy. As in the rest of continental Europe, after World War II and until the 1980s, academic research in Italy was funded predominantly by public sources: interaction with industry was not perceived to be a fundamental mission of universities and funding from private sources was regulated in order to avoid excesses in the consultancy activities of faculty at the expense of teaching and research. In practice, collaborative activity between university and industry was not uncommon but was entirely generated by the relationship of specific individual scientists with the few firms active in R&D (the most famous example being the collaboration between Nobel Prize winner Giulio Natta from Milan Polytechnic and Montecatini, which led to the development of isotactic polypropylene).

The autonomy acquisition process began at the end of the 1980s (Law n. 168/1989), with the creation of a specific institution responsible for the management of research results, the Ministry of University and Scientific and Technological Research (MIUR). Starting from the early 1990s, the new Ministry granted universities with teaching, scientific, organisational, financial, and accounting autonomy, allowing them to create their own independent systems with statutes and regulations. The new regime fundamentally changed the nature of universities, which, for the first time were allowed to plan and control their budget, and to retain any surplus generated. Moreover, this regulation introduced competition among universities for student recruitment. Since the late 1990s, universities responded to such normative changes by putting in place mechanisms to commercially exploit research results, to encourage the collaboration with industrial partners, and to allow the creation of spin-offs by their employees.

Notwithstanding these changes, the Italian university system lags behind most developed countries, both in terms of scientific output and interaction with industry. Several reasons lie behind this phenomenon. First, the legislation regulating formal collaboration activities between university and industry and intellectual property rights (IPRs) remains quite ambiguous. When universities were granted higher levels of autonomy in 1989, IP rules were still governed by a 1939 law, which granted to employers IPRs on employees'

inventions. This meant that it was technically possible for universities to register patents generated by their researchers under the university name. In 2001, the newly elected government introduced an article in the *Legge Finanziaria* that established the so-called professor's privilege, according to which researchers working in universities and public research institutes retain the rights to their inventions while their employers are entitled to a proportion of the royalties. This law clearly ran counter to the legislation being adopted in other European countries, where professor's privilege was abandoned between 2000 and 2002, and also to previous encouragements to universities to create or to improve their technology transfer offices (TTO) in order to stimulate invention disclosure by faculty members (Balconi, Breschi et al. 2002). This reform was received with much scepticism and the reaction forced policymakers to amend the law, which resulted in even more ambiguity. The new *Codice della Proprietà Intellettuale* (IPR law) issued in 2005, states that when the research conducted by an academic researcher is totally or partially funded by a private company (or another non-academic actor), the professor's privilege does not hold, and the IPRs on the invention are retained jointly by the university and the company (Lissoni, Calderini et al. 2004; Galli 2007). The professor's privilege applies if the research is funded totally by the university. This dual mechanism, almost unique in patent legislation worldwide, is likely to result in litigation when the academic research activity is funded by industry partners. Changes have been proposed but they not have been implemented yet. This ambiguity creates transactional barriers when trying to establish research partnerships between universities and industry, lowering incentives for firms to look for collaboration partners in academia.

Furthermore, the Italian university systems retain strong elements of inertia that limit the extent of possible change. Italian university professors are civil servants and their careers are essentially determined by bureaucratic and automatic rules based on seniority. Italian academic institutes are often dominated by a single professor and characterized by feudal-like research paths (Bruno and Orsenigo 2003). Universities are autonomous in terms of budget allocations and design of curricula; however, their funds come almost entirely from the government and they are only partially allocated through competitive processes. Overall, the university system is underfunded and struggles to compete on the international level. Italy university *Baroni* (full professors leading research groups and departments) control and mobilize internal resources, but there are very limited incentives to attract external resources, making collaboration with industry a low priority for Italian academics.

UNITED KINGDOM

United Kingdom was the hub of the 18th century and 19th century industrial revolutions. The country was the first to witness the mechanisation of the textile industry, the development of iron-making techniques, the introduction of steam power and railways. Throughout history, the state in Britain has not generally acted as a catalyst of industrial and technological development (as in France or in Japan), but has provided regulatory functions and the advancement and military protection of foreign trade (Owen 2012). The UK industrial policy has been heavily influenced by some characteristics that the UK shares with the US: strong resource-based industries, large and sophisticated capital markets, heavy commitment to defence production, attachment to individualism and liberal economic ideals (Walker 1993).

United Kingdom started to lose technological and economic leadership towards the end of the 19th century. Thereafter, policies to restore that leadership have been of very diverse nature. During the 1960s and the 1970s, the country witnessed a rather substantial government intervention to increase investment and to improve industrial management. From the 1980s, a full faith in the effectiveness of market mechanisms was restored: competition became the principal instrument for improving industrial efficiency. The government encouraged home-grown ventures by creating an environment supportive of entrepreneurs, rather than by supporting particular industries. Because of national security concerns, the only industry which continued to receive a steady influx of government support was aerospace. In all other sectors, the industrial structure was largely determined by the market. Some scholars argue that this focus on productivity improvements and cost reductions (which characterise UK manufacturing sector) neglected the importance of expanding and creating new and durable technological capabilities (Walker 1993). R&D spending in the UK declined steadily during the 1980s, while it increased in the rest of Western Europe (Walker 1993). On the other hand, favoured by the liberal economic policy, international investments in the country increased dramatically, making R&D in Britain highly internationalized (Owen 2012).

After Mrs Thatcher resigned in 1990 and during the Labour governments, industrial policy remained, somehow surprisingly, largely hands-off. In an effort to encourage high-value-added sectors of the industry, the Labour government supported some particular industries (such as biotechnology), but on a modest scale. Emphasis was put on horizontal policies, such as improving the supply of finance for entrepreneurs, providing tax incentives

for R&D and increasing the science budget. The dominant view was that the Government's primary responsibility was to deliver conditions of macroeconomic stability and to tailor regulation, tax, and competition policies to support business R&D growth in the UK (HM Treasury, DTI et al. 2004). At the same time, the government followed its predecessors in welcoming inward investment in the country. Over time, this laissez-faire approach started to encounter the scepticism of several British business leaders. These concerns were voiced by Sir John Rose, chief executive of Rolls-Royce, who deplored the loss of expertise in industries such as railways and power, while urging the government to give a clearer sense of direction for industry¹. Changes in government thinking on this topic started to become evident in a White Paper published in 2009, in which Peter Mandelson argued for the necessity of 'targeted intervention' by the government to help business exploit newly available opportunities, especially in advanced technologies (BERR 2009).

The Conservative-Liberal coalition government has withdrawn several of these target interventions. While it is not supporting any specific company, the current government is trying to revive the manufacturing sector by addressing some specific problems, such as promoting innovation through the creation of Technology Innovation centres (recently renamed Catapult Centres), loosely based on the Fraunhofer model in Germany. The UK economy has largely shifted towards the provision of services: while this follows an international trend, the shift in Britain has been especially pronounced. It is interesting to note that UK nonmanufacturing sectors are heavy and highly sophisticated technology users, and Britain leads other European countries in terms of application of new technologies. The UK retains also strong capabilities in science-heavy sectors, such as chemical and pharmaceutical, and aerospace (Porter 1990).

While British industrialization did not rely on mass education, the UK presents an advanced scientific system, making the country an elite performer in science. In 2008, researchers in the UK published 76,683 scientific articles, the third highest performance in the OECD area after the United States and Japan. The UK performs above OECD average also in the number of researchers per thousand employments and the share of science and engineering degree in all new degrees (OECD 2010).

Historically the UK university system was dominated by the so-called Ancient Universities (such as Cambridge and Oxford) created between the 12th and 16th century, the University of London (19th century) and the Red Brick Universities, created before the First

¹ Sir John Rose, "Why manufacturing matters", Gabor lecture at Imperial College, November 15, 2007

World War in large industrial cities such as Sheffield and Birmingham. Changes began in 1963 when the Robbins Report recommended that education enrolment should be increased in order to meet the needs of the economy. In particular, it recommended a 266% increase in higher education as a whole over a 20-year period, and a 392% increase in science and technology subjects (Robbins 1963). New universities (were built on campuses designated outside towns and cities. Finally, in 1992, a group of former polytechnics and colleges of higher education were given university status by John Major's government. These institutions focused mainly on applied education for work and had their roots in engineering and applied science although after being given university status have begun to expand into the humanities.

Universities in the UK are characterized by a high degree of autonomy in terms of budget, recruitment and choices of curricula. The funding regime of UK universities makes the academic system extremely competitive and entrepreneurial. Central government funding for science and research activities in universities flows through three main routes. The first (and most important) is represented by the so-called Dual Support system, which is composed by a block grant funding for Higher Education Institutions, complemented by project funding. The block grant funding is administered by the Higher Education Funding Council for England (HEFCE) (and analogous bodies in Wales, Scotland and Northern Ireland): it is quality based and it is allocated based on the periodic assessment of British Universities (the Research Assessment Exercise, now called Research Excellence Framework). This funding provides resources for basic research infrastructure and permanent staff salaries: ideally it provides institutions with the flexibility to react quickly to new areas of investigation and to perform 'blue skies' research. The project funding comes from specific programmes (responsive mode) of the seven Research Councils through grants to individual academics and departments: proposals are evaluated by peer review and the allocation decision follows a strategic direction. In 2010, HEFCE distributed 1,730M£ as block grant funding, while the RC awarded grants for 2,600M£ (HEFCE 2011). Other public organizations (such as the NHS), foundations and firms also provide funds to British universities. For example, in 1998 the Wellcome Trust has established a partnership with the UK government to fund world-class biomedical research in the country. Unlike in the Italian system, researchers are often required to acquire external resources through competition.

The second route is a dedicated capital funding through the Science Research Investment Fund. The third route is the Knowledge Transfer funding, currently distributed Higher Education Innovation Fund (HEIF), which in 2002 replaced the Higher Education

Reach-out to Business and the Community Initiative (HEROBAC), launched in 1999. These programmes began by allocating funding to universities on the basis of competitive tenders, but in 2003 they moved to block funding based on performance measures. Overall, the UK government has provided almost £700 million pounds (in constant 2003 prices) in direct support to English universities for third stream activities, between 2000 and 2008, with another £340 million pounds committed for the 2009-2011 period (PACEC 2009). Funding includes support for a range of commercial activities, including academics' commercial ventures, personnel exchanges between university and industry, and university patenting; however, the majority of these funds have been used to build up and extend the efforts of university TTOs (Mustar and Wright 2010).

The rationale to establish knowledge transfer support stemmed from the consideration that UK science base could contribute to the country's overall economic growth. Systematic efforts to promote university-industry interactions started in the 1990s, particularly following the 1993 government White Paper 'Realising our potential', which advocated an systemic approach to identify the roles of different actors in the innovation process and to encourage collaboration among them to promote knowledge exchange (HM Treasury 1993). An extremely significant signal came from the UK Science and Innovation Investment Framework for the period 2004/2014. Gordon Brown's government set the objective to increase R&D intensity to 2.5% by 2014, and to increase funding for the science base at an annual rate of 5.8% (HM Treasury, DTI et al. 2004). The logic was that securing the growth and excellence of UK public science would act as a platform for successful innovation by business and public services. In turn, this would attract talented individuals and corporate investment in the country. Achieving a better integration of the research base with the evolving needs of the UK economy would ultimately support economic growth. In order to achieve this objective, the government advocated the need for a tighter relationship between university and industry. The Framework (which responded to some of the issues raised in the Lambert Review of Business-University Collaboration) stated that 'over the next ten years, it is critical that the levels of business engagement with the science base increase, to realize fully the economic potential of the outputs of our science base' (HM Treasury, DTI et al. 2004)(p.75). Much of this emphasis on business engagement with the science base was ultimately translated in encouraging universities to spin-out companies and to develop patentable inventions which could be licensed out (Mustar and Wright 2010). The Coalition government has repeatedly affirmed its commitment to university-industry collaboration as a policy priority (BIS 2010).

The Research Councils have also encouraged university-industry collaboration. The 2006 Warry Report (Warry 2006) underlined how RC could foster structural changes by promoting and demonstrating the economic and social impact of their investments. This resulted in a requirement for all applicants for RC grants (since April 2009) to produce Impact Summary and Pathways to Impact statements, declaring the possible economic and social impact of the results of their proposed research project. This new requirement was met with scepticism from the research community, and especially researchers in basic fields who investigate fundamental scientific problems which do not (and cannot) have immediate applicability to current problems in business or society.

Implications for the interpretation of the analysis

Italy and United Kingdom presents two very different situations both in terms of industrial structure and organization of the academic sector. In particular, Italian academia is characterized by a very bureaucratic system and scarce resources. On the other hand, the UK academic system is more competitive and less centralized. These characteristics create differences in terms of the necessity of academics to reach to external actors in order to finance their research. On the other hand, academics in both countries show similarities in terms of individual autonomy, even when operating under different resources constraints. Having these two countries in this thesis is interesting because it shows that issue related to academic engagement are interesting for researchers in general, notwithstanding the differences in the way universities are administered. This is relevant as policy efforts to foster academic entrepreneurship and technology transfer for academics are often initiated at the European level. From an empirical point of view, however, I cannot claim the generalizability of my results from one country to the other as the data collection presented a different design.

CHAPTER 3 – DATA

This chapter presents a description of the databases used in the analysis. One database (UNIVERSITAS Database) has been developed for Italy and one database (IPGC-AIM Database) has been developed for the United Kingdom. In this chapter, I describe the methodology used to collect primary data through surveys and the processes used to link these data with secondary sources.

UNIVERSITAS DATABASE: ITALIAN ACADEMIC RESEARCHERS

The questionnaire

The research questions are addressed using data collected through a questionnaire administered to academic researchers in three Italian universities: Università Statale di Milano, Politecnico di Milano and Università della Calabria. These universities represent three different kinds of institution. The University of Milan focuses on the basic science disciplines, the Polytechnic of Milan specializes in the engineering disciplines, and the University of Calabria covers both. Moreover, the first two institutions are located in the heavily industrialized area of Northern Italy, while the third is based in the less industrialized south of Italy, which is more focused on traditional production sectors. In addition, the three universities are among the most active Italian universities in terms of involvement in technology transfer. They all have fairly large TTOs as measured by the number of permanent staff, patent applications, and spinoff companies, and they were among the original founders of *Netval* (the association of Italian TTOs). For all these reasons, the three institutions represent the possible different typologies of universities present in Italy, and therefore they can be seen as a reasonably representative sample of the Italian higher education sector. The scientific disciplines represented are mainly in the engineering sciences (civil engineering, industrial engineering, information engineering, process engineering, general engineering, chemistry) and life sciences (biology, medicine, pharmacy). These disciplines were selected because they are considered to be more exposed to pressures related to technology transfer. Researchers' names, affiliations and academic ranking were obtained from the Italian Ministry for University and Research website, which lists all researchers employed in Italian universities (because they are civil servants). Email contacts were obtained directly from the universities. Gender and age were gathered from researchers'

personal web pages. The population investigated is composed of 2,163 tenured university researchers affiliated to Italian institutions.

The survey was administered exclusively online via a dedicated website. The interface was built by a software programmer. The researchers were sent personalized emails containing a link to the survey, which explained the nature and the objective of the research (February 2008). The email stressed that researchers with experience of collaboration with industry as well as those with no collaboration experience were being invited to complete the questionnaire. After one month a reminder was sent. In total, I received 731 usable responses from the survey. Given the total population of 2,163, this was a response rate of around 34%. This result can be considered satisfactory if compared to surveys conducted on similar populations.

In order to check the reliability of the sample, I performed some tests on the response population, to look for sources of bias in the sample. In particular, I performed an analysis of response rates along different known dimensions (age, tenure, field, university, patenting experience, etc.) for both respondents and non-respondents. A Chi-square test shows that the sample population is not significantly different from the whole population. Also, before the final questionnaire was administered, I conducted a pilot to test that the questions were phrased clearly, and to reduce possible ambiguities. I contacted five researchers from a university not included in the sample and I asked them to respond to the questionnaire. I observed them while they were completing the questionnaire, monitoring the time required to complete it. I then asked their opinions about the clarity of the survey. No major inconsistencies emerged in this pre-test phase.

The questionnaire contained four sections:

- Background information (Section A);
- Collaboration with industry (Section B);
- Patenting (Section C);
- Technology Transfer Office (Section D).

The first section (*Background information*) asks for individual information which allows customization of the information provided in the other three sections of the survey. In particular, it identifies researchers in biomedical disciplines and evaluates the degree of familiarity with their university TTO.

The second section (*Collaboration with industry*) included a question evaluating the intensity of the researcher's interaction with industry and a set of 11 items regarding the perceived benefits and costs derived from collaboration. The list of items was compiled based

on previous both qualitative (Van Dierdonck, Debackere et al. 1990; Owen-Smith and Powell 2001) and quantitative (Baldini, Grimaldi et al. 2007; Davis, Larsen et al. 2009) studies.

The third section (*Patenting*) is more detailed. First, it gathers information at the level of knowledge of IPR issues, and their perceived relevance in the researcher's scientific domain. It also has a set of items on the factors influencing the propensity to become an academic inventor (Baldini, Grimaldi et al. 2007; Davis, Larsen et al. 2009) and three questions evaluating the researchers' opinion on the current Italian IPR law for academic institutions. The third part of this section is addressed only to biomedical researchers and investigates ethical considerations regarding the commercialization and patenting of university research in the pharmaceutical domain.

The last section (*Technology Transfer Office*) contains six questions asking about the researcher's interaction with the university TTO. All question (except those on the IPR legislation) required answers on a Likert scale going from 1 (totally disagree) to 4 (totally agree). At the end of the questionnaire, there was space for respondents to add comments.

Patent data

Data on patents in which the academics surveyed appear either as inventors or applicants were extracted from the Italian section of the KEINS database². The KEINS database originates from the EP-INV database produced by CESPRI-Università Bocconi, which contains all European Patent Office (EPO) applications, reclassified by applicant and inventor (from 1978, updated yearly), and from lists of all ranks of university professors (from assistant to full professor). Academic inventors were identified by matching names and surnames of inventors in the EP-INV database with those on the lists of professors, and by checking, by email and by phone, the identities of the matches in order to exclude homonyms. Detailed information on the construction of this database can be found in Lissoni et al. (2008).

Publications

The survey respondents were matched to the publication records contained in ISI Web of Science³. Web of Science is an online academic citation index provided by Thomson Reuters which provides access to multiple databases, cross-disciplinary research, and in-depth exploration of specialized subfields within an academic or scientific discipline. It includes

² I am grateful to Francesco Lissoni for sharing the KEINS data

³ I am grateful to Christian Catalini for performing the matching

over 12,000 journals and 120,000 conference proceedings across the sciences, social sciences, and arts and humanities. In particular, for every respondent in both waves of the survey, information was collected on all his/her publications, including:

- Title of the publication;
- Type of publication;
- List of authors;
- Name of the journal/conference;
- Year of publication;
- Number of citations received (as of 2007);
- Scientific disciplines associated to the publication.

Journal names included in the publication records were matched with the classification of ISI journals developed by CHI-Research (Noma 1986). This classification is based on expert assessments of individual research journals, which are assigned to one of four, mutually exclusive categories ('levels' in CHI terminology) according to the journal's degree of 'appliedness' reflected by its content (Noma 1986; Hamilton 2003). There are two related classification systems. One is specific to biomedical fields, and journals are assigned to one of the following levels: (1) Clinical observation; (2) Clinical observation and investigation; (3) Clinical investigation; (4) Basic biomedical research. The other covers all other fields of science: (1) Applied technology; (2) Engineering science—technological science; (3) Applied research—targeted basic research; (4) Basic scientific research. I recognize that the CHI database may provide outdated information for some of the journals; however, it represents a readily available and straightforward classification of a large number of scientific journals, making it a useful source of information for the purpose of this research.

IPGC-AIM DATABASE: UK ACADEMIC RESEARCHERS

EPSRC database

I obtained detailed information on Principal Investigators and Co-Investigators who received grants from the UK Engineering and Physical Sciences Research Council (EPSRC) in the period 1992-2006. The EPSRC is the largest funder of research in the UK and disbursed £817m in 2011 for research across all fields of engineering, mathematics, chemistry and physics. EPSRC has released a Delivery Plan for 2011/12 to 2014/15 focusing on three core goals: delivering impact, developing leaders, and shaping capabilities. The RCs vision is to move from being a funder to being a sponsor of research, where its investments

will be a national resource focused on outcomes for the UK good, and where it more proactively partners with supported researchers.

The EPSRC encourages partnerships between researchers and third parties, such as private firms, public bodies, non-profit organizations, etc. However, for most projects, there is no requirement for an industry partner. The selection of projects is mainly based on peer review.

I used EPSRC records to obtain information on each academic's research funding profile, including amounts of funding received. These data are comprehensive and cover all academics granted EPSRC funding in the UK over a period of 15 years. They contain the following information:

- Name of grant holders (Principal Investigators and Co-Investigators);
- Grant reference number;
- Name of the partner organizations (if present);
- Total amount of the grant;
- Start and end date;
- Scheme title (for non-collaborative grants).

The questionnaire

The research questions are addressed using data collected through a questionnaire administered to Principal Investigators and Co-Investigators on EPSRC funded research projects. Researchers' names, contact details and details of their grants were provided by the EPSRC and double-checked on the web to ensure they were as accurate as possible. The population investigated is composed 6,160 university researchers affiliated to British institutions. The scientific disciplines represented are mainly in the physical sciences (aeronautical and aerospace engineering, computing/computer science, mathematics, civil engineering, materials science, chemistry/chemical engineering, physics, electrical and electronic engineering, environmental science, mechanical engineering, statistics) with a small proportion in other disciplines (biology related subjects, medicine, pharmacy, business). The population includes researchers awarded collaborative grants (with an industry partner) and researchers awarded grants without private company involvement. Where the available information allowed, I removed individuals no longer active in academia or who had moved abroad. Since the survey population covers the grants period from 1995, many individuals to whom the survey was sent belonged to one of those groups. In total, I received 150 'returns to sender' because the persons listed either had left academia, had retired or had

died. I exclude all of these in the calculation of the response rate because they could be differentiated from non-responses.

The survey was administered exclusively online and was designed using an online tool (LimeSurvey). A few days before the online questionnaire was launched in March 2009, recipients were sent a letter signed by Professor Delpy, Chief Executive of the EPSRC, explaining the purpose of the study and inviting researchers to participate. The researchers then received a personalized email with a link to the survey. After two weeks a first reminder was sent, followed by a second reminder one week later. These contacts elicited 1,636 responses. In order to improve response rates, researchers who did not complete the questionnaire were contacted directly by phone to encourage them to respond. This approach yielded another 448 responses. In total, I received 2,084 usable responses from the survey. Given the total population for the survey of 6106, the response rate was around 34%. This result can be considered satisfactory if compared to surveys conducted on similar populations. It should be noted also that during the administration of the survey, a questionnaire targeting the same population was being circulated by Cambridge University (as part of a larger project), and the EPSRC was surveying stakeholders in relation to the proposed changes to the review mechanisms of grants and the request for evidence of research impact.

In order to check the reliability of my sample, I undertook some tests on the respondent population, looking for sources of selection bias in the sample. In particular, I analysed whether there were any differences in the typology of university affiliations of respondents compared to the rest of the sample: I performed a non-parametric test (Wilcoxon-Mann-Whitney) and found no significant differences. Unfortunately, I cannot compare respondents and the rest of the sample on the basis of demographic characteristics since these were collected through the survey. I have compared early versus late respondents, finding no significant differences. Moreover, as the questionnaire targeted only grant holders, there is the risk that a sample selection bias is present, as non grant holders may behave differently in terms of their engagement with industry. As I do not possess any information on the academics who did not receive any grant from 1992 to 2006, I used the group of academics in our survey who did not receive any grant in the last five years (from 2000 to 2006) as a proxy for non grant holders. I then compared their level of involvement with industry with the level of the academics who received a grant in the last five years, finding no statistically significant difference. Specific concerns about sample selection are also addressed in each chapter.

Before administering the final questionnaire, I conducted a pilot to test that the questions were phrased clearly and to reduce possible ambiguities. I contacted 33 researchers from 11 different departments in Imperial College London (one Professor, one Reader and one Lecturer from each department) and I asked them to respond to the questionnaire. Eight researchers completed the questionnaire, and four completed it partially. I followed up with a telephone call (to both respondents and non respondents) to ask their opinions on the clarity of the survey and the time needed to complete it: no major inconsistencies emerged in this pre-test phase.

The questionnaire builds on a previous research effort, conducted at Science and Technology Policy – SPRU, University of Sussex, in 2004 and sponsored directly by the EPSRC (D'Este, Nesta et al. 2004; D'Este and Patel 2007). The main focus of the survey was channels of interaction and joint publications. I tried to find possible synergies with this previous work and to extend it. Therefore, a portion of the population surveyed in the present research is composed of researchers who responded to the 2004 questionnaire (756 individuals answered both waves of the survey). Results for the majority of questions in section A are broadly comparable between the two populations.

The survey has six sections:

- University-industry interactions (section A);
- Your work: structure, interaction style and motives (section B);
- Relationship with industry and support from the university (section C);
- Entrepreneurial orientation and venture creation (section D);
- Commercial ventures (section E);
- Personal background (section F).

The first section (*University-industry interactions*) included questions taken from the 2004 survey (reasons for involvement in collaboration activities with industry, frequency and forms of interaction, constraints to collaboration) in order to obtain a panel and to analyse how the basic motivations and barriers for collaboration have evolved during time, and whether forms of interaction have changed. Forms of interaction include a large variety of channels such as creation of new physical facilities with industry funding, joint research agreements, contract research agreements, consultancy agreements, training of company employees, postgraduate training with a company, attendance at conferences with industry and university participation, and attendance at industry sponsored meetings. In this section, respondents were asked to indicate the factors that influenced their decision to interact with industry. A range of potential factors was included, some of which were related more to

financial incentives, such as securing additional research income, and others more to research incentives, such as access to research expertise of industry researchers or inspiration for new projects. Working with industry can raise problems for academics. These may be related to the different incentives and institutional regimes operating in the university system compared to industry. They may be barriers related to the orientation of academics, which tends to be longer in terms of time frame. They may arise out of transactions associated with industry collaboration, including disputes over IP, timing of publications and universities' rules and the regulations. In this section, academics were asked to rate the importance of a range of different constraints on relationships with industry.

The first section also includes two questions not in the 2004 survey, asking about previous work experience in the private sector (number of years an academic spent in employment by a private firm) and share of the researchers' research budget from industry partners (Blumenthal, Causino et al. 1996).

The second section (*Your work: structure, interaction style and motives*) analyses in depth researchers' everyday work structures. In order to obtain a sense of how academics spend their time – balancing their research, teaching and engagement efforts, I included a question in the survey that asked academics how they allocated their work time in an average week among different categories of activities. Activities included: doing research that does not involve industry, university administration, teaching and related activities, working on research activities with people in industry (excluding consulting and activities related to the creation/management of commercial ventures), consulting and activities related to the creation/management of commercial ventures. The second new question in the section investigates individual motivations for becoming an academic researcher. Items were extracted from the Survey of Doctorate Recipients⁴ conducted by National Science Foundation in the United States (Sauermann and Cohen 2010). Items included motives related to financial benefits (such as salary and other benefits) and motives related to the intrinsic characteristics of the academic job (such as intellectual challenge and degree of independence).

The third section (*Relationship with industry and support from the university*) explores the impact of the environment (department and university, industrial partners, research council) on researchers' behaviour. One question is a slight modification of the inter-organizational trust scale developed by Zaheer et al. (1998) and considers the relationship

⁴ <http://www.nsf.gov/statistics/srvydoctoratework>

between the academic and the industry partner. Personal and trust-based relationships between university scientists and industry partners are crucial for the effectiveness of knowledge transfer activities. Researchers were asked to indicate their agreement to statements such as: ‘During collaborative projects, my industrial partners usually treated my problems constructively and with care’, ‘My industrial partners may use opportunities that arise to profit at my expense or at the expense of the university’ and ‘I trust my industrial partners to treat me fairly’.

The second question targets the supportiveness of the researcher’s department and university of affiliations for industry collaboration. Respondents were asked to rank their agreement with a set of statements such as: ‘My department (or university) is very effective in supporting collaboration with industry’, and ‘My department (or university) is an obstacle in the collaboration with industry’.

The last question in the section investigates the impact of RC policies on scientists, and especially the effect of Research Assessment Exercise (RAE) conducted in 2008 (Brinn, Jones et al. 2001). This section assesses the impact of the environment on individual researcher behaviour, in terms of the research conducted and the engagement with industry.

The fourth section (*Entrepreneurial orientation and venture creation*) explores the entrepreneurial attitudes and activities of the researchers investigated. The first question in the section focuses on the entrepreneurial orientation of the academic and is derived from a question developed by Nicolaou et al. (2008). The following three questions serve as filters to identify: (a) academics who have already started a business; (b) academics who are planning to start a business; (c) academics who are not interested in starting a business. These were extracted from the Global Entrepreneurship Monitor (Autio 2005; Reynolds, Bosma et al. 2005). Individuals in group (c) skip the next section and go directly to the last section of the questionnaire. Individuals in groups (a) and (b) are asked about the factors influencing their decision to start a business (Carter, Gartner et al. 2003) and about the barriers encountered in attempts to start a new venture. Factors influencing the decision to start a business range from financial benefits (‘To achieve greater financial security’, ‘To increase my personal income’), to recognition (‘To achieve something and to receive recognition for it’, ‘To have more influence in my community’), to intellectual challenge (‘To be at the forefront of scientific and technological developments’, ‘To challenge myself’). Barriers could be at the personal level (‘Family pressure’, ‘Lack of time’), or at the institutional level (‘Lack of support from the university/colleagues’, ‘Lack of mentors’).

Group (b) was then directed to the last section while group (a) was asked to respond to questions in the fifth section (*Commercial ventures*). This section explores in more detail the types of companies created by academic entrepreneurs. It asks first about the name and year of venture foundation. Then researchers are asked to categorize the business models of the firms they had created: providing research-based consultancy or research services to customers; developing IPRs that can be licensed or sold to customers; or producing and marketing a product with its own manufacturing facilities. Another question investigated the role of the researcher in the companies they had created or helped to create: director, consultant, chairperson, manager, member of the scientific board, none.

The last section in the questionnaire (*Personal background*) collects demographic information: age, gender, academic title, year of the PhD and awarding institution. Missing demographic characteristics were filled wherever possible by manual checks on personal web-pages. The last question in the survey explores the construct of self-monitoring. Research on self monitoring typically uses multi-item self-reporting measures to identify people with high or low self-monitoring. The most frequently used instruments are the 25-item, true-false, original self-monitoring scale (Snyder 1974) and the 18-item refinement of this measure (Lennox and Wolfe 1984; Gangestad and Snyder 1985; Snyder and Gangestad 1986). In order to be consistent with most of the management journal literature using this measure, I used the 18-item true-false scale.

A detailed descriptive analysis of the results from the questionnaire is contained in the report compiled for the EPSRC 'The Republic of Engagement' (Salter, Tartari et al. 2010). The full questionnaire is reported in the Appendix.

ISI Web of Science

The respondents to the survey were matched to the publication records contained in ISI Web of Science. In particular, for every respondent to both waves of the survey I collected information on all his/her publications, including:

- Title of the publication;
- Type of publication;
- List of authors;
- Name of the journal/conference;
- Year of publication;
- Number of citations received (as of 2010);
- Scientific disciplines associated to the publication.

The search was performed manually both to comply with legislation concerning the automated acquisition of information from online databases and to treat possible cases of homonymy. The following approach was followed. A first search was performed via the name of the individual researchers and the last university of affiliation. This allowed me to find the link to the correct researcher in the ISI database. Through the link, I retrieved the list of publications. However, some names are very common, which produced some problems. Therefore, I checked that the discipline of the articles listed were compatible with the departmental affiliation of the researcher. Finally, journals names were linked to the CHI database.

Research Assessment Exercise

I matched the sample of respondents with the population of academics included in the RAE conducted in 2008 by the Higher Education Funding Council for England, the Scottish Funding Council, the Higher Education Funding Council for Wales and the Department for Employment and Learning, Northern Ireland).

The RAE was a government-mandated evaluation (now replaced by the REF) to assess the quality of research of all universities and colleges in the UK. The assessment is carried out via disciplinary panels' reviews of the publications, research environment and research esteem of each department. Results are used as the basis for determining the allocation of research funding to universities that is not allocated via competitive bidding for grants. RAE submissions contain information on individuals' 'units of assessment', usually department or similar unit.

These submissions contain rich information about the character of the department, including size of the unit of assessment and amount and nature of funding it received in each of the previous seven years. In particular, I collected the following information at the level of units of assessment:

- Number of researchers rated 4* (world-leading in terms of originality, significance and rigour), 3* (internationally excellent in terms of originality, significance and rigour but which nonetheless falls short of the highest standards of excellence), 2* (recognized internationally in terms of originality, significance and rigour) and 1* (quality that is recognized nationally in terms of originality, significance and rigour);
- Research income (without industrial funding) for the academic years 2004/2005, 2005/2006 and 2006/2007;

- Research income from commercial companies for the academic years 2004/2005, 2005/2006 and 2006/2007;
- Number of full-time academics per unit of assessment.

At the level of universities, I collected information relative to the number of units of assessment submitted by each institution.

The matching was performed at the level of the names and affiliations of individuals. An automated matching procedure was programmed in STATA9 (surname, initials, university of affiliation). Results of the matching were then checked manually and a subsequent automated matching was performed excluding initials. Results were rechecked manually. Around 300 individuals could not be matched following this procedure; therefore, they were matched manually or were assigned to a unit of assessment based on their scientific discipline (verified on their personal website).

Higher Education-Business and Community Interaction Survey (HE-BCI)

Universities of affiliation of the respondents were matched with data derived from the government's Higher Education-Business and Community Interaction Survey (HE-BCI) conducted in 2008, and covering the years 2005-2007. This annual survey examines the exchange of knowledge between universities and society. It collects financial and output data at university level on a range of activities, from the commercialization of new knowledge, through the delivery of professional training, consultancy and services, to community-oriented activities.

In particular, I collected the following information at the level of the institution (for the academic years 2005/2006 and 2006/2007):

- Income from collaborative research involving both public funding and funding from business;
- Income from contract research;
- Income from contract research with non-commercial organizations;
- Income from consultancy contracts;
- Income from consultancy contracts with non-commercial organizations;
- Cumulative portfolio of active patents;
- Number of disclosures;
- Number of new patent applications filed;
- Number of full-time academics employed.

The matching was done at the level of institution: universities were assigned an HESA code and then matched to the HE-BCI database through an automated procedure programmed in STATA9. Universities belonging to the Russell Group (collaboration of 20 universities that together receive two-thirds of research grant and contract funding in the United Kingdom), the 1994 Group (coalition of 19 top smaller research-intensive universities in the United Kingdom founded in 1994 to defend their interests following the creation of the Russell Group) or ex-polytechnic (institutions of higher education that were given university status by John Major's government in 1992) are flagged.

REGIO database

I assigned to the universities the code for the region (NUTS2 level) in which they are located. These codes are used to link the data to the REGIO database developed by Eurostat (2003 VERSION). Eurostat's regional statistics cover the principal aspects of economic and social life in the European Union, including demography, economic accounts and labour market data.

In particular, I collected the following information at the level of region (I used the year 2003 since it was the most complete):

- Gross Domestic Product (GDP);
- Business Research and Development (R&D) expenditures;
- EPO Patent applications per million of inhabitants;
- Number of start-ups per 1000 residents;
- Number of residents.

Other data sources

Data collected through the questionnaire were linked to other sources of information.

The sample was matched with the membership lists of The Royal Society and The Royal Academy of Engineering. The Royal Society is the oldest scientific academy in the world. It was founded in 1660 and awards fellowships each year to 44 of the best scientists, in recognition of their achievements. There are currently 1,400 Fellows, of which 60 are Nobel laureates. The Royal Academy of Engineering includes the UK's most eminent engineers. Each year up to 60 Fellows are elected on the basis of nominations by the existing (at the time of writing 1,426) Fellows. The sample of respondents was also matched with the list of academics included in ISIHighlyCited.com. This database contains the 250 most cited researchers in 21 broad subject categories, comprising less than one-half of 1% of all

publishing researchers and, therefore, highlighting truly outstanding scientific contributions. For these three data sources, the matching was conducted manually on the basis of last names, initials and scientific discipline.

The Times Higher Education Supplement methodology was used for two purposes. Universities in which respondents were awarded their PhD are flagged if they were included in the 2004 edition of the World Universities Ranking. The average quality of the unit of assessment (based on the percentage of faculty ranked in the four different categories) was computed according to the methodology presented in the Times Higher Education Supplement in 2009.

CHAPTER 4 - SET THEM FREE: SCIENTISTS' EVALUATIONS OF THE BENEFITS AND COSTS OF UNIVERSITY-INDUSTRY RESEARCH COLLABORATION⁵

INTRODUCTION

An undoubtedly crucial feature of the university environment is autonomy: the defining characteristic of academic research is that individual scientists retain decision rights over the projects they take on and the methods they use to tackle them. Scientists value creative control (Aghion, Dewatripont et al. 2008) and are even willing to accept lower wages to maintain it (Stern 2004). This peculiar characteristic generates a special set of motivations and rules of behaviour for individuals engaged in research activity in an academic context. University scientists operate in an 'open-science' community, ruled by the norms of universalism, disinterestedness, originality, organized scepticism, communalism, and a belief that the discoveries generated through publicly funded research should be placed in the public domain (Merton 1973). In exchange for adherence to these principles, scientists are granted freedom of inquiry and are rewarded with peer esteem, promotions, research grants, and scientific prizes. Academic scientists are also free to establish new research lines based on their perception of opportunities or on pure individual curiosity.

However, the academic incentive system often deviates from this ideal. The fiscal budget constraints facing policy makers in many developed and developing countries encourage universities to embrace more competitive sources of funding (Geuna and Nesta 2006) and increase technology commercialization through patenting and licensing (Cohen, Nelson et al. 2003; Siegel, Waldman et al. 2003). Since the 1980s, there has been increasing pressure on academics to collaborate with industry partners and to commercialize the results of their research.

It remains the case, however, that collaborating with industry constitutes discretionary behaviour for academics. For a multiplicity of reasons, researchers may decide to engage (or not to engage) in technology transfer activities. Their decisions are shaped by the incentive systems in place and by individual perceptions of the potential benefits and costs of collaboration (Owen-Smith and Powell 2001). Scientists' evaluations are crucial because they

⁵ This chapter is co-authored with Stefano Breschi and it is published in *Industrial and Corporate Change* (2012), 21(5), pp. 1117-1147

reflect a subjective understanding of the issues related to university-industry collaboration and, more importantly, because they influence the willingness to participate in collaborations with the private sector. In turn, this affects the success or failure of university technology-transfer policies (Davis, Larsen et al. 2009).

This paper explores the extent to which scientists' collaboration decisions are explained by individual evaluations of the expected benefits and costs of collaboration with industry, controlling for the institutional environment and for personal characteristics such as age, gender, tenure, and scientific field. We analyse survey data from 657 Italian researchers at three large universities, in 9 different scientific fields. Our analysis shows that access to financial and non-financial resources is the most important factor spurring academic researchers to increase their collaborations with industry. At the same time, access to resources appears to be an insignificant factor for promoting collaboration. The perception that collaboration will limit a researcher's freedom is one of the main factors hindering it. At the same time, and somewhat surprisingly, it appears that the possibility that private sponsors might claim ownership and limit the diffusion of research results does not significantly deter researchers' engagement in collaboration activities.

This paper makes two contributions to the literature. First, the analysis explicitly includes researchers with and without experience in collaboration and patenting activities. Recent work on academics' motivations has tended to focus on two forms of collaboration, namely academic entrepreneurship (Jain, George et al. 2009; Krabel and Mueller 2009) and academic patenting (Baldini, Grimaldi et al. 2007; Davis, Larsen et al. 2009). However, university patenting represents only a small fraction of the total knowledge transfer from academia to the private sector (Agrawal and Henderson 2002), and the phenomenon of university-industry interaction is much more varied (Debackere and Veugelers 2005). A focus on academic entrepreneurs or inventors may provide incomplete descriptions of researchers' attitudes towards engagement with industry. Engagement in collaborative activities (such as joint research projects, contract research, consultancy, personnel exchanges) is more frequent and more widespread across the population of academic researchers than patenting or entrepreneurship (D'Este and Patel 2007; Perkmann and Walsh 2007). Our work accounts for this wider population of collaborators. Second, unlike many of the existing analyses of university-industry collaboration, which are qualitative, this paper provides direct *quantitative* evidence that individual preferences shape researchers' choices about industry collaboration. Our analysis thus responds directly to some of the concerns cited in the literature on university-industry collaboration.

BENEFITS AND COSTS OF UNIVERSITY-INDUSTRY COLLABORATION

From both a policy perspective and an academic perspective, interest in university engagement with industry partners has grown considerably in recent years. This conversation would be considerably enhanced by a deeper understanding of why individual researchers collaborate (Rothaermel, Agung et al. 2007). The literature on the ‘entrepreneurial university’ tries to isolate and analyse the organizational features of universities that facilitate or hinder the commercialization of university inventions (Rothaermel, Agung et al. 2007). However, although some studies highlight the role of academic scientists as being extremely important in the commercialization of university inventions (Zucker and Darby 1996), little is known about the processes through which individual scientists choose to collaborate with industry. This is not limited to the field of academic entrepreneurship; it extends to the wider field of strategic management. As Felin and Foss (2005) point out, recent research on strategic organization has focused on structure, routines, capabilities, and other collective conceptualizations that obscure the critical role of individuals. Behind this approach is the often implicit assumption that individuals are homogenous (Henderson and Cockburn 1994; Dansereau, Yammarino et al. 1999). We argue, instead, that individuals deserve careful theoretical and empirical consideration (Felin and Foss 2005); after all, individuals are the antecedents to organizations and the collective phenomena observed within them. This argument becomes more compelling when we consider an organizational setting in which individuals enjoy great autonomy and freedom to choose their behaviour, as is the case in universities.

We assume that an individual’s decision to engage in a given activity follows a standard cost-benefit analysis. We assume also that an academic researcher’s utility from collaborating with industry depends on, among other things, the expected benefits of collaboration (e.g., access to resources, salary funding or augmentation, etc.) and its expected costs (i.e., loss of academic freedom, restrictions on open-science behaviour, etc.). Notwithstanding this simplistic approach to the construction of a researcher’s utility function, we do not assume that all individuals will behave in a similar fashion given a specific set of benefits and costs. We recognize that individuals are heterogeneous in terms of their characteristics, tastes, aversion to risk, and underlying motivations for conducting research, and, therefore, are likely to have different perceptions and evaluations of the benefits and costs of engaging with industry (Owen-Smith and Powell 2001). Moreover, these evaluations are particularly important for researchers who enjoy considerable freedom in their work

(Sauermann, Cohen et al. 2010). Scientists' evaluations are crucial because they reflect a subjective understanding of the issues related to university-industry collaboration and, even more importantly, because they influence the willingness to participate in collaboration activity with the private sector, which will affect the success or failure of university technology-transfer policies (Davis, Larsen et al. 2009).

The literature on academic entrepreneurship, and on university-industry relationships more generally, has sparked an active debate around the role and identity of universities and the evolution of their traditional missions (Rothaermel, Agung et al. 2007). Universities are increasingly seen as one of the engines of economic growth and are being asked to contribute to economic development and competitiveness (Feller 1990). Policy makers are putting emphasis on knowledge transfer and the commercialization of academic research. For example, most research projects funded by the European Commission require at least one industry partner, and this requirement is becoming the norm for government-funded research in many countries. This is being accompanied by the creation of new mechanisms to foster collaboration between universities and industry and to facilitate technology transfer: technology transfer offices (TTO) are becoming larger and more professional (Kirby 2006; Woolgar 2007), and more science parks are being created where universities and firms can meet and collaborate (Hall, Link et al. 2000; Adams, Chiang et al. 2001; Siegel, Westhead et al. 2003). New rules and regulations governing the conduct of research encourage academics to operate under intellectual property (IP) regimes that are similar in some respects to the regimes of private organizations; they include the 1980 Bayh-Dole Act in the U.S. and similar legislation in Europe (Mowery, Nelson et al. 2001; Nelson 2001; Mowery and Sampat 2005; Verspagen 2006). However, the academic system still retains certain characteristics that differentiate it from other knowledge-producing organizations. In exchange for adherence to the principles of an "open-science" community, scientists are granted freedom of inquiry and are rewarded with peer esteem, promotions, research grants, and scientific prizes. Academic scientists are free to establish new lines of research based on their perceptions of opportunities or on pure individual curiosity, and they benefit from a reward system based on the establishment of intellectual priority through publication (Stern 2004). These characteristics create tension between the traditional first and second missions of a university (teaching and research) and its new 'third mission' (Etzkowitz 1998) of social and economic development. This tension is apparent in academics' attitudes towards collaboration with industry (Lee 1996).

When universities start to engage actively in technology development, it may threaten the traditional norm of openness. Empirical evidence shows that a strong push for academic patenting may restricts communication among scientists and limit or promote delays in the publication of scientific papers and data (Blumenthal, Campbell et al. 1996; Campbell, Weissman et al. 2000; Louis, Jones et al. 2001; Campbell, Clarridge et al. 2002). In a study by Campbell et al. (2002), 20% of the scientists interviewed admitted they had withheld data and 75% believed that this phenomenon was reducing open communication in science and slowing the rate of scientific advancement. Withholding data violates the classical ethos of academic science and also conflicts with an intrinsic aspect of the reward systems in place in universities, which are based on the establishment of intellectual priority through publication (Stephan 1996; Stern 2004). Because publications are critical to academics' advancement in the university, academics will be deterred from collaborating when private research sponsors require publication delays (Thursby and Thursby 2002) or require that selected research results remain secret. Thus, we hypothesize that:

H1. The propensity of an academic to collaborate with industry will be negatively associated with her evaluation of the costs in terms of restrictions on the free circulation of knowledge and research results.

Critics of the growing involvement of universities in technology transfer activities argue that a more entrepreneurial university may aggravate the conflict between advancing knowledge and generating revenue (Rothaermel, Agung et al. 2007), affecting the long-term production of scientific knowledge and skewing public research agendas towards marketable research at the expenses of fundamental research (Lee 1996; Henderson, Jaffe et al. 1998; Nelson 2001; Verspagen 2006). Although it is widely recognized that academic research is characterized by individual scientists retaining decision rights about which projects to undertake and what methods to use to tackle them (Aghion, Dewatripont et al. 2008), only a few empirical studies explicitly address the unintended consequences of cooperative research and their impact on academic freedom. The few results that do exist do not provide conclusive evidence about the direction of this effect. Blumenthal et al.'s (1996) study of a life sciences faculty in the U.S. shows that academics that receive industry support are more likely to report that their choice of research topics is influenced by a project's commercial potential. Behrens and Gray (2001) focus on graduate students, a population that many believe is particularly susceptible to the unintended consequences discussed in the literature, but their results do not support claims that industry sponsorship negatively affects the student

experience and its outcomes. Despite the limited empirical evidence available, as Richard Nelson suggested, ‘the traditions of the scientific community are extremely strong where freedom to pursue research is concerned’ (1962, p.573). Thus, we hypothesize that:

H2. The propensity of an academic to engage with industry will be negatively associated with her evaluation of the costs in terms of the loss of academic freedom.

Despite these concerns about engaging with industry, there is a history of complementarity between university and industry research (Rosenberg and Nelson 1994), especially in the so-called Pasteur’s quadrant disciplines (Stokes 1997). For researchers in more applied science fields, such as engineering, practical problems do indeed provide powerful stimuli for the development of new ideas (Rosenberg 2002). There is a growing empirical literature that points to the complementary relationships between research productivity and commercial activity (Mansfield 1995; Zucker, Darby et al. 1998; Murray 2002); several authors show that scientists collaborating with industry develop closer contacts with researchers in companies and use this network as a source of ideas for new research projects of scientific importance (Mansfield 1995; Agrawal and Henderson 2002). Moreover, academic researchers collaborating with industry may have more opportunities to access state-of-the-art equipment, artefacts, and data that facilitate their projects than researchers who do not collaborate. Some resources are generally difficult to obtain within the university environment; for example, specific rare reagents used by biotechnology companies or ‘real-world’ data on manufacturing processes or the operation of engineering machinery (D’Este and Perkmann 2011). Additional benefits from industry cooperation include supplementing research money and securing funds for graduate students and researchers in the laboratory (Mansfield 1995; Murray 2002). Thus,

H3. The propensity of an academic to engage with industry will be positively associated with the expected benefits in terms of the additional resources collaboration makes available.

DATA AND METHODOLOGY

Data

The aim in this paper is to explore the extent to which the propensity to engage in collaboration with industry is explained by individual researchers’ evaluations of the expected benefits and costs of such collaboration, controlling for institutional environments

and for personal characteristics such as age, gender, tenure and scientific field. To this end, we exploit information from a survey administered to 2,163 researchers at three Italian large universities (University of Milan, Polytechnic of Milan, and University of Calabria) active in various scientific fields (Life Sciences, Civil Engineering, Process Engineering, System Engineering, Information Engineering, Industrial Engineering, Medical Sciences, Biology, and Chemistry). The questionnaire was administered electronically between February and April 2008. The choice of research setting was based on the following logic: first, the three universities represent three different kinds of institution. The University of Milan focuses on the basic science disciplines, the Polytechnic of Milan specializes in the engineering disciplines, and the University of Calabria covers both. Second, the first two institutions are located in the heavily industrialized area of Northern Italy, while the third is based in the less industrialized south of Italy, which is more focused on traditional production sectors. Third, the three universities are among the most active Italian universities in terms of involvement in technology transfer. They all have fairly large TTOs as measured by the number of permanent staff, patent applications, and spinoff companies, and they were among the original founders of *Netval* (the association of Italian TTOs). For all these reasons, we expect to find at least a minimum level of university-industry interaction at these institutions. In terms of the choice of scientific fields, we focused on researchers in departments more likely to have joint research projects with industrial partners (we therefore excluded social sciences and humanities departments).

The questionnaire was constructed based on previous work in the same field (Van Dierdonck, Debackere et al. 1990; Owen-Smith and Powell 2001; Baldini, Grimaldi et al. 2007). It consists of three parts. The first collects information on researchers' perceptions about collaboration with industry, the second investigates their opinions about various issues related to academic patenting, and the last enquires about interactions with the university TTO. We adopted a three-step procedure to develop and select the items to be included in the different sections of the questionnaire. First, we analysed two qualitative studies (Van Dierdonck, Debackere et al. 1990; Owen-Smith and Powell 2001) and one quantitative study about Italian academic inventors (Baldini, Grimaldi et al. 2007), from which we derived a set of possible items. In order to improve the response rate, we restricted the initial set of items through a review process guided by our knowledge of the literature on the benefits and costs of university-industry interaction. It should be noted that we do not use a previously validated set of items in our study. As there is no clear theory about university-industry relationships, there are no validated scales to employ in analyses. We collected items that, based on

previous studies, seemed relevant, but which are not necessarily connected. Finally, we ran a pilot to make sure that questions were phrased clearly and to reduce possible ambiguities. We asked five researchers from a university not included in the sample to complete the questionnaires in our presence, and to give us feedback on its clarity; we were also able to check the time needed to complete it. This pre-test phase did not highlight any major inconsistencies.

We collected a total of 731 completed questionnaires, achieving a response rate of 34%. For each respondent, we used the Ministry of University and Research's database on academic researchers to collect biographical information, such as gender, age, academic rank, and scientific field. For each respondent we also collected the number of publications in internationally refereed journals, using the ISI-Web of Science, the number of publications in basic and applied scientific journals, using the classification of ISI journals developed by CHI-Research (Hamilton 2003), and the number of EPO (European Patent Office) patents signed by the researcher with companies and with universities and public research organizations. We recognize that the CHI database may provide outdated information for some of the journals; however, it represents a readily available and straightforward classification of a large number of scientific journals, making it a useful source of information for the purpose of this research. We were left with 657 complete observations.

Dependent variables

In order to understand the determinants of the choice to engage in industry collaboration, we specify a model where the dependent variable is a categorical variable that measures the extent to which an academic collaborates with industry (COLLABORATION). The variable is defined as follows: 0 = no collaboration, 1 = infrequent collaboration, 2 = frequent collaboration, 3 = habitual collaboration.

We chose to ask the researchers about their collaboration activities using a categorical variable in order to decrease the non-response rate and response bias. Collaboration activities with private companies are subject to particularly ambiguous regulation in Italian universities: on the one hand, because academic researchers are full-time civil servants, their collaboration activities should be only research related, with private consultancies kept to a minimum; on the other hand, frequent budget cuts at the national level force academic researchers to source additional revenue to finance their research (and sometimes their basic salaries). Many researchers opt not to inform the central university administration about collaborations so that they can retain any supplementary research funds within their

departments. For these reasons, questions about the frequency of engagement with industry may be seen as sensitive. As Tourangeau and Smith (1996) state, ‘a question is sensitive if it raises concerns about disapproval or other consequences [...] for reporting truthfully, or if the question itself is seen as an invasion of privacy.’

The response to this question in our survey may be subject to different sources of bias. First, as discussed above, respondents may underreport collaboration activity out of fear of negative consequences. This problem may be exacerbated since the owners of the most sensitive information may be the least likely to report it. As pointed out in the literature, response bias is very likely to be caused by the respondents’ desire to present themselves in a favourable light (Catania 1999). Second, although the questionnaire was administered on-line and highlighted standard confidentiality clauses, respondents were aware that the survey was not anonymous (we retained researchers’ names in order to link them to additional sources of data). This likely influences possible response bias since it has been shown that the level of information revealed by a respondent is positively related to the level of privacy of the interview (Newman, Des Jarlais et al. 2002).

Independent variables

The group of independent variables includes measures of the benefits and costs of collaboration as evaluated by the researchers. Using factor analysis (principal-components factor method), we identified three factors related to those evaluations (SECRECY, FREEDOM, RESOURCES). Table 1 presents the results of the analysis.

Each of the three factors identified has strong resonance with previous work on university-industry collaboration. Researchers’ evaluations of the possible outcomes of collaboration activity shape their decisions to begin collaborating and the intensity of their interactions. Problems related to the diffusion of the results of research projects sponsored by industry (SECRECY) are often highlighted as an important drawback to university-industry relations: Blumenthal et al. (1996) and Campbell et al. (2000) report that scientists tend to withhold data as a result of their collaboration activities with industry. Although autonomy is considered a crucial feature of the university environment, problems related to the perceived loss of academic freedom and the shift towards short-term or applied research when collaborating with industry (FREEDOM) are rarely analysed in the empirical literature. The evidence is mixed: Behrens and Gray (2001) report no significant impact of industry funding on academic freedom, while Lee (1996) highlights that researchers are concerned about the impact of close university-industry cooperation, which is likely to interfere with academic

freedom (the freedom to pursue long-term, disinterested, fundamental research). Finally, several authors point to the numerous possible positive outcomes of collaboration with industry (RESOURCES): new ideas and learning possibilities (Lee 2000; Baldini, Grimaldi et al. 2007; D’Este and Perkmann 2011), increased status and prestige in the scientific community (Baldini, Grimaldi et al. 2007), job opportunities for students (Lee 2000; Ponomariov 2008), and access to resources and equipment (D’Este and Perkmann 2011).

The reliability of the factors is estimated using Cronbach’s Alpha measures, which demonstrate how well a set of items (or variables) measures a single one-dimensional latent construct (reliability coefficient for indexes). The Cronbach’s Alpha for each of the three factors is 0.7, which is widely accepted as a good reliability score. In order to construct the factors each variable is weighted proportionally to its involvement in the factor itself; the more involved a variable, the higher the weight. Variables not at all related to a given factor are weighted near zero. To determine the score for a case on a factor, then, the case's data on each variable is multiplied by the pattern weight for that variable. The sum of these weight-times-data products for all the variables yields the factor score.

Table 1: Factor analysis (rotation method: Orthogonal Varimax)

	<i>Factor 1: ‘RESOURCES’</i>	<i>Factor 2: ‘FREEDOM’</i>	<i>Factor 3: ‘SECRECY’</i>
Collaboration with industry generates new ideas for research	69*	-36	
Collaboration with industry makes instruments and infrastructures more easily available	72*		
Collaboration with industry increases researchers’ visibility	67*		
Collaboration with industry increases the funds for research	66*		
Collaboration with industry helps students to find a placement outside academia	63*		
Collaboration with industry endangers the mission of university of focusing on basic research		83*	
Collaboration with industry limits the choice of research topics		76*	
Industry activities are not interesting enough for an academic researcher		67*	
Industrial partners require secrecy over research results			85*
Industrial partners require the ownership of the research results			76*
Collaboration with industry limits or slows down the communication of research results in the scientific community		35	60*

*Notes: Printed values are multiplied by 100 and rounded to the nearest integer. Values greater than 0.35 are flagged with an *. Values less than 0.3 are not printed.*

Control variables

A first group of variables is related to researchers' individual characteristics. We included the researchers' age (AGE) and his or her position in the university system. All the researchers surveyed hold tenured positions: in Italy professors are civil servants, whose recruitment rules, duties, and wages are fixed by national laws. There are three levels: Assistant Professor (*Ricercatore universitario*---the reference group), Associate Professor (*Professore associato*), and Full Professor (*Professore ordinario*).⁶ Empirical evidence about the effect of age and career experience on the level of collaboration with industry is mixed: Bercovitz and Feldman (2008) find a negative effect of career on collaboration, while Link et al. (2007) and Ponomariov (2008) observe a positive effect of tenure on collaborative activity. A variable for researchers' gender (GENDER) is included in the regression: Link et al. (2007) find a positive effect of being male on collaboration with industry. We also take account of the possible influence of the researcher's scientific field through eight discipline dummies for *civil engineering*, *industrial engineering*, *information engineering*, *process engineering*, *pharmaceutical sciences*, *medicine*, *natural sciences* (biology and chemistry), and *general engineering*, which acts as the reference group. The literature highlights differences in collaborative behaviour between the physical and life sciences, and between basic and applied disciplines. Owen-Smith and Powell (2001) in their comparison of life sciences and physical sciences faculties, show that cultural norms across scientific fields may be critical for shaping faculty involvement in entrepreneurial activities. Kenney and Goe (2004) argue that academic researchers from the same scientific discipline have a set of common perceptions and practices that are likely to influence their degree of engagement in knowledge transfer activities. Moreover, the nature of some scientific disciplines tends to define the extent of the researcher's engagement in collaboration with industry. In more applied fields of science, such as engineering, collaboration is more likely (Rosenberg and Nelson 1994); among researchers working in the Pasteur's Quadrant disciplines (Stokes 1997), practical problems are a strong stimulus for the development of new ideas (Rosenberg 2002). Finally, we should consider that different scientific disciplines reflect different technological opportunities. This can be seen clearly in the pattern of academic patenting: in the U.S. in 1998, 41% of the academic patents registered at the U.S. Patent and Trademark

⁶ In Italy, university professors are civil servants and their careers are determined essentially by bureaucratic and automatic rules based on seniority. Mobility between academia and the commercial world is practically non-existent due to the formal structure of the system and because Italian academic institutes are often dominated by one particular professor and characterized by feudal-like research paths (Bruno and Orsenigo 2003).

Office were in biomedicine, a level consistent with patenting data for Europe and the EPO (Geuna and Nesta 2006).

A second group of variables is related to researchers' scientific productivity. The possible influence of the researchers' productivity and research orientation is accounted for in the regressions using the number of publications (PUBLICATIONS), the number of patents that list the researcher among the inventors (PATENTS), and the share of publications that appeared in applied journals (APPLIED). We collected this information up to and including 2006. Several authors (Blumenthal, Campbell et al. 1996; Gulbrandsen and Smeby 2005; Ponomariov 2008; Davis, Larsen et al. 2009) take account of the effect of researchers' productivity and research orientations on the propensity to collaborate with industry, but data are often at the university or department level and the evidence provided is mixed.

The last group of variables refers to the institutional level. We include dummy variables for the institution with which the researcher is affiliated: University of Milan 'Statale' (STATALE), Polytechnic of Milan (POLI), and University of Calabria (UNICAL), in order to take account of the universities' different research orientations. Descriptive statistics and a correlation matrix are presented in Tables 2, 3, and 4.

Table 2: Distribution of respondents over different dimensions

Faculty	Total frequency	Academic position	Total frequency
Pharmaceutical Science	10.0%	Full professor	26.1%
Engineering	8.7%	Associate professor	31.5%
Civil and Environmental Engineering	5.3%	Assistant Professor	36%
Industrial Engineering	9.6%	Emeritus	6.4%
Process Engineering	5.8%		
Systems Engineering	7.6%		
Information Engineering	8.9%		
Medical Sciences	31.3%		
Biology and Chemistry	12.7%		
University	Total frequency	Academic inventor	Total frequency
STATALE	48.2%	NO	92.2%
POLI	37.2%	YES	7.8%
UNICAL	14.6%		

Table 3: Descriptive statistics (chapter 3)

Variable	Mean	Std. Dev	Min	Max
Engagement with industry	1.76	1.07	0.00	3.00
Benefits	0.00	1.00	-4.09	1.96
Freedom	0.00	1.00	-2.50	2.57
Secrecy	0.00	1.00	-3.09	2.22
Share of applied publications	0.23	0.28	0.00	1.00
Gender (male=1)	0.71	0.46	0.00	1.00
Patents	0.31	1.78	0.00	31.00
Publications	29.94	46.34	0.00	416.00
Age	48.94	10.31	30.00	75.13

Table 4: Correlation matrix (chapter 3)

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
[1] Engagement with industry	1.00																			
[2] Benefits	0.13	1.00																		
[3] Freedom	-0.32	0.00	1.00																	
[4] Secrecy	0.02	0.00	0.00	1.00																
[5] Share of appl pubs	0.15	0.14	-0.04	-0.10	1.00															
[6] Gender	0.22	-0.02	-0.09	-0.03	0.19	1.00														
[7] Patents	0.14	0.03	-0.11	0.17	-0.02	0.08	1.00													
[8] Publications	0.01	-0.10	-0.06	0.06	0.13	-0.02	0.02	1.00												
[9] Age	-0.03	-0.01	-0.10	0.10	0.09	0.08	0.13	0.14	1.00											
[10] Full professor	0.08	-0.01	-0.12	0.05	0.10	0.23	0.06	0.22	0.54	1.00										
[11] Associate professor	0.02	-0.10	-0.08	-0.04	0.04	0.01	0.05	-0.04	0.08	-0.43	1.00									
[12] Pharmaceutical Science	-0.05	-0.01	0.01	0.09	-0.20	-0.24	-0.01	0.00	-0.03	-0.03	-0.01	1.00								
[13] Civil Engineering	-0.01	0.02	0.03	-0.08	0.02	0.04	-0.04	-0.06	0.03	0.04	-0.01	-0.09	1.00							
[14] Process engineering	0.15	-0.02	-0.07	0.10	0.08	0.10	0.18	-0.04	-0.03	0.05	-0.05	-0.10	-0.07	1.00						
[15] Systems engineering	0.10	0.00	-0.10	-0.03	-0.03	0.04	-0.04	0.00	-0.06	0.03	0.00	-0.10	-0.07	-0.08	1.00					
[16] Information Eng	0.13	-0.04	-0.04	-0.04	0.06	0.12	-0.01	-0.03	-0.05	0.04	0.03	-0.12	-0.07	-0.08	-0.09	1.00				
[17] Medicine	-0.11	0.03	-0.05	-0.12	0.23	-0.07	-0.06	0.16	0.14	-0.05	0.06	-0.22	-0.14	-0.16	-0.16	-0.18	1.00			
[18] Natural Science	-0.19	-0.04	0.11	0.20	-0.24	-0.12	0.07	0.09	0.09	0.01	-0.08	-0.16	-0.10	-0.12	-0.12	-0.13	-0.25	1.00		
[19] Statale	-0.20	-0.02	-0.04	0.11	-0.03	-0.26	-0.01	0.24	0.21	-0.05	0.02	0.26	-0.23	-0.27	-0.27	-0.30	0.60	0.28	1.00	
[20] Poli	0.28	0.01	-0.09	-0.06	0.09	0.24	0.04	-0.14	-0.13	0.06	0.00	-0.29	0.31	0.35	0.36	0.40	-0.45	-0.33	-0.75	1.00

We are aware of problems of common method bias caused by the fact that the same respondent provides the measure of the predictor and the criterion variable (Podsakoff, MacKenzie et al. 2003). However, we include several features to mitigate this problem. First, many of the questionnaire items were derived from different sources (there is no implicit theory linking them); second, they do not imply univocal social desirability. Also, our regressions include objective measures obtained from secondary sources (such as publication and patent data) and not directly from respondents. We explored the issue of non-response bias and as suggested by Armstrong and Overton (1977) and performed an analysis of response rates along different known dimensions (age, tenure, field, university, patenting experience, etc.) for both respondents and non-respondents. A Chi-square test shows that the sample population is not significantly different from the whole population. We also analysed whether there were differences in the study variables between early and late respondents⁷: respondents in later waves are assumed to have responded based on increased stimulus and, therefore, are expected to be more similar to non-respondents. We performed a t test of the three independent variables and found a statistically significant difference for secrecy between respondents and late respondents. As expected, late respondents were more concerned about confidentiality, and we can assume that such individuals would be less willing to respond to a survey. We are aware that this difference could bias the results of our regression and address this problem later by performing a robustness check.

Estimation

Given the categorical and ordinal nature of our dependent variable (COLLABORATION), we employ an ordered logistic regression. This model is equivalent to $j - 1$ binary regressions (where j is the number of levels of the dependent variable) with the critical assumption that the slope coefficients are identical across each regression (proportional odds assumption or parallel regression assumption). The ordered logistic model simultaneously estimates $j - 1$ multiple equations; since our dependent variable has four outcomes, we have three equations: (1) compares category 0 to 1, 2, 3; (2) compares categories 0, 1 to 2, 3; (3) compares categories 1, 2, 3 to 4 (Long and Freese 2006). In order to test the parallel regression assumption for each variable individually, we apply a Wald test by Brant (1990). If the test is statistically significant, this provides evidence of a violation of the hypothesis and indicates that the ordered logistic model may not be the most appropriate

⁷ Late respondents are the ones who answered after an email reminder was sent.

specification to model the propensity to collaborate. In this case the Brant test shows that the parallel regression assumption has been violated and, therefore, the ordered logistic is not an appropriate model. To overcome this problem, we use a generalized ordered logistic regression, which relaxes the assumption of parallel regression and allows the coefficients of the independent variables to change across multiple equations (Williams 2006). Since the Brant test shows that the parallel regression assumption is violated for two variables (RESOURCES and SECRECY), we use a generalized ordinal logistic model, in the parameterization proposed by Peterson and Harrel (1990) and Lall et al. (2002), called Unconstrained Partial Proportional Odds Model. In this parameterization, each variable has an associated beta coefficient. Also, each variable can have $K-1$ Gamma coefficients where K is equal to the number of categories for the dependent variable and the Gammas represent deviation from proportionality. If the Gammas for a variable are all zero (thus coefficients are equal across all levels of the regression), then the variable meets the parallel lines assumption.

RESULTS

Table 5 presents the baseline model (including only control variables) with COLLABORATION as the dependent variable and the percentage changes in odds for the same variables. As the parallel regression assumption is not violated for any of the control variables, estimating a generalized ordered logistic model is equivalent to estimating an ordered logistic model (all the Gammas are zero). First, we find a significant effect associated with gender, with males significantly more likely (64%) than females to collaborate with industry partners. This effect is consistent with previous research (Link, Siegel et al. 2007) and highlights that female academics may be disadvantaged (in terms of prestige or visibility) when they try to identify potential collaborators outside academia. Being a full professor has a positive and statistically significant effect on the level of engagement with industry (22%), while there is no statistical difference between the associate and assistant professor levels. Most collaborations are motivated by personal contacts, and more experienced researchers are likely to have larger networks to rely on to find potential partners in the private sector (Link, Siegel et al. 2007). Moreover, the marginal cost of collaboration is likely to be higher for more junior researchers since they are more affected by pressure to perform well and to publish (Thursby, Thursby et al. 2007). Age, however, has a negative and statistically significant effect: for every additional year, the propensity to collaborate declines by 2%. As observed by Bercovitz and Feldman (2008), this finding reflects a training effect: individuals

who were trained when universities' engagement with industry was less relevant or even discouraged (the age of the 'Ivory Tower') probably developed norms that make collaboration with private companies more problematic. We test for non-linearity by introducing the square term of age, but the coefficient associated with this term is not statistically significant. In line with the literature (Landry, Amara et al. 2006; Bozeman and Gaughan 2007; Arvanitis, Kubli et al. 2008; Ponomariov and Boardman 2008; Krabel and Mueller 2009; Sellenthin 2009), the share of past publications in applied journals and the number of patents listing the researcher as an inventor significantly and positively affect a researcher's propensity to collaborate with industry partners, although the total number of publications has no effect. Also, inclusion in two additional patents increases the odds of collaborating by almost 100%.

Turning to the scientific disciplines, we find a negative and significant effect on the propensity to collaborate with industry for civil engineering, medicine, and the natural sciences, with the biggest effect related to natural sciences (-66%). The result for medicine is perhaps surprising until we remember that we are comparing it with engineering, whose research results are likely to be closer to industrial application. Natural sciences, on the other hand, is the most basic discipline in our sample and, as expected, researchers in that domain are less likely to collaborate with industry. In fact, research shows that applied research fields, such as engineering, make collaboration or engagement in commercial activities more likely (Lee 1996; Landry, Amara et al. 2006; Arvanitis, Kubli et al. 2008). Researchers affiliated with disciplines in which the commercialization of scientific results is common, and is perceived as a signal of high-quality research, are also more likely to engage in entrepreneurial activities (Krabel and Mueller 2009). Finally, being affiliated with the Polytechnic of Milan or with the University of Milan has a clearly positive impact on the propensity to collaborate with industry. Researchers from the Politecnico are 173% more likely to collaborate with industry partners than researchers from the University of Calabria. This could be expected based on the more applied vocation of the former institution, the presence of a strong and efficient TTO, and its location in a highly industrialized region. Previous work highlights that collaboration and entrepreneurial activity are enhanced by the presence of formal support infrastructure and incentive mechanisms (Landry, Amara et al. 2006; Renault 2006; Yang, Chang et al. 2006; Sellenthin 2009). As an additional control, we examine the average amount of funds these universities receive from private companies for research (as observed in 2005-2008); the results are consistent with the specification, including the institution dummies.

Table 5: Ordinal Logit model: only control variables

VARIABLES (X)	Coefficients	Percentage changes in odds	
	Engagement with industry	For unit increase in X	For SD increase in X
Share of appl pubs	0.60* (0.289)	82.0	18.2
Gender	0.50** (0.175)	64.2	25.4
Patents	0.38*** (0.091)	46.5	96.9
Publications	0.00 (0.002)	0.1	3.3
Age	-0.02+ (0.010)	-1.9	-17.8
Full professor	0.44+ (0.254)	54.8	22.0
Associate Professor	0.22 (0.196)	24.2	10.5
Pharmaceutical Science	-0.43 (0.436)	-35.2	-13.4
Civil Engineering	-0.93* (0.392)	-60.6	-19.1
Process Engineering	0.13 (0.395)	13.9	3.4
System Engineering	-0.01 (0.388)	-1.5	-0.4
Information Engineering	-0.21 (0.361)	-18.6	-5.6
Medicine	-0.77+ (0.449)	-53.6	-28.4
Natural Science	-1.09* (0.424)	-66.4	-32.7
Statale	0.63+ (0.357)	88.0	37.1
Poli	1.00** (0.352)	173.2	62.7
Constant - cut 1	-1.68*** (0.496)		
Constant - cut 2	-0.62 (0.493)		
Constant - cut 3	1.01* (0.494)		
Observations	657		

*Notes: Standard errors in parentheses; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$, and marginal effects*

Table 6 shows the results of the regression analysis with the full set of variables using the generalized ordered logistic specification; Table 7 reports the marginal effects. Regression (1) contrasts COLLABORATION = 0 with COLLABORATION = 1, 2, 3; regression (2) contrasts COLLABORATION = 0, 1 with COLLABORATION = 2, 3 and regression (3) contrasts COLLABORATION = 0, 1, 2 with COLLABORATION = 3. The model suggests that access to financial and non-financial resources is an important factor spurring academic researchers to increase their collaboration with industry. In particular, the effect of getting access to these resources increases if the researcher is collaborating with industrial partners. If we consider regression (1), which we can assume represents the choice to embark on a collaborative project with a private firm, we observe that access to additional resources seems not to play a role in shaping the decision process. The explanation could be that researchers who have never been involved in such collaborative projects do not have a clear idea of their outcomes and may be more likely to avoid collaboration on principle. Hypothesis 3, therefore, is partially confirmed. The perception that collaboration would limit academic freedom is the greatest hindrance to it, which confirms Hypothesis 2.

When we look at the marginal effects, we see that individuals that are very concerned about the possible loss of research autonomy (keeping constant the other variables) are more likely to answer ‘never’ or ‘rarely’ to the question about collaboration (a small increase in FREEDOM makes respondents 8% more likely to collaborate – COLLABORATION = 0). Finally, the possibility that private sponsors might claim ownership of research results and limit their diffusion does not significantly affect the propensity of academic researchers to engage in collaborative activities, thereby rejecting Hypothesis 1. In particular, we observe a slightly significant positive effect in regression (1). This would mean that people who are worried about possible secrecy-related problems are more likely to start collaborating with industry. This result might seem surprising, but it must be remembered that regression (1) represents the choice to start a collaborative project with a private firm. This coefficient, therefore, may simply underline lack of information about diffusion-related practices in collaborative activities.

Table 6: Generalized Ordered Logistic Model, Unconstrained Partial Proportional Odds specification: all variables

VARIABLES	(1) 0 vs (1,2,3)	(2) (0,1) vs (2,3)	(3) (0,1,2) vs 3
Benefits	0.03 (0.109)	0.29** (0.093)	0.44*** (0.103)
Freedom	-0.58*** (0.082)	-0.58*** (0.082)	-0.58*** (0.082)
Secrecy	0.21+ (0.109)	0.12 (0.091)	-0.12 (0.100)
Share of applied publications	0.50+ (0.298)	0.50+ (0.298)	0.50+ (0.298)
Gender	0.43* (0.178)	0.43* (0.178)	0.43* (0.178)
Patents	0.33*** (0.097)	0.33*** (0.097)	0.33*** (0.097)
Publications	0.00 (0.002)	0.00 (0.002)	0.00 (0.002)
Age	-0.02+ (0.010)	-0.02+ (0.010)	-0.02+ (0.010)
Full professor	0.29 (0.260)	0.29 (0.260)	0.29 (0.260)
Associate Professor	0.13 (0.203)	0.13 (0.203)	0.13 (0.203)
Pharmaceutical Science	-0.24 (0.442)	-0.24 (0.442)	-0.24 (0.442)
Civil Engineering	-0.96* (0.405)	-0.96* (0.405)	-0.96* (0.405)
Process Engineering	0.03 (0.420)	0.03 (0.420)	0.03 (0.420)
System Engineering	-0.26 (0.398)	-0.26 (0.398)	-0.26 (0.398)
Information Engineering	-0.20 (0.377)	-0.20 (0.377)	-0.20 (0.377)
Medicine	-0.54 (0.456)	-0.54 (0.456)	-0.54 (0.456)
Natural Science	-0.78+ (0.433)	-0.78+ (0.433)	-0.78+ (0.433)
Statale	0.16 (0.370)	0.16 (0.370)	0.16 (0.370)
Poli	0.92* (0.360)	0.92* (0.360)	0.92* (0.360)
Constant	2.07*** (0.507)	0.95+ (0.502)	-0.83+ (0.502)
Observations	657	657	657

*Notes: Standard errors in parentheses; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$*

Table 7: Marginal effects

VARIABLES	0	1	2	3
Benefits	-0.00364 (0.0138)	-0.0502*** (0.0146)	-0.0190 (0.0185)	0.0728*** (0.0166)
Freedom	0.0737*** (0.0106)	0.0354*** (0.00543)	-0.0118*** (0.00435)	-0.0974*** (0.0131)
Secrecy	-0.0267* (0.0136)	0.00440 (0.0139)	0.0419** (0.0176)	-0.0196 (0.0167)
Share of applied publications	-0.0637* (0.0378)	-0.0306* (0.0182)	0.0102 (0.00710)	0.0841* (0.0496)
Gender	-0.0575*** (0.0211)	-0.0266** (0.0124)	0.0126*** (0.00365)	0.0715** (0.0314)
Patents	-0.0417*** (0.0125)	-0.0198*** (0.00585)	0.00655** (0.00315)	0.0550*** (0.0157)
Publications	-0.000161 (0.000227)	-7.74e-05 (0.000109)	2.57e-05 (3.72e-05)	0.000213 (0.000300)
Age	0.00237* (0.00128)	0.00114* (0.000618)	-0.000379 (0.000241)	-0.00314* (0.00169)
Full professor	-0.0351 (0.0296)	-0.0180 (0.0173)	0.00429* (0.00219)	0.0487 (0.0461)
Associate Professor	-0.0162 (0.0246)	-0.00800 (0.0129)	0.00237 (0.00274)	0.0219 (0.0349)
Pharmaceutical Science	0.0311 (0.0615)	0.0138 (0.0244)	-0.00637 (0.0162)	-0.0385 (0.0697)
Civil Engineering	0.146** (0.0719)	0.0417*** (0.00986)	-0.0480 (0.0327)	-0.140*** (0.0478)
Process Engineering	-0.00327 (0.0525)	-0.00159 (0.0259)	0.000500 (0.00762)	0.00437 (0.0707)
System Engineering	0.0355 (0.0565)	0.0149 (0.0206)	-0.00775 (0.0158)	-0.0426 (0.0614)
Information Engineering	0.0263 (0.0521)	0.0115 (0.0205)	-0.00538 (0.0132)	-0.0324 (0.0595)
Medicine	0.0719 (0.0684)	0.0314 (0.0228)	-0.0156 (0.0234)	-0.0877 (0.0679)
Natural Science	0.113 (0.0732)	0.0416** (0.0163)	-0.0350 (0.0320)	-0.119** (0.0571)
Statale	-0.0208 (0.0451)	-0.00960 (0.0225)	0.00326 (0.00501)	0.0271 (0.0627)
Poli	-0.108*** (0.0316)	-0.0653** (0.0278)	0.00749 (0.0158)	0.166** (0.0720)
Observations	657	657	657	657

Notes: Standard errors in parentheses; *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$

We performed several robustness checks to ensure the consistency of our results across different specifications.

To control for different attitudes between collaborators and non-collaborators, we performed a Heckman Ordered Logit (Greene 2008) where the selection equation distinguishes between researchers who collaborate with industry ($\text{COLLABORATION} > 0$) and researchers who do not ($\text{COLLABORATION} = 0$), while the second equation analyses the intensity of collaboration. As in the main specification, the choice of collaborating, as opposed to not collaborating, is not affected by the perception of increased resources; the other results are similarly unchanged. We divided the sample into early and late respondents to check whether different attitude towards secrecy-related issues was biasing the regression: the results are robust after the sample split. We performed several sample splits across different dimensions (position, discipline, and university of affiliation) and the main results were consistent across all specifications.

Finally, we investigate whether the non-significance of the coefficient of **SECRECY** could be connected to researchers' experience. Most work on this topic studies experienced collaborators (e.g., academic inventors) or researchers in the field of biomedicine, where commercial opportunities are particularly high. Our sample is composed of researchers with very different levels of experience in collaborating with industry or commercializing research, and who belong to scientific fields with different technology transfer opportunities. We try to explain whether the perception of secrecy-related problems is a function of the researchers' experience in technology transfer and research commercialization. To do so, we perform an ordinary least squares regression with **SECRECY** as the dependent variable and several measures of commercial experience as independent variables.

We use two specifications: the first includes a measure for degree of knowledge of the TTO in the researcher's university (measured on a 5-point Likert scale), a measure for degree of knowledge about IP regulations (measured on a 4-point Likert scale), and a measure for the degree of perceived relevance of IP protection in the researcher's scientific field (measured on a 4-point Likert scale). The second specification includes the same measure of knowledge of the TTO but uses a more restrictive measure of experience with IP, i.e., the number of patents on which the researcher is named as an inventor. We include the same controls at the individual, university, and discipline levels as in the main regression. The results show that researchers with higher levels of IP knowledge or experience (both specifications provide similar results in terms of the sign and magnitude of the coefficients)

are more concerned about secrecy: however, the magnitude of the effect is small. We discuss the implications of these results in the next section.

DISCUSSION AND IMPLICATIONS

Our analysis suggests that academics' engagement with industry is strongly informed by their evaluations of the expected benefits and costs. We identified three factors that can contribute to the decision to engage in collaborative activities with industrial partners: one positive (access to resources) and two negative (loss of academic freedom and concerns related to secrecy/diffusion). We found that increased collaboration is spurred by the potential to access/acquire new resources and hindered by perceptions that collaborating will reduce a researcher's autonomy. Interestingly, problems related to secrecy or the diffusion of research results do not appear to influence the decision to collaborate with industry.

These results resonate with the recent literature on university-industry interactions and with the wider discussion about how changes in the social and institutional context can influence or affect scientists' approach to their research (Elzinga 1997; Polanyi 2000 [1962]). Several scholars emphasize that the scientific community is characterized by the possibility of pursuing research freely and according to personal curiosity (Nelson 1962; Stern 2004; Aghion, Dewatripont et al. 2008). This academic freedom may be hindered if universities are encouraged (or in extreme cases, forced) to produce research results with commercial potential and to move away from basic research (Lee 1996; Henderson, Jaffe et al. 1998; Davis, Larsen et al. 2009). Our results are pertinent to these concerns and support them empirically; previous empirical evidence provides contrasting results (Blumenthal, Campbell et al. 1996; Behrens and Gray 2001).

The magnitude and direction of our findings on the effect of possible additional resources are largely in line with the previous literature on this topic. Collaborating with industry is clearly a way for academics to increase their resources for research (Lee 2000; Owen-Smith and Powell 2001; D'Este and Perkmann 2011), particularly as fiscal budgetary constraints have forced policy makers in many developed and developing countries to encourage universities to pursue more competitive funding sources (Geuna and Nesta 2006) and to devote more effort to commercializing technology with patents and licensing (Cohen, Nelson et al. 2003).

Our finding that the propensity to collaborate with industry partners is not significantly impacted by a potential increase in secrecy or by publication delays is more unexpected. The Mertonian ethos includes the element of communalism, which depicts

knowledge as a cumulative and collective good (Merton 1973): scientists are not only free to communicate their research results in the academic community, but these communications are part of the reward mechanism based on peer recognition, and a control mechanism based on peer review. Previous research highlights that working with industry can restrict communication within the scientific community (Welsh, Glenna et al. 2008), increase secrecy (Blumenthal, Campbell et al. 1996; Campbell, Weissman et al. 2000; Campbell, Clarridge et al. 2002) and limit or delay publication of research findings (Lee 2000; Thursby and Thursby 2002).

We investigated whether these results are driven by differences in the commercial experience of the researchers in our sample; our analysis shows that IP knowledge or experience contributes only marginally to the level of perception of secrecy-related costs. Our results for the impact of concerns related to secrecy and diffusion on the propensity to collaborate would seem to hold for the whole sample of researchers interviewed. However, we do not suggest that our results mean that academics are *not* concerned about possible limits on the diffusion of their work. Rather, we believe that our findings highlight the reinforcement of a trend already present in academia, and which possibly has been underpinned by more frequent collaboration with private companies and a stronger emphasis on the commercialization of university research.

The recent debate over how scientists disclose, share, and publish their work tends to overlook a strand of literature which highlights that ‘some academics engage in practices that lead to the privatization of knowledge’ (Stephan 1996), p. 1208), even outside the context of research commercialization or collaboration with industry. Several authors point out that many scientists engage in secretive behaviours (Hagstrom 1974; Sullivan 1975; Ziman 1996; Ravetz 1999) because they are concerned about others using the results of their discoveries; these concerns are becoming greater as advancements in information technology make data collection and manipulation less costly and reproduction much easier (Eisenberg 2006). Moreover, new rules and regulations adopted to foster technology transfer are encouraging academics to operate in an IP regime more similar to that of a private company (e.g., patenting activity as a requirement for career advancement). These policies are increasing the likelihood that academics will engage in secretive behaviours, thereby shifting the predominant values of academia towards the values of private science. It is important to recognize that the Mertonian ethos does not represent the only possible behaviour for university researchers but, in line with the sociological literature of professions, it should rather be seen as a group of morally regulated role expectations for members of academia

(Goode 1957; Wilensky 1964). Numerous sociologists of science have questioned the validity of Merton's norms ruling academic science (Kaplan 1964; Cotgrove and Box 1970; Barnes 1971): however, as observed by Shapin (2008), the Mertonian theory of academic values emerged in a period when academic social science was trying to establish itself as a scientific discipline by proposing theories of great predictive power. Given the preparadigmatic stage of literature in the area of university-industry interactions (Rothaermel, Agung et al. 2007), researchers have employed theories from different fields in order to analyse and make sense of the phenomenon. Merton's original conceptualization of the normative structure of science has largely been used in this area of research as a starting point to define some common theoretical rules governing a group of heterogeneous individuals and it is in this light that we have interpreted the results of our analysis.

From a policy perspective, our study points to several areas for possible action. First, it seems clear that there is a need to tailor policies for university-industry collaboration to the specific characteristics of researchers operating in different scientific fields, who pursue projects of very different natures. One-size-fits-all policies do not account for these differences and may create incentive systems that are neither appropriate nor effective.

Second, our findings suggest that the expected benefits from collaboration are not clearly perceived by all researchers: academics who are not already involved in industry collaborations fail to recognize the potential opportunities of engaging with industry. University administrations and TTOs should try to raise awareness about the resources researchers can obtain from collaborations; even when resources are scarce, TTOs should widen their field in order to work with academics not yet engaged in collaborative or commercialization activities.

Third, as pointed out by several scholars (Nelson 1962; Stern 2004; Aghion, Dewatripont et al. 2008), the scientific community operating in academia is motivated by the freedom to choose their own research and research methods. This is a distinguishing feature of the university environment. In order to maintain this feature and to provide an efficient balance between basic research, oriented to the long term, and more applied research, oriented to the short term, it will be necessary to have clear norms to rule the relationships between university and industry in terms of engagement in collaborative research projects. To protect the university mission to provide knowledge valuable for the whole society, university administrations and governments (which are still the major funders of academic research) should formulate regulations that ensure academic independence and research autonomy, even when funding is from private sources.

For these hypothetical regulations to be truly effective, these efforts should be coordinated not only at the local level but also on a global scale. In a largely interconnected world, and in order to promote the mobility of researchers and their collaboration activities, it will be important for researchers to be able to pursue their research agendas in the same ways in different countries. It is the case, for example, that when intellectual property regimes change across countries (as in the case of the professor's privilege), it may hinder collaboration between academics and companies in different geographic areas by increasing the uncertainty around the ownership of the research results.

Finally, we need to be more aware of the shift towards secrecy-based models of university research. This shift, already present in the scientific community, appears to be increasing due to recent policies designed to foster technology transfer and by the increasing professionalization of TTOs. The result is that the traditional norms of openness and communalism governing academia have been partially abandoned. Researchers are so embedded in this new model that they do not express a particular concern about the restrictions on communication and diffusion that may result from engaging with industry. Policy makers need to be conscious of this issue: if the academic incentive system is accommodating deviations from the traditional scientific norms of openness (Azoulay, Ding et al. 2009), the equilibrium between the two systems of public and private science may be completely upset (Dasgupta and David 1994), endangering and fundamentally altering the societal role of public research (Nelson 2001).

LIMITATIONS AND FUTURE RESEARCH

Our paper has some limitations that provide avenues for future research. On the empirical side, we cannot observe differences in behaviour across different types of university-industry collaborations. We are aware that the phenomenon of university-industry interaction is varied and includes collaborative research, contract research and consulting, development of IP Rights, involvement in graduate education and staff training, and research staff exchanges. However, because our interest is academics' general attitudes towards university-industry interaction, we believe our findings provide valuable insights into the mechanisms underlying academics' propensity to collaborate. Future research could unpack the different collaborative activities that academics engage in and explore whether the evaluation of expected benefits and costs is different for different kinds of collaboration.

From a theoretical perspective, our microeconomic approach to university-industry collaboration is only one of several potentially relevant theoretical lenses. In particular, if we

consider the benefits and costs we discussed as proxies for individual motivations or attitudes, there are rich organizational behaviour, organizational theory, and industrial organizational psychology literatures that investigate how attitudes influence behaviours. While our economic approach is not a substitute for these theories, it does complement them. If we consider, for example, one of the most widely used theories explaining how behaviours are formed, Ajzen's theory of planned behaviour (Ajzen 1991), we can treat our benefits-costs analysis as a reduced version of that model: we analysed how attitudes drive behaviours. We are certainly not suggesting that social norms and perceived controls are not relevant to the formation of behaviours. However, given that attitudes are crucial drivers of intentions and, consequently, of behaviours (Armitage and Christian 2003), we think our analysis is both relevant and reliable.

Because we measure behaviours directly, we are not able to test the mediation effect of intentions on behaviours. Again, in this specific context, we are confident about the robustness of our results since the behaviours we observe present no major barriers or have major uncertainties related to them. Models examining the researcher's decision to engage with industry would undoubtedly be enriched by an analysis of the impact of perceived control and social norms. In particular, research is beginning to analyse the effect of the social environment and peer pressure on academics' decision to disclose inventions or start companies (Stuart and Ding 2006; Bercovitz and Feldman 2008).

Our analysis is also partially consistent with Vroom's expectancy theory (Vroom 1964). This theory posits that an individual will choose certain behaviour based on the expectation of the outcome of that behaviour. In particular, this theory speaks directly to the formation of a motivation to pursue certain behaviour. Motivation is a product of an individual's expectation that a certain effort will lead to a certain type of performance, that this type of performance will be instrumental for achieving a certain result, and that the result is desirable. According to Vroom's theory, individuals deciding among behavioural options select the option with the greatest motivational force. This is in line with the mechanisms of choice dictated by the benefit-cost analysis we employ. Moreover, consistent with expectancy theory, we analyse academics' perceptions about the outcomes of a specific behaviour, namely collaboration with industry. However, as with the case of Ajzen's theory of planned behaviour, we are not able to control for what Vroom calls instrumentally (that is, the belief that an individual will receive a positive outcome if the performance expectations are met), as we are not able to single out the 'rules of the game' that govern the relationship between collaboration with industry and an academic career.

Another avenue for future research is to analyse how these attitudes are formed and why. This kind of analysis is not possible in the economic framework our paper employs. However, understanding the antecedents to academics' attitudes to industry could greatly improve the design of policies used to foster technology transfer while balancing commercial efforts with the diffusion of knowledge in society.

Another limitation of our study regards our inability to make inferences about the directionality of the effects observed. Given our research design, it is not possible to determine for sure the temporal precedence between the dependent variable and the predictors. It is indeed possible that collaboration experiences have determined academics' evaluation of benefits and costs of collaborating with industry. For these reasons, we make claims about positive and negative associations rather than claiming causal mechanisms. Future research should address this problem by using longitudinal panel data studies, as they can identify more precisely the temporal link between perceptions and subsequent behavioural choices, which cross-sectional data cannot distinguish.

Finally, our analysis suffers from a shared problem among studies of university-industry interactions in that it is limited to a single period of time and a single country. While we believe the universities analysed are representative of the higher education sector in Italy, we cannot generalize our claims to other countries presenting very different university institutional systems. This issue affects a large part of research on university-industry relationship: in terms of the role of national policies, comparative empirical evidence is particularly limited. Most existing studies also focus on the U.S., the U.K. or other European countries (Spain, Germany, Sweden) while largely ignoring Asia, South America, and other non-Western nations. Indeed, in advanced, industrialized countries the differences are not very manifest: bilateral comparisons of the U.K. and Germany (Princen 1992), Germany and the U.S. (Peredo and Chrisman 2004), and Sweden and Ireland (Klofsten and Jones-Evans 2000) reveal no major discrepancies in the determinants of academic engagement. However, Lee (1998) has observed that the increase in collaboration activities between universities and industry is tightly linked to the career system in place in the U.S.; namely, where promotion is determined by scientific productivity, which is fostered in turn by access to research funds, academics find an incentive to engage with private companies. This model is largely replicated in the U.K. but may be less stringent in other countries, such as Italy, where funding mechanisms follow a different pattern or where the academic system is more centralized (Princen 1992).

We still largely ignore how frequently, and in which form, these activities take place in developing countries, where, on the one hand, governments are highly constrained in terms of the availability of research funds, and, on the other hand, the private sector may be discouraged from collaborating with the public sector because appropriability mechanisms are difficult to enforce. These issues open up important avenues for future research to get a better understanding of the collaboration mechanisms in place in less developed countries and of how the interaction between universities and private companies may enhance technology transfer and economic development generally. This would also help us understand what university-conducted research might look like if governments continue to reduce their financial support for public science. Without adequate public funding, researchers may be forced to compete to acquire a greater proportion of their resources from private sources.

CHAPTER SUMMARY

This chapter analyses the impact of scientists' evaluation of the benefits and costs of collaboration on the intensity of their engagement with industry. Exploiting information derived from a survey administered to researchers in three large Italian universities, this chapter shows that access to financial and non-financial resources are the most important factors spurring academic researchers to increase collaboration with industry. The perception that collaboration will limit a researcher's freedom is one of the main factors hindering it. At the same time it appears that the possibility that private sponsors might claim ownership and limit the diffusion of research results does not significantly deter researchers' engagement in collaboration activities. This work seeks to make two contributions to the literature. First, the analysis explicitly includes researchers with and without experience in collaboration and patenting activities. This is important because, since university patenting represents only a small fraction of the total knowledge transfer from academia to the private sector, a focus on academic entrepreneurs or inventors may provide incomplete descriptions of researchers' attitudes towards engagement with industry. Second, while many existing analyses of university-industry collaboration are qualitative; this chapter provides direct quantitative evidence that individual preferences shape researchers' choices about industry collaboration.

CHAPTER 5 - THE EFFECT OF SELF-MONITORING ON ACADEMICS' ENGAGEMENT WITH INDUSTRY

πόλλ' οἶδ' ἀλώπηξ, ἀλλ' ἐχῖνος ἐν μέγα
(The fox knows many things, but the hedgehog knows one big thing)
Archilochus⁸

INTRODUCTION

In his seminal work on the behavioural patterns of scientists, Merton (1969) states that James Watson's personal account of the discovery of the DNA was destined to be a marker in the history of scientists' behaviour. The public was struck by the revelation that scientists were human after all – perhaps too human, since they were portrayed by their fellow scientist, Watson, as displaying overly human characteristics of jealousy, stupidity, competitiveness and ambition. A closer look at the history of science shows that revelations of this sort abound. From the numerous accounts of Newton's obsessive need to establish his scientific priority against Leibniz in the invention of calculus, to anecdotes about Cavendish's pathological shyness, which meant he could communicate with his female servants only through written notes. So, scientists are characterized by very human traits and driven by similar motives to non-scientists.

Since the publication of Merton's article, social studies of science moved away from the myth of scientists as over-rational, objective and methodical individuals and the focus now is on systematically analysing scientists' personal attributes and how they affect their behaviours. These efforts, however, tend to concentrate on scientists' performance of scientific research, and only a few works include other activities researchers engage in.

Since the 1980s, universities have had pressure on them to contribute to national economic development and growth (Feller 1990). Alongside the traditional missions of teaching and research, a 'third mission' has emerged (Etzkowitz, Webster et al. 2000). Universities are becoming more entrepreneurial and are asking their researchers to be active in knowledge transfer and technology commercialization. This new set of activities, however, may not be embraced in the same way by all academics, even among those working in the

⁸ Frag. 201, in M.L.West (ed.), *Iambi et Elegi Greci*, vol.1 (Oxford, 1971)

same institution. The literature shows that individuals' alignment with universities' third mission depends on the incentives and the support mechanisms in place (Owen-Smith and Powell 2001), and also more importantly, on the characteristics of individual researchers (Klofsten and Jones-Evans 2000). Besides demographic elements and characteristics related to scientific productivity, scholars have started to analyse the impact of psychological characteristics on the willingness of academics to participate in academic entrepreneurship (Jain, George et al. 2009; Clarysse, Tartari et al. 2011).

In this paper I seek to expand analysis of the role of individuals' psychological characteristics in encouraging academics to collaborate with industry, focusing on the specific trait of self-monitoring. Self-monitoring is the individual's active construction of the public self to achieve social ends (Gangestad and Snyder 2000). This concept is interesting in the context of university-industry interaction because it relates to how individuals react when faced with different (and ambiguous) tasks and environments, as in the case of university researchers engaging in collaborative activities with private firms.

I use data on a large-scale sample of UK academic researchers working in the physical and engineering sciences. I combine data from multiple sources, including a survey, the records of the UK's largest research council and other public records. First, I explore the effect of self-monitoring on individual behaviour and then extend the analysis to understand the contingencies that affect this relationship. My results suggest that high self-monitoring academics tend to engage more with industry than their low self-monitoring colleagues. However, certain individual and environmental characteristics have the potential to mitigate this effect. In particular, the influence of self-monitoring is lower for academics whose visibility outside the university is high or those driven by extrinsic motivations. Moreover, when the environment is especially favourable to collaboration with industry, high levels of self-monitoring are less relevant for determining individual engagement with private companies.

THE PSYCHOLOGY OF SCIENCE

Compared to research on other occupations, there is a relative lack of work on the psychological attributes of scientists. Mahoney (1979, p.349) states that towards the end of the 1970s 'in terms of behaviour patterns, affect, and even some intellectual matters, we know more about alcoholics, Christians, and criminals than we do about the psychology of the scientist'. Research in this area has increased since that time but, except for the work of Feist (1998; 2006), it has remained fragmented. In other disciplines, such as philosophy,

history and sociology, the origins of science, and the development of scientific processes and values have been investigated. However, as stated by Feist (2006, p. x), 'a complete understanding of scientific thought and behaviour requires a psychological perspective'. Study of the psychology of science should be aimed at explaining how scientific thought and behaviour are the outcomes of a person's unique personality traits and social influences.

Science is often associated with a set of norms, values and rule of behaviour which positions it somewhat apart from other realms of human endeavour. It is believed that the scientific community is ruled by norms of universalism, disinterestedness, originality, organized scepticism, communalism and conviction that the discoveries generated through publicly funded research should be placed in the public domain (Merton 1973). This set of norms determines the rules of conduct of scientists and, in exchange for adherence to these principles, researchers are granted freedom of enquiry and are rewarded with peer esteem, promotions, research grants and scientific prizes. This social structure and historical recollections of the lives of former great scientists have contributed to creating an image of the 'ideal' scientist as objective, rational, open-minded, of utmost integrity and intelligence, and willing to share research results with the scientific community. Indeed, as Knickerbocker (Knickerbocker 1927, p. vii) suggests, 'the history of science is as inspiring in its human values as are the legends of the saints'.

Archival data and empirical research have challenged most of these absolute characteristics (Kaplan 1964; Cotgrove and Box 1970; Barnes 1971). Scientists' perceptions of reality, far from being completely objective, are influenced by their theoretical expectations (Kuhn 1962; Elzinga 1997). Several eminent scientists have displayed dogmatic faith in their theories, even in the face of contradictory data (Weimer 1979). Albert Einstein said that he would have rejected the data before he would have rejected his theory of relativity. Far from being neutral about their investigations, scientists derive much of their motivation and professional satisfaction from their emotional involvement in their work. This is particularly relevant in the scientific profession where initiative, persistence and endurance seem to be as (if not more) important than intelligence in determining scientific performance (Zuckerman 1970; Reilly 1976). The rules of behaviour in science remain very relevant as the pursuit of a career in research involves long training and socialization processes through which academic norms become inextricably linked to researchers' identity roles (Van Maanen and Schein 1977; Jain, George et al. 2009).

In recognizing the human nature of scientists, the literature proposes a set of characteristics, which, on average, differentiate scientists from non-scientists. Scientists have

been observed to be more introverted than individuals in other occupations (Wilson and Jackson 1994; Feist 1998). Scientific work requires inductive and deductive reasoning, creative thinking and reflection - activities best performed alone, without the distractions of interacting with other people, which produces the tendency for scientists to be less sociable, gregarious and expressive than people in other professions. This reasoning, based on logic and facts, makes rational decision making an important feature of the scientist: in his meta-analysis Feist (1998) shows that scientists score higher than non-scientists on scales measuring tough-mindedness. On the other hand, given the uncertain nature of research, scientists also appear to be more inclined towards innovative thinking, more open-minded and more non-conformist (Feist 1998; Lounsbury, Foster et al. 2012). As these characteristics are part of personality, and traits and personality are fairly stable over time, it is possible to assume that individuals do not manifest these features because of their profession, but rather that they are rather selected into the specific job because of these characteristics.

ACADEMIC ENGAGEMENT AND SELF-MONITORING

Researchers in universities traditionally performed the dual role of education and research. Since the Second World War, we have observed increased professionalization of research in academia, characterized by intense competition between scientists on the one side and extreme specialization of skills on the other (Ben-David 1960; Ben-David 1971). This 'modern competitive science' has resulted in changes to some of the crucial characteristics of academic research: because of specialization, teams have become increasingly important; because of the decline in public funding, scientists in public organizations are being compelled to augment their research budgets by funding from other sources.

This shift has become especially marked since the 1980s, and we have witnessed increased pressures on universities to act as engines of economic growth (Feller 1990) and the subsequent institutionalization of academic entrepreneurship and commercialization of university research (Geuna and Muscio 2009). Academic researchers increasingly are expected to interact with industry; however, as university career systems continue to be dominated by the old paradigm of exclusively rewarding scientific productivity expressed as published papers, scientists' training seldom provides the skills required to collaborate with private companies and, for some scientists, the logics and *modus operandi* of industry can conflict with their own values of freedom of enquiry, openness and dissemination.

Researchers who engage in technology transfer or in entrepreneurial activities need to acquire a new set of often unfamiliar skills. While increased team size in science means that

academics are often required to manage large laboratories, collaboration with industry entails new issues related to the coordination of complex projects involving different stakeholders, and mediation between different working cultures and the establishment of fruitful dialogue. Much managerial work involves communicating with others (Gronn 1983), performing a variety of different roles (Mintzberg 1973) and relating to the needs of large numbers of different people (Kotter 1982). When collaborating with firms, academics need to bridge across two domains and adapt to the logic that prevails in industry. They need to be proactive in looking for possible partners and must have the skills to manage and negotiate projects involving multiple actors. These activities may require different personal characteristics from those usually associated with the scientific profession. As highlighted in the previous section, scientists tend to be more introverted, reflective, tough-minded and unsociable than non-scientists. On the other hand, collaboration may require skills closer to those possessed by successful managers, who tend to be extroverted, comfortable with team working and able to relate to different audiences (Barrick and Mount 1991).

Performance in the work environment undoubtedly is affected by many personality variables (Barrick and Mount 1991): among these, self-monitoring theory provides compelling arguments for linking individual differences in self-monitoring with a range of job outcomes relevant in the context of university-industry collaboration (Caldwell and O'Reilly 1982; Baron 1989; Deluga 1991; Kilduff 1992; Jenkins 1993; Kilduff and Day 1994). Self-monitoring is the individual's active construction of the public self to achieve social ends: according to this theory, individuals differ in the extent to which they are willing and able to monitor and control their self-expression in social situations (Gangestad and Snyder 2000). In social situations, high self-monitoring individuals question: 'who does this situation want me to be and how can I be that person?', while low self-monitoring individuals ask 'who am I and how can I be me in this situation?' (Mehra, Kilduff et al. 2001). Following Sir Isaiah Berlin's famous metaphor (Berlin 1953), high self-monitors are like foxes, pursuing many different objectives and presenting the right image to the right audience, while low self-monitors are like hedgehogs, relating everything to a single central vision and being always true to themselves. An interesting characteristic of self-monitoring is that it seems to remain constant over time: as Jenkins (1993, p.84) notes 'research suggests that self-monitoring is a stable personality trait throughout one's lifespan'. Support for this claim comes from different sources: first of all, observations on monozygotic and dizygotic twins show that the latent causal variable corresponding to self-monitoring has a biological basis

(Gangestad and Snyder 1985; Snyder and Gangestad 1986). Additional support comes from studies that test the construct over longer periods of time (Snyder 1987).

High self-monitoring individuals show a desire to project positive images of themselves in order to impress others and, therefore, are motivated to pursue behaviours that will help them to be accepted or to gain status (Gangestad and Snyder 2000; Turnley and Bolino 2001). On the other hand, low self-monitoring individuals behave in ways that are consistent with their core values and beliefs, insisting on being themselves despite social expectations (Gangestad and Snyder 2000). As a consequence of their social ambition, high self-monitors tend to perform better than low self-monitors in boundary-spanning activities that require individuals to be sensitive to different social cues (Caldwell and O'Reilly 1982).

Several studies analyse the impact of self-monitoring in the workplace. High self-monitors are more at ease in social situations and, therefore, are more likely to be employed in management or sales positions (Day and Kilduff 2003). They seek prestige and, as a consequence, are less well represented in lower-level jobs (Kilduff and Day 1994; Day and Kilduff 2003) and tend to get more promotions (Kilduff and Day 1994). Since they perform well in boundary-spanning roles and are socially ambitious, they are more likely to occupy leadership positions (Zaccaro, Foti et al. 1991) and other central positions in organizations (Mehra, Kilduff et al. 2001).

In the context of university-industry collaboration, self-monitoring theory provides several elements that may contribute to explaining individual differences in engagement behaviours. High self-monitoring individuals rely more on social cues from others to guide their behaviour than on their own inner attitudes and emotions and, therefore, are more likely than low self-monitors to resolve conflicts through collaboration and compromise (Baron 1989) and to perform well in boundary-spanning tasks (Caldwell and O'Reilly 1982). This is an important characteristic for academics who want to collaborate with firms because they must strike a balance between their own values and priorities and the prevalent industry logic. Because they are more sensitive to the external environment, high self-monitoring academics may be able to frame problems so that they are more appealing to different audiences. Low self-monitors, on the other hand, are more interested in self-validation and largely lack the skills required for social interactions: it is more difficult for them to find potential partners for collaboration and to establish connections. Associating with high-profile companies may help academics to improve their images - both inside and outside of academia: since high self-monitors are socially ambitious, they may proactively seek industry partners that are not in their personal network of contacts. In addition, engaging with industry involves not only

dealing with industry partners, but also with the university bureaucracy. Because high self-monitors are more motivated to engage in behaviours that will help them to be accepted or to gain status (Gangestad and Snyder 2000; Turnley and Bolino 2001) and, at the same time, are more able to adapt to the feedback they receive from the situation they are in, they may have a transactional advantage compared to their low self-monitoring colleagues, in dealing with their universities' regulations and internal politics. Thus,

Hypothesis 1: The position of a researcher on the self-monitoring scale is positively related to his/her individual engagement with industry.

Having established that self-monitoring exerts a significant influence on academics' propensity to work with industry, we need to investigate whether there are individual or environmental characteristics that can attenuate this relationship.

The effects of hierarchies in academia have been investigated by sociologists in the context of their role in generating and reproducing inequality in social outcomes. This process is caused by the fact that an actor's status is often used as a critical lens through which his/her quality is judged. Individual status is often amplified by specific designations, such as those associated with prestigious prizes or affiliations, creating sudden breaking points in an otherwise smooth quality distribution (Azoulay, Stuart et al. 2011).

The role of scientific status in university-industry collaboration, therefore, is particular important for two reasons. First, when firms are looking for collaborators, they will look for high-quality researchers capable of delivering good quality results. In some cases, firms may be able to identify the right expert, but often they will need to rely on some measure of reputation in order to guide their search for potential collaborators. It is easier for high-status scientists to make contact with external organizations that require their scientific expertise and want to engage in collaborative activities, as the companies involved can infer the academic's scientific quality from his/her status in the field. Second, the status some scientists acquire in the academic system can generate benefits within both the confined professional community of academia and in other fields. For instance, the annual Nobel Prizes are covered by the mainstream media and the cultural capital of Nobel Prize winners is recognized beyond their professional communities.

Thanks to their reputation, high-status academics have access to a large pool of potential partners: because a large share of academic engagement is initiated based on personal contacts (Louis, Blumenthal et al. 1989; Van Dierdonck, Debackere et al. 1990), the number

and reach of the scientist's personal connections are crucial for determining his/her collaboration activities. Moreover, since high profile academics are more visible than their colleagues, they will be more likely to be invited by firms to collaborate even without any proactive seeking of engagement opportunities. This privileged position makes other personal characteristics less relevant in determining the researcher's collaborative behaviours. High-status researchers do not need to actively see out potential partners; therefore, they do not need characteristics such as extroversion and expressiveness, which facilitate contact formation and boundary spanning. For this reason, it is less necessary for high-status academics to be high self-monitors in order to collaborate with industry. On the other hand, an excellent reputation can act as a substitute for those personal characteristics useful for collaborations that low self-monitoring individuals lack. As prestigious academics are very visible even outside academia, it is easier to engage with external actors even for low self-monitors. Thus

Hypothesis 2: The positive relationship between the position of a researcher on the self-monitoring scale and his/her individual engagement with industry will be less pronounced for high status scientists

Understanding individuals' motives to engage in a certain task is important because they are correlated to task performance (Cockburn, Henderson et al. 1999; Prendergast 1999). Motives can be defined as individuals' preferences for the benefits that can be derived from engaging in a certain activity (Sauermann and Cohen 2010). The psychology literature categorizes motivational factors as intrinsic and extrinsic motives (Amabile 1996; Ryan and Deci 2000). Individuals are intrinsically motivated if they seek benefits that originate within themselves and the task they are performing; they are extrinsically motivated if they value the benefits that are provided by an external entity, such as the market or a superior. Extrinsic benefits do not derive directly from engaging in an activity, they are indirect outcomes and include monetary or other tangible rewards, such as prestige.

This categorization of motives has been extensively employed in analyses of scientists' motivations (Stephan and Levin 1992; Katz 2004; Giuri, Mariani et al. 2007). Intrinsic motivation has long been associated with scientific work (Hall and Mansfield 1975); however, we cannot ignore that in the scientific reward structure financial remuneration is central. The motivation to be successful in winner-takes-all contests in science can stem from two different (but not mutually exclusive) forces: scientists may want to solve a particular

problem because of the intrinsic utility they derive from solving puzzles, alternatively they may be seeking recognition and the associated financial rewards. Academics' income streams can be greatly enhanced by technology transfer and commercialization activities (Stephan and Everhart 1998). Therefore, if academic researchers put high value on extrinsic benefits in their job, they will be more likely to seek them through engagement in collaboration with private companies. Moreover, researchers working in academia may be motivated by reasons which are not directly related to research. Academics who progress through the university's administrative hierarchy may be seeking status and prestige: the dean of a university enjoys high visibility and a recognition that are independent of scientific merit.

As already highlighted, high self-monitoring academics may engage with industry for a variety of reasons. For example, if they are socially ambitious and keen to gain prestige, they may try to associate with high-profile companies to improve their image both inside and outside academia. Since their actions are often directed towards impressing others, they may engage in behaviours considered appropriate in their environment, independent of their personal assessment of the value of such behaviours. Low self-monitoring academics, on the other hand, tend to be 'true to themselves' and to behave in a fashion consistent with their core values and beliefs. If a low self-monitoring researcher is extrinsically motivated, it means that she/he will actively look for extrinsic benefits (such as financial remuneration and prestige) in order to remain faithful to his/her personality and behaviours. This means that highly extrinsically motivated individuals will seek collaboration with industry independent of any personal characteristics that might facilitate this relationship. At the same time, self-monitoring will differentiate individuals who are not extrinsically motivated. Low self-monitoring scientists who are not driven by extrinsic motives will tend not to engage with industry: they lack the personal characteristics that ease the relationship, and such engagement is not aligned with their own inner motivations. For high self-monitors, this misalignment between motives and academic engagement is less important: they will collaborate with industry in any case. Thus,

Hypothesis 3: The positive relationship between the researcher's position on the self-monitoring scale and his or her individual engagement with industry will be less pronounced for scientists extrinsically motivated in their profession.

Finally, it is possible that the environment may influence the importance of self-monitoring in facilitating individuals' engagement with industry. The literature shows that the

presence of formal support mechanisms facilitates academic collaboration with firms and engagement in knowledge transfer activities (Siegel, Waldman et al. 2003; Lockett and Wright 2005; Landry, Amara et al. 2006). Working with industry, and commercializing research are activities that require different skills from the traditional academic repertoire (Owen-Smith 2003). Making contact with potential industrial partners, managing relationships in fruitful ways and recognizing the economic or technological value of scientific findings are non-trivial activities that can benefit from organizational support. On the other hand, in environments that are not organized to provide support for collaboration activities, or which do not provide encouragement for academics to engage with industry, researchers have to rely on their personal skills and efforts to make contact with possible collaboration partners (Van Dierdonck, Debackere et al. 1990; Owen-Smith and Powell 2001).

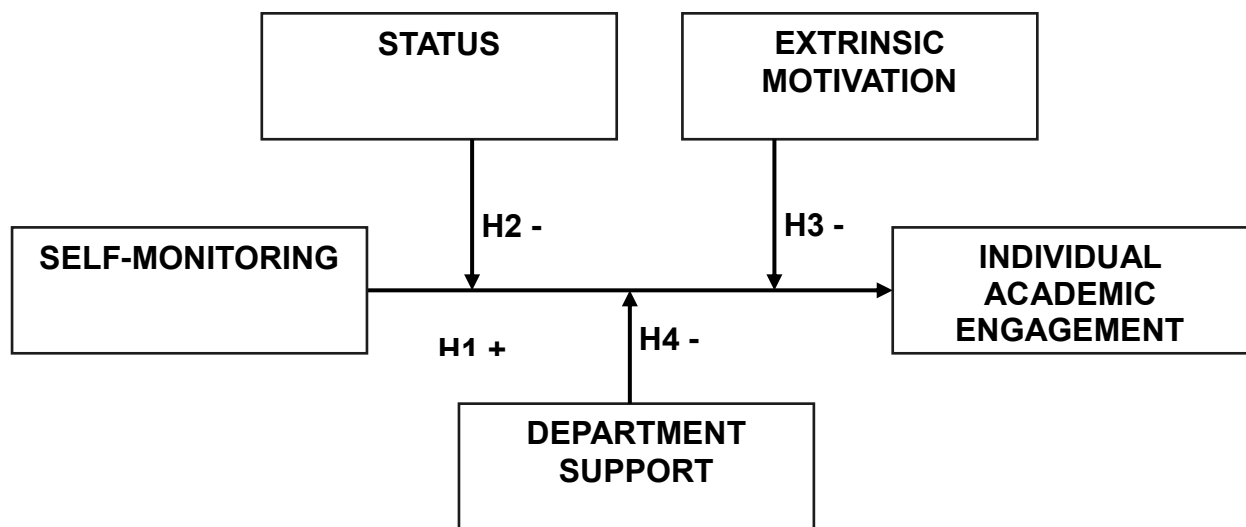
Psychological climate theory claims that individuals tend to respond primarily to cognitive representations of the environments rather than to the actual environment (James and Sells 1981; James, James et al. 1990). In this context, climate can be defined as the collection of signals from the organization individuals receive about the expectations for behaviour and the potential outcomes of those behaviours. This means that academics' engagement with industry may be influenced by their perception of the level of supportiveness of the environment they operate in, rather than the level of resources actually available to facilitate collaboration. Given the centrality of departments in academic life, the support researchers perceive from their department of affiliation is crucial for determining their choices of behaviours. It has been shown that being embedded in an academic department with a culture that is supportive of entrepreneurial activities can counteract the disincentives created by a less than strongly supportive university environment (Kenney and Goe 2004).

High self-monitoring academics possess some specific characteristics that ease their contact with external organization and interactions with different actors. It is less important for them to feel supported by their department. On the other hand, if departments are very supportive of academic engagement, and opportunities for collaboration are abundant, even those individuals who do not possess the characteristics that normally would allow them to be successful in finding suitable partners and to establish collaboration projects can be overtaken by a 'tidal wave' of engagement, thus

Hypothesis 4: The positive relationship between the position of a researcher on the self-monitoring scale and his/her individual engagement with industry will be less pronounced for scientists who perceive their departments to be supportive of engagement with industry.

Figure 2 illustrates the hypothesized model.

Figure 2: Hypothesized model, Effect of self-monitoring on individual academic engagement



DATA AND METHODOLOGY

Data

To explore my hypotheses, I draw on a unique dataset covering a population of 6,200 academic researchers in the UK. I compiled the dataset from multiple sources.

First, I obtained information on this population from the records of principal investigators and co-investigators in projects funded by the UK Engineering and Physical Sciences Research Council (EPSRC) in the period 1992-2006. The EPSRC is the largest funder of research in the UK, especially in the fields of engineering, mathematics, chemistry, and physics. These data are comprehensive and cover all academics awarded EPSRC grants in the UK over a period of 15 years.

Second, I administered an internet-based survey to all the academics identified as grant holders in the EPSRC records and who, at the time of my fieldwork, were still listed on their university website as being active academics. The questionnaire covers various aspects

of researchers' engagement with industry, such as engagement types and frequencies, and attitudes towards engagement, as well as individual motives and traits. The survey was built on and extends previous surveys of academics, including surveys conducted by D'Este and Patel (2007) in the UK, and the Research Value Mapping Program in the US (Bozeman and Gaughan 2007; Link, Siegel et al. 2007). A pilot study was conducted with 30 academics at Imperial College London. I administered the full questionnaire between April and September 2009. I sent a letter signed by the EPSRC's Chief Executive Officer and followed it a few days later with a personalized link to access the survey. Non-respondents were sent (up to two emails) and also received telephone reminders. This yielded a total of 2,194 completed questionnaires (34% response rate).

Third, to capture details of respondents' scientific productivity over their career, I collected extended bibliographic information on individuals from the ISI Web of Science, including number of journal articles, number of citations, journal names and associated disciplines.

Fourth, I matched my sample with the population of academics included in the Research Assessment Exercise (RAE) conducted in 2008 (HEFCE, SFC et al. 2008). The RAE was a government-mandated programme to assess the quality of research of all universities and colleges in the UK; its results were used to determine the allocation of research funding to universities other than that received through competitive bidding for grants. RAE submissions contain information on individuals' 'units of assessment' (usually their departments), including their size and the amount and nature of funding received from 2001 to 2008.

Finally, I matched the universities included in the sample with data derived from the government's Higher Education-Business and Community Interaction Survey (HE-BCI) conducted in 2008 and covering the years 2005-2007 (HEFCE 2008). This annual survey collects financial and output data at the university level, on a range of activities from commercialization of new knowledge, the delivery of professional training, consultancy and services, to community-oriented activities.

I performed several checks on the sample used in the analysis to ensure its representativeness of the population being studied. To ensure reliability of the response pool, I tested for sources of bias in the sample. I performed a Wilcoxon-Mann-Whitney test to check for differences in the typology of university of affiliation of respondents compared to the rest of the sample, and found no significant differences. Since the survey targeted only grant holders, there is a risk of sample selection bias because non-grant holders may behave

differently in terms of engagement with industry. Since I do not have information on researchers that did not receive grants in the period 1992 to 2006, as a proxy for non grant holders. I used the group of academics included in the survey who had not been awarded an EPSRC grant in the previous five years (2000 to 2006). I compared their levels of industry engagement with those of academics who had been awarded grants in that period, and found no statistically significant difference.

Dependent variable

My dependent variable captures academics' industry engagement behaviour across different activities. The questionnaire asks how many times the researcher engaged in different kinds of activities in the two years preceding the survey: (1) contract research projects, (2) joint research projects, (3) consultancies, (4) creation of commercial ventures. For the first three items respondents had to indicate frequency: '0 times', '1-2 times', '3-5 times', '6-9 times', 'more than 10 times'. In order to obtain a continuous variable for the analysis I assigned a numerical value to each frequency category. I decided to take the mid values: for example, for the category '3-5 times' I assumed the value 4 (D'Este and Patel 2007). I then computed the sum of the number of times academics were involved in each activity. In enquiring about commercial ventures, the questionnaire asked for the exact number of start-ups created. I summed the values to obtain the total number of engagement instances, and a variable measuring *individual engagement*.

In order to check that results are not dependent on this particular construction of the dependent variable, I run the main model using different specifications of the dependent variable. The results are discussed in the 'Robustness checks' section.

Independent variables

The main independent variable is the individual's score on the *self-monitoring* scale. Self-monitoring was measured using the 18-item scale developed by Snyder and Gangestad (1986). The scale includes items such as 'In different situations and with different people, I often act like very different persons', and 'I can only argue for ideas which I already believe' (reverse coded). Individuals were asked to rank the items as true or false relative to themselves. Items were scored zero if individuals answered true on reverse coded items and 1 otherwise (and *vice versa*); they then were summed ($\alpha=0.73$). High scores indicate respondents are higher up the self-monitoring scale.

To analyse the contingencies of the relationship between self-monitoring and engagement with industry, I interacted the main independent variable with two individual-level variables and one environmental-level variable.

High-status academics are defined as researchers who are fellows of the Royal Society or the Royal Academy of Engineering. The Royal Society is the oldest scientific academy in the World – it was founded in 1660 – and awards fellowships each year to 44 of the best scientists in recognition of their achievements. There are currently 1,400 Fellows, 60 of whom are Nobel laureates. The Royal Academy of Engineering includes the UK's most eminent engineers. Each year up to 60 Fellows are elected on the basis of nominations by the existing Fellows. Fellowship in these societies brings high visibility and prestige outside academia, in part because Fellows are allowed to append their membership of the Society to their titles. I chose affiliation to the Royal Society or The Royal Academy of Engineering because, although correlated to scientific productivity, it represents a distinct and visible shock that greatly amplifies the status of the academic even outside academia (Azoulay, Stuart et al. 2011).

Extrinsic motives are measured by a question that asks researchers to rate the importance (on a 5-point Likert scale) of a set of benefits deriving from their profession as researchers, going from salary to intellectual challenge. The items are extracted from the Survey of Doctorate Recipients⁹ conducted by the National Science Foundation in the US (Sauermann and Cohen 2010). Factor analysis (principal component-factor, orthogonal varimax rotation) identified a factor comprising four items (salary, benefits, job security, opportunities for career advancement), which summarize extrinsic motives ($\alpha=0.73$).

Finally, I measured the level of support for industrial engagement in the department from the responses to a question asking researchers to state their agreement, on a 5-point Likert scale, (from *strongly disagree* to *strongly agree*) to four statements: 'My department is very effective in supporting collaboration with industry', 'My department is an obstacle in the collaboration with industry' (reverse coded), 'My department reward me for working with industry', and 'My department actively encourages me to work with industry'. Items were assigned a value of 1 if the researcher scored them 4 or 5 (1, 2 or 3 in the case of the reverse coded item). To obtain the variable *departmental support*, scores were summed ($\alpha=0.78$). I use a subjective measure of departmental supportiveness in order to capture individual perceptions of the assistance received in collaborating with industry since this is a powerful

⁹ <http://www.nsf.gov/statistics/srvydoctoratework>

predictor of researchers' willingness to engage in technology transfer activities (Owen-Smith and Powell 2001). I specified the same model using as a proxy for availability of opportunities in the department for engagement with industry, the amount of industry funding per employee received by the department in the year preceding the survey. The results are discussed in the 'Robustness checks' section.

Control variables

I include in the model several controls at the individual, department and university levels, to take account of individual and environmental effects observed previously to have an effect on the behaviour of academics towards activities with industry.

The first group of control variables relates to the researcher's individual characteristics. I include a set of characteristics for researchers such as *gender*, *academic age* (defined as current age minus their age at PhD award), and their *academic rank* (coded as a dummy which identifies the group of professors). Link et al. (2007) find a positive effect of being male and having tenure, on collaboration activities with industry, while, according to Bercovitz and Feldman (2008), the longer the length of time since completing their PhD degree, the less likely researchers will be to embrace commercialization behaviours. I control also for number of years of work experience in the private sector (*industry experience*) because researchers who have worked as employees in industry might be expected to have a better understanding of the private sector's *modus operandi*. I include the number of publications in the five years preceding the survey on which the academic appears as an author (*publications*) and the total amount of research funds received from the EPSRC in the period 2000-2006 standardized by average level of funding in the researchers discipline (*grants*). To control for training effects, I include a dummy variable identifying a holder of a British doctoral degree (*British PhD*). The researcher's scientific discipline is taken into account by introducing a dummy variable (*basic discipline*) identifying basic disciplines (mathematics, chemistry, physics). The researchers' scientific fields tend to define the extent of their engagement in collaborative activities with industry: more applied fields of science, such as engineering, make collaboration more likely (Lin and Bozeman 2006). It has been observed also that for researchers working within the so-called Pasteur's Quadrant (Rosenberg and Nelson 1994), practical problems provide a powerful stimulus for the development of new ideas (Stokes 1997). I also include a variable for *intrinsic motives*, obtained through factor analysis of the items related to the benefits deriving from their profession as researchers (as in the case for extrinsic motives). Adherence to the traditional

academic norms of openness may influence scientists' attitudes to collaboration: agreement with the values of academic capitalism (as opposed to Mertonian values) strong predictors of involvement with industry (Renault 2006).

A second group of variables is related to department and university characteristics. I include in the regressions *department research quality* (measured as the percentage of staff rated 4* and 3* in RAE 2008) and total income received from industry per FTE (full time employee) in 2005-2007 (*department industry funds*). I take account of the profile of the universities in the sample by introducing measures of their quality based on the overall RAE 2008 score (*university research quality*) and I control for institutional involvement in commercialization and collaboration activities including the income received by the university from industry, per employee, in the period 2005-2007 (*university industry funds*). Institutional support has become more relevant for fostering collaboration between universities and industry and facilitating the technology transfer process. From the late 1980s, when researchers considered that personal networking efforts with industry were more effective than institutionalized transfer mechanisms (Lee 1996; Landry, Amara et al. 2006; Arvanitis, Kubli et al. 2008), we observe a shared belief that collaboration and entrepreneurial activities are enhanced by the presence of formal support infrastructures and institutional incentive mechanisms (Van Dierdonck, Debackere et al. 1990), with those at department or research group level having a stronger effect (Chrisman, Hynes et al. 1995; Owen-Smith and Powell 2001; Landry, Amara et al. 2006; Renault 2006; Yang, Chang et al. 2006; Baldini, Grimaldi et al. 2007; Sellenthin 2009).

Estimation

In order to investigate the impact of self-monitoring on individual industrial engagement, I use an ordinary least squares (OLS) model. This kind of model assumes a normal distribution of the dependent variable: I therefore employ the natural logarithm of *individual engagement*. To address the possible problem of heteroskedasticity, I use robust standard errors. Finally, OLS models assume that standard errors are independently and identically distributed: if errors are clustered, OLS estimates are unbiased, but standard errors may be incorrect, leading to incorrect inferences. Since the respondents in my sample come from different disciplines, I can expect some group correlation that is unobservable; therefore I cluster errors by scientific discipline. As a robustness check, I clustered errors also by department and university; the results were consistent with the main specification. All

continuous variables (with the exception of the dependent variable) are standardized to facilitate comparison.

RESULTS

Tables 8 and 9 present the descriptive statistics and correlations for the variables employed. Correlations are generally low to moderate; therefore multicollinearity is not a problem in the estimations.

Table 8: Descriptive statistics (chapter 4)

Variable	Obs	Mean	Std. Dev.	Min	Max
Individual engagement	1081	1.31	0.82	0	3.43
Female	1081	0.11	0.32	0	1
Academic age	1081	20.50	9.71	2	55
Professor	1081	0.51	0.50	0	1
Industry experience	1081	2.85	5.20	0	40
Publications	1081	24.29	25.80	0	393
Grants	1081	880976	2004434	1016.4	3.10E+07
UK PhD	1081	0.84	0.37	0	1
Basic discipline	1081	0.37	0.48	0	1
Intrinsic motive	1081	0.02	0.99	-4.72	1.84
Department quality	1081	62.53	15.62	10	95
Dept. industry income	1081	11107.74	12311.12	-175.96	64556.93
University quality	1081	2.67	0.21	1.75	3.15
Univ. industry income	1081	27.66	18.46	1.84	95.59
High-status	1081	0.07	0.25	0	1
Extrinsic motive	1081	0	1	-3.84	2.60
Department support	1081	2.32	1.16	0	4
Self-monitoring	1081	7.88	3.57	0	18

Table 9: Correlation Matrix (chapter 4)

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]
[1] Individual engagement	1.00																	
[2] Female	-0.07	1.00																
[3] Academic age	0.07	-0.18	1.00															
[4] Professor	0.17	-0.12	0.53	1.00														
[5] Industry experience	0.21	-0.08	0.11	0.06	1.00													
[6] Publications	0.10	-0.03	0.17	0.27	-0.07	1.00												
[7] Grants	0.08	-0.05	0.16	0.21	0.04	0.18	1.00											
[8] UK PhD	0.16	0.01	0.11	0.07	0.09	0.04	0.10	1.00										
[9] Basic discipline	-0.19	0.01	0.03	0.05	-0.11	0.10	0.08	-0.09	1.00									
[10] Intrinsic motive	0.03	0.11	-0.07	0.01	-0.07	0.08	-0.01	0.00	0.08	1.00								
[11] Department quality	0.04	0.00	0.02	0.01	0.00	0.08	0.09	0.05	-0.18	0.00	1.00							
[12] Dep. industry income	0.27	0.01	0.05	-0.03	0.11	0.04	0.02	0.10	-0.36	-0.02	0.24	1.00						
[13] University quality	-0.08	0.02	0.01	-0.01	-0.08	0.14	0.09	-0.01	0.13	0.04	0.63	0.09	1.00					
[14] Univ. industry income	0.16	-0.02	0.02	0.04	0.09	-0.04	0.06	0.02	-0.12	-0.08	0.03	0.27	-0.06	1.00				
[15] High-status	0.11	-0.05	0.31	0.24	0.06	0.20	0.18	0.09	-0.07	-0.03	0.16	0.12	0.14	0.07	1.00			
[16] Extrinsic motive	0.06	0.00	-0.07	-0.03	-0.05	0.03	0.02	-0.02	-0.01	-0.02	-0.06	0.04	-0.07	0.03	-0.07	1.00		
[17] Department support	0.13	-0.03	-0.02	0.04	0.01	-0.01	0.05	0.06	-0.11	0.03	0.05	0.17	-0.08	0.03	0.09	0.05	1.00	
[18] Self-monitoring	0.09	-0.03	-0.11	0.02	0.00	0.03	0.06	0.10	0.01	0.02	0.06	-0.01	0.07	0.03	0.00	0.08	0.06	1.00

Table 10 presents the results of the econometric analysis. Model (1) provides a baseline model (controls and moderators) with the natural logarithm of the number of collaboration activities with industry as the dependent variable. Gender presents a significant coefficient in the regression. Women seem to collaborate less with industry (Thursby and Thursby 2005; Ding, Murray et al. 2006; Murray and Graham 2007); *ceteris paribus*, women engage with industry 13% less than men. Academic age has a negative and statistically significant effect: as observed by Bercovitz and Feldman (2008) the earlier the researcher completed his training, the less likely s/he will be to engage in collaboration activities with industry. Being a professor has a positive and strong effect on the level of engagement with industry (Link, Siegel et al. 2007). *Ceteris paribus*, professors engage 26% more than non-professors. As expected, work experience in the private sector is also positive and significant (Audretsch 1998). The number of publications in the five years preceding the survey has a positive and significant effect on engagement with industry, while the amount of funding received from the EPSRC is not statistically significant. Academics trained in the UK are significantly more likely to engage with industry than those who received their training in another country. Interestingly, being affiliated to a basic discipline does not have a significant effect on engagement; the literature highlights how different fields of science present different technological opportunities and, therefore, different patterns of university-industry interaction (Link, Siegel et al. 2007). Being intrinsically motivated as an academic is not significant in determining engagement with industry. Scientific quality at both department and university level is not significant, while the amounts of department and university funds coming from industry are positively correlated with individual engagement. Faculty members from departments or universities involved in high levels of commercial activities are more likely to engage in collaboration with industry because they benefit from more opportunities.

Table 10: Regression results, standardized variables

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Female	-0.1318* (0.046)	-0.1237* (0.046)	-0.1200* (0.045)	-0.1272* (0.045)	-0.1320** (0.043)	-0.1312** (0.041)
Academic age	-0.0687* (0.024)	-0.0592* (0.025)	-0.0584* (0.025)	-0.0610* (0.024)	-0.0596* (0.026)	-0.0607* (0.025)
Professor	0.2608*** (0.035)	0.2512*** (0.036)	0.2485*** (0.035)	0.2535*** (0.037)	0.2549*** (0.037)	0.2543*** (0.037)
Industry experience	0.1367** (0.035)	0.1360** (0.034)	0.1369** (0.035)	0.1376** (0.034)	0.1324** (0.035)	0.1352** (0.035)
Publications	0.0624** (0.018)	0.0619** (0.018)	0.0603** (0.018)	0.0613** (0.018)	0.0606** (0.018)	0.0587** (0.019)
Grants	0.0134 (0.049)	0.0112 (0.049)	0.0152 (0.050)	0.0123 (0.049)	0.0138 (0.051)	0.0181 (0.051)
UK PhD	0.2461* (0.100)	0.2302* (0.099)	0.2290* (0.099)	0.2299* (0.100)	0.2248* (0.100)	0.2241* (0.100)
Basic discipline	-0.1402 (0.123)	-0.1420 (0.122)	-0.1401 (0.122)	-0.1400 (0.124)	-0.1397 (0.122)	-0.1362 (0.124)
Intrinsic motive	0.0475 (0.028)	0.0471 (0.028)	0.0476 (0.027)	0.0460 (0.027)	0.0506 (0.029)	0.0496+ (0.027)
Department quality	0.0135 (0.032)	0.0123 (0.033)	0.0124 (0.033)	0.0132 (0.034)	0.0160 (0.033)	0.0165 (0.034)
Dept. industry income	0.1531** (0.046)	0.1546** (0.046)	0.1542** (0.046)	0.1563** (0.046)	0.1558** (0.046)	0.1569** (0.046)
University quality	-0.0719 (0.041)	-0.0752+ (0.041)	-0.0752+ (0.041)	-0.0766+ (0.042)	-0.0745+ (0.040)	-0.0759+ (0.042)
Univ. industry income	0.0622* (0.023)	0.0605* (0.024)	0.0603* (0.024)	0.0626* (0.024)	0.0645* (0.025)	0.0660* (0.025)
High-status	0.1225+ (0.091)	0.1222 (0.093)	0.1190 (0.089)	0.1267+ (0.093)	0.1209 (0.094)	0.1227+ (0.091)
Extrinsic motive	0.0409+ (0.026)	0.0373+ (0.026)	0.0381+ (0.027)	0.0365+ (0.026)	0.0360 (0.027)	0.0360+ (0.026)
Department support	0.0469+ (0.032)	0.0446+ (0.033)	0.0455+ (0.033)	0.0422 (0.033)	0.0476+ (0.033)	0.0457+ (0.032)
Self-monitoring		0.0520* (0.021)	0.0610** (0.020)	0.0569** (0.021)	0.0484* (0.020)	0.0617** (0.021)
High status*Self-monitoring			-0.1478* (0.062)			-0.1309* (0.061)
Extrinsic motiv.*Self-monitoring				-0.0592** (0.020)		-0.0593** (0.020)
Dept. support*Self-monitoring					-0.0585** (0.020)	-0.0514* (0.020)
Constant	1.0317*** (0.128)	1.0503*** (0.129)	1.0516*** (0.129)	1.0534*** (0.131)	1.0562*** (0.132)	1.0598*** (0.133)
Observations	1,081	1,081	1,081	1,081	1,081	1,081
R-squared	0.190	0.194	0.196	0.199	0.199	0.205

Notes: Ordinary Least Squares, robust standard errors clustered by discipline. One-tailed tests for main variables, two-tailed tests for controls. ⁺ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

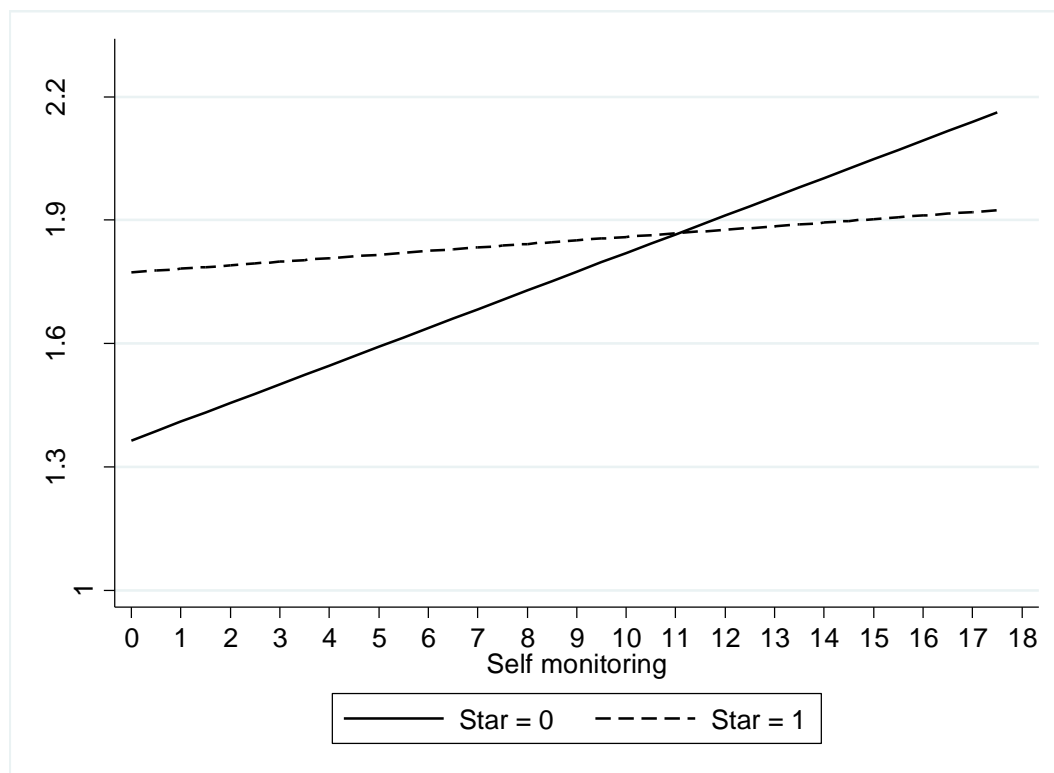
For the variables later employed as moderators, I find that high-status academics seem to collaborate more with industry: this is a function of the esteem they enjoy outside the academic world, which makes them more visible to possible industrial partners and, therefore, more likely to receive offers to collaborate. High-status academics collaborate with industry 12% more than their less visible colleagues. Extrinsic motives are positively and significantly correlated with industry engagement: academics who are motivated by tangible rewards and benefits provided by an external entity are more likely to engage in collaboration activities that increase their utility in tangible terms (Stephan and Everhart 1998). Finally, academics who perceive that their department is supportive of industry engagement activities are more likely to collaborate with industry partners: as observed in previous studies, support mechanisms at the level of the organization facilitate collaboration between academics and firms, not only by giving practical support but also by creating a favourable institutional culture (Owen-Smith and Powell 2001).

Model (2) builds on the previous baseline specification by adding the variable capturing the individuals' score on the self-monitoring scale. The influence of self-monitoring is positive and significant, suggesting that high self-monitoring individuals engage more intensively in collaboration with industry, as predicted by H1. In particular, a standard deviation increase in the self-monitoring score increases individual engagement with industry by 5.2%, *ceteris paribus*. The effect is not as strong as other individual determinants, but it is relevant. All the control variables maintain the same effect as in the baseline model.

In Model (3), I test H2 by introducing status as a moderator. As predicted the effect of the interaction term on self-monitoring is negative and significant, confirming the hypothesis. Figure 3 shows the predicted relationship between self-monitoring and academic engagement for high-status versus non-high-status scientists. High-status scientists are highly visible vis-à-vis audiences other than academia and they possess the resources necessary to seek engagement opportunities: the effect of self-monitoring on their engagement activities is therefore almost irrelevant. Low self-monitoring academics who are affiliated to prestigious scientific bodies have easier access to a large pool of opportunities for collaboration, which facilitates their engagement activities with industry, compared to their low self-monitoring colleagues who do not enjoy the same status. Figure 4 illustrates the significance of the moderation effect along the range of possible values of the independent variable. In analysing a moderation effect, we are comparing difference in the values of the dependent variable for a certain group (i.e. high-status academics) with the values of the dependent variable for another group (i.e. non high-status academics). In order to understand if the difference is

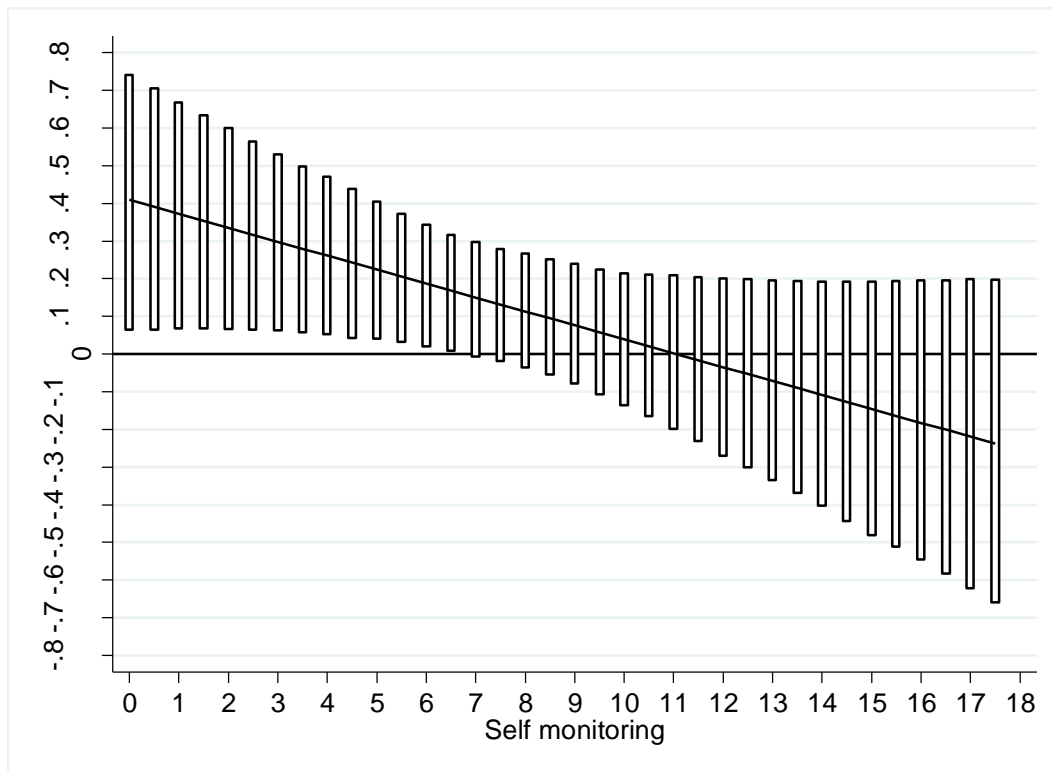
significant along the whole range of values that can be assumed by the independent variable, we need to take account of the effect of the independent variable on the dependent variable, which is conditional on the values that the moderator takes. This has implications for the variance of the marginal effect of self-monitoring of academic engagement (Brambor, Clark et al. 2006). The confidence interval of the difference between the effect of self-monitoring on engagement for the high-status group versus the non-high-status group was computed following Zelner's (2009) methodology and code for STATA. In this particular case, the difference between the two groups is significant only for low values on the self-monitoring scale (up to 6): this means that after that value the slopes for the two groups are not statistically different.

Figure 3: Relationship between self-monitoring and academic engagement, high-status vs. non high-status



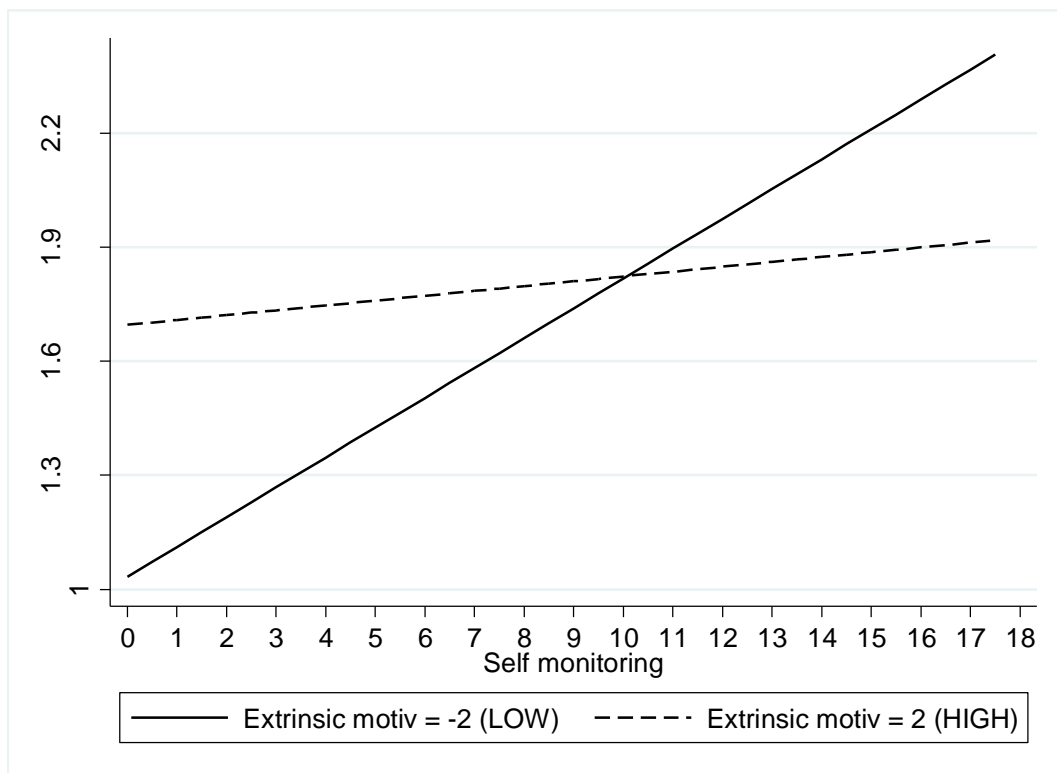
Notes: all continuous variables set at mean value, female=0, professor=1, UK PhD=1, Basic= 0

Figure 4: Difference in academic engagement between high-status and non high-status, by self-monitoring (95% confidence interval)



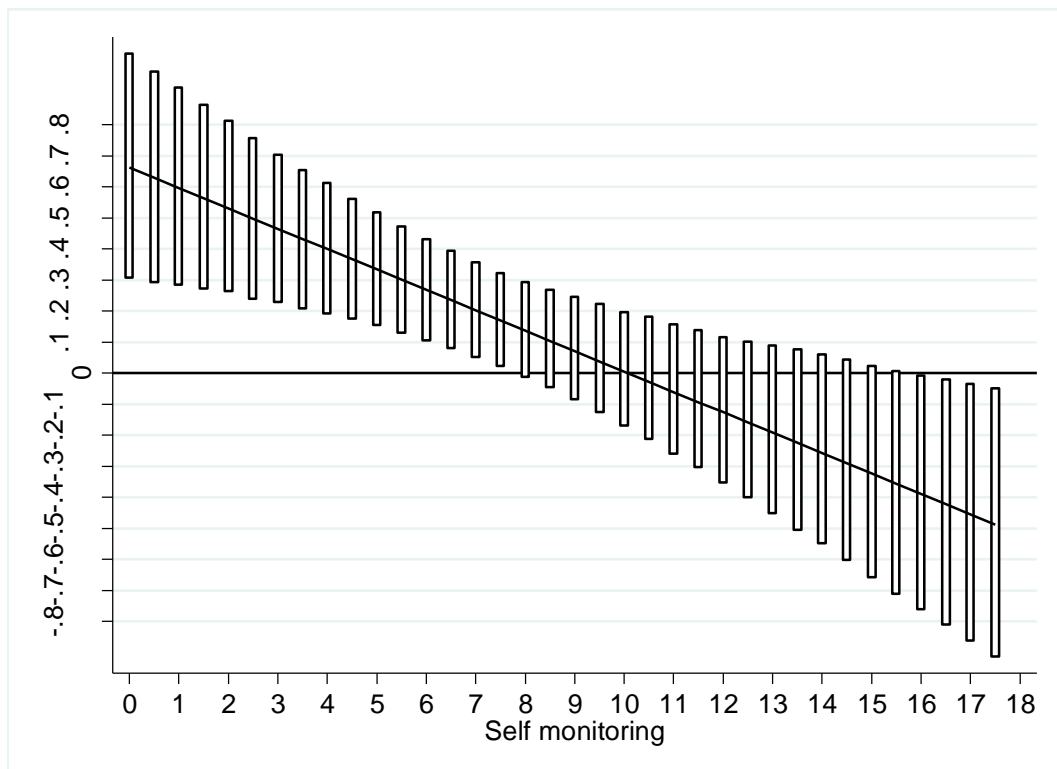
Model (4) includes extrinsic motives as a moderator. The interaction term with self-monitoring is significant and has negative sign, confirming H3. Figure 5 shows the predicted relationship between self-monitoring and academic engagement for highly extrinsically motivated scientists versus low extrinsically motivated researchers. Extrinsically motivated scientists value the benefits derived from by external entities, and real rewards. Collaboration with industry can provide researchers with tangible rewards in terms of increased funds for their lab and for themselves. Low self-monitoring individuals tend to behave in a way that is always consistent with their core values and beliefs; therefore, if a low self-monitoring researcher is extrinsically motivated, it means that s/he will actively seek out extrinsic benefits, for example, by engaging with industry. The statistical significance of the difference between the two groups is shown in Figure 6.

Figure 5: Relationship between self-monitoring and academic engagement, high extrinsic motives vs. low extrinsic motives



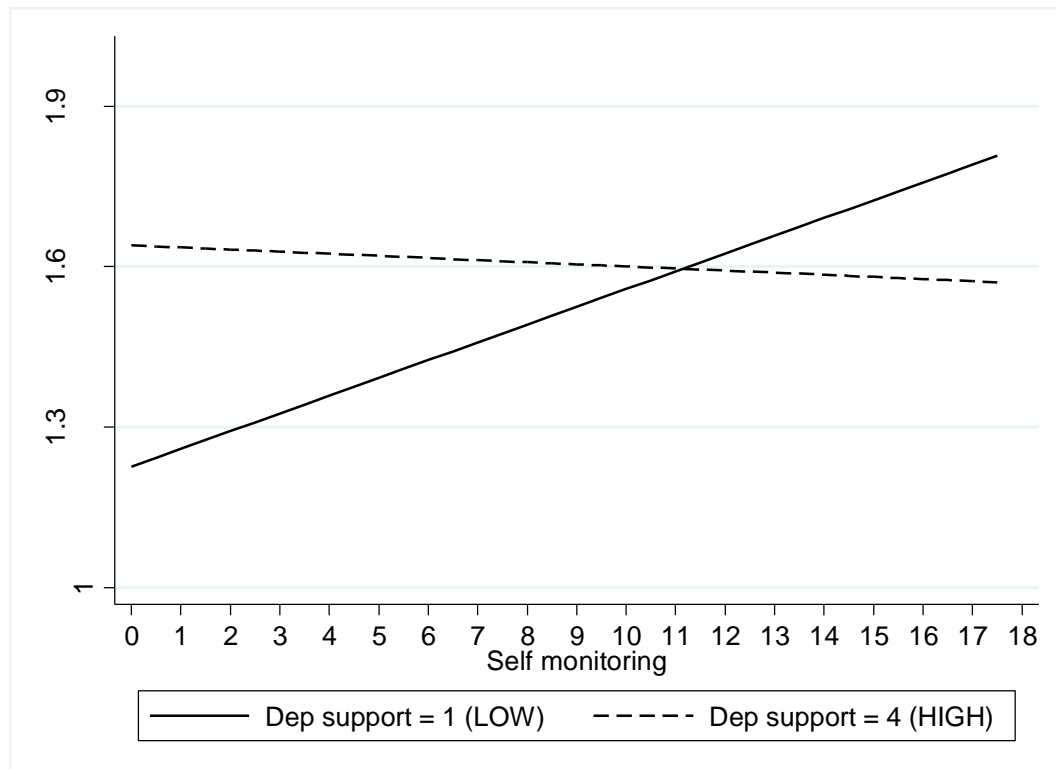
Notes: all continuous variables set at mean value, female=0, professor=1, UK PhD=1, Basic= 0, star=0

Figure 6: Difference in academic engagement between high extrinsic motives and low extrinsic motives, by self-monitoring (95% confidence interval)



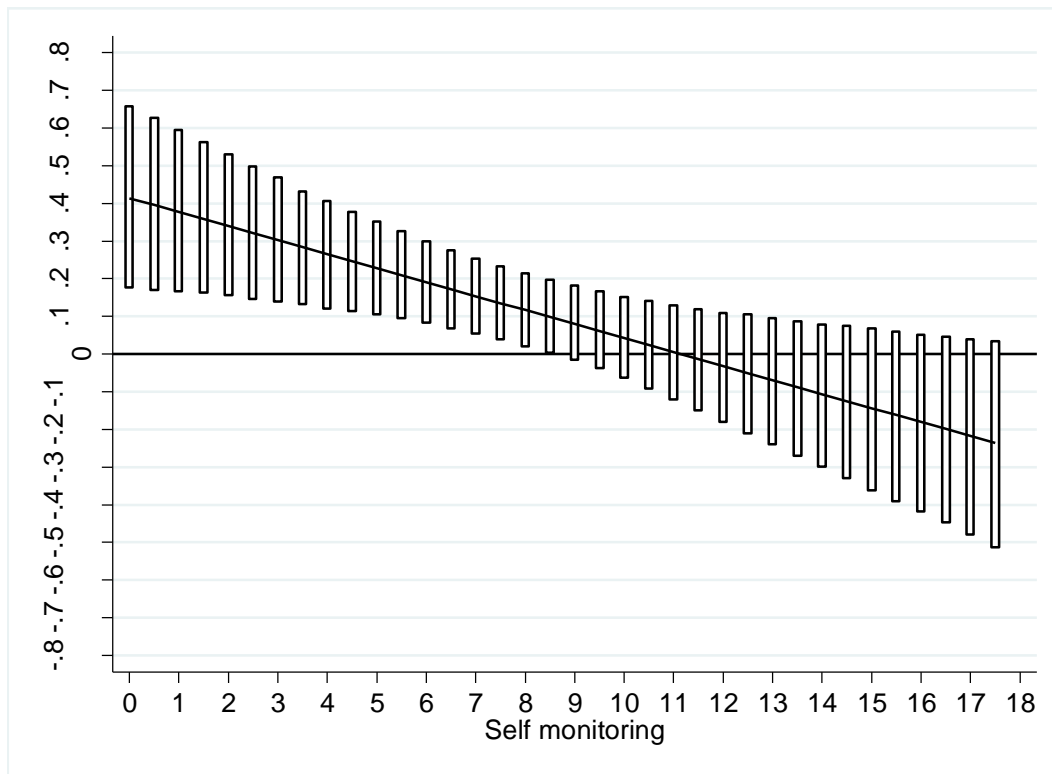
Model (5) tests H4 by including departmental support as a moderator. The hypothesis is confirmed as the sign of the interaction term for self-monitoring is negative and significant. Figure 7 shows the predicted relationship between self-monitoring and academic engagement, for scientists in supportive environments versus scientists working in not supportive departments. When the department is perceived as munificent in the provision of resources and support to foster engagement with industry, then the opportunities for collaboration are more easily accessible to everyone and individual differences in the ability to work across organizations and to manage collaboration activities become less relevant. The statistical significance of the difference between the two groups is shown in Figure 8.

Figure 7: Relationship between self-monitoring and academic engagement, high department support vs. low department support



Notes: all continuous variables set at mean value, female=0, professor=1, UK PhD=1, Basic= 0, star=0

Figure 8: Difference in academic engagement between high department support and low department support, by self-monitoring (95% confidence interval)



Finally, Model (6) tests the full moderated model. Results remain consistent and the explanatory power improves compared to the model including only the main direct effect (Model 2), with R^2 increasing significantly from 0.194 to 0.205 (F test=2.77, p -value=0.048).

ROBUSTNESS CHECKS

I performed several robustness checks to confirm the reliability of my results. I performed the same econometric analysis using different versions of the dependent variable. Different engagement activities require different levels of effort from academics and some activities are more frequent than others. In this case, research contracts and consultancies are more frequent than the creation of a new commercial venture. For this reason, I construct a dependent variable that takes account of the infrequency and difficulty of certain items. This variable is a modified version of the index developed by Bozeman and Gaughan (2007) and is constructed as follows. First, for every type of industry engagement, I established whether a researcher had collaborated or not (occurrence), then I computed the frequency for each type of engagement for the whole population. I constructed the index by multiplying the actual number of interactions declared by each academic for each channel and the frequency of their non-occurrence in the population and summed the scores. The results using this

weighted dependent variable remained consistent with the main specification. To ensure the results were not dependent on the choice to use the mid value for the categories of different channels of engagement, I constructed the same variable using the lower value in the categories. Results are consistent with the main specification.

Finally, as the moderating variable to test H4 measures academics' perceptions of departmental support, I tested the hypothesis using a more factual measure of departmental munificence. I interact self-monitoring with the amount of funds the department received from industry in the year preceding the survey (per employee). I assume that a department that is heavily funded by industry will encourage its members to collaborate with private companies. The sign of the moderation is consistent with the main specification but is no longer statistically significant. I decided to keep the subjective measure of support in the main model because, in my view, it is a more accurate measure of individuals' perceptions of the opportunities available to them. In the case of department funds from industry I use the average value; however, I have no information that allows me to assess whether funds are homogeneously distributed in the department (signalling that, in effect, there is explicit support for engagement activities) or whether they are concentrated in the hands of few researchers. In the latter scenario, these funds may be measuring the ability to attract resources of only a few individuals, independent of the environment in which they operate, but not the actual opportunities to which all other academics are exposed.

DISCUSSION

My analysis suggests that self-monitoring may be a relevant factor in explaining academics' engagement with industry. High self-monitoring individuals are socially ambitious, adaptable and good at boundary spanning; therefore, they tend to collaborate more with industry than their low self-monitoring colleagues across various channels of interaction. Also, the influence of self-monitoring on researchers' collaboration activities is moderated by individual and environmental characteristics. For high-status researchers who have achieved high visibility outside academia, the influence of their self-monitoring score is less pronounced. The same applies to academics who are extrinsically motivated in their job and who value tangible benefits. Individuals who operate in an environment which is very supportive of industrial engagement need to rely less on their self-monitoring profiles because opportunities are readily available to everyone.

My study makes several contributions. First, I add to the work on university-industry relations and commercialization of university technologies. Scholars have pointed to the need

to pay greater attention to the microfoundations of university-industry collaboration (Rothaermel, Agung et al. 2007). While several studies investigate the psychology of scientists, at the individual level the literature on university-industry collaboration focuses mainly on demographic characteristics and productivity. Some scholars point out that individuals in organizations may outperform their peers because of differences in personality (Mehra, Kilduff et al. 2001). While my findings confirm the role played by some key demographic characteristics, in particular academic rank, industry experience, gender and academic age, by analysing the effect of self-monitoring on academics' engagement with industry, I provide novel insights on the individual determinants of engagement activity, and especially the effect of researchers' personality. Self-monitoring theory provides compelling evidence suggesting that self-monitoring is a relatively stable trait across a life time; it is possible, therefore, to advance some causality claims about the relationship between self-monitoring and academic engagement.

My study also provides a broader view of academic engagement, encompassing several collaboration mechanisms in addition to academic entrepreneurship. A large part of the literature on university-industry interactions analyses the incidence and impact of filing patents and founding spin-offs by academic scientists (Agrawal and Henderson 2002; Shane 2002). Patents, licensing and new venture creation are clearly relevant means of technology transfer, but they are also less frequent than forms of interaction, such as joint research projects and consultancy agreements (Louis, Blumenthal et al. 1989; Agrawal and Henderson 2002; Gulbrandsen and Smeby 2005; D'Este and Patel 2007). While entrepreneurship is an 'extreme' commercialization behaviour, which requires a huge effort and a specific set of skills, academic engagement through joint research projects and consultancies is activity that requires different and more nuanced involvement with industry and may be within reach of a larger share of academics.

Finally, from a policy perspective, because collaboration with industry represents discretionary behaviour among academics, and the individual willingness to participate in knowledge transfer is what eventually determines its success, it is important to understand who in the university is more likely to engage with industry. Recognizing that individuals are different and that their personality differences affect the way they see opportunities and respond to incentives, is crucial for the design of effective mechanisms to foster technology transfer activities. A support system that focus for the main part on few selected activities (such as spin-off creation) may not be an efficient way to promote collaboration with industry because the differences between individual researchers, both in terms of their characteristics

and motivations, make them sensitive to different kinds of incentives and different levels of support. This does not mean that only individual characteristics matter for determining academic engagement with industry or that the only viable option is to pre-select individuals with the characteristics that will make them more likely to collaborate with private companies. For example (as in the case presented in this study) low self-monitors, who would naturally be less inclined to participate in technology transfer, can be supported in this activity through their organization, which needs to make the opportunities for collaboration more accessible to its members.

Limitations and future research

This study suffers from some limitations which suggest avenues for future research. First, although I have shown that high self-monitoring individuals are more at ease in boundary spanning roles required for activities involving industry, I cannot make any claims about differences in scientific productivity. Future research should explore whether differences in personality contribute to different trajectories in terms of scientific research. Second, my analysis provides insights into the relationship between self-monitoring and the number of instances of collaboration between researchers and industry. Some of the personal characteristics associated with self-monitoring may also contribute to the success of these collaborations. We can imagine that since high self-monitors are better at understanding the feedback they receive from certain situations, they will also be better at managing collaboration activities, making them smoother and consequently more successful. On the other hand, low self-monitors are generally more committed to the relationships they initiate: it is plausible then that after embarking on engagement with a specific partner, they will be especially dedicated to the project, which will lead ultimately to high levels of trust. Future research could try to unpack this relationship between self-monitoring and the quality of the interaction in order to deepen our understanding of the mechanisms that lead to repeated collaboration between certain academics and companies.

CHAPTER SUMMARY

This chapter analyses the impact of self-monitoring (a personality trait) on academics' engagement activities with industry. Using data from a large survey addressed to academics in physical sciences faculties in UK universities, I suggest that high self-monitoring individuals collaborate more with industry than their low self-monitoring colleagues, across a variety of channels of interaction. Furthermore, the influence of self-monitoring on

researchers' collaboration activities is moderated by both individual and environmental characteristics. For high-status researchers who have already achieved high levels of visibility outside academia, the influence of their self-monitoring score is less pronounced. This applies also to academics who are extrinsically motivated in their jobs and who value tangible benefits. Individuals who operate in an environment that is very supportive of industrial engagement need to rely less on their self-monitoring profiles since opportunities are readily available to everyone. With this work, I contribute to the current debate on the need to pay greater attention to the microfoundations of university-industry collaboration. While my findings confirm the role played by some key demographic characteristics, I provide novel insights into the individual determinants of engagement activity, and especially the effect of researchers' personality.

CHAPTER 6 - THE IMPACT OF ENTREPRENEURIAL CAPACITY, EXPERIENCE AND ORGANIZATIONAL SUPPORT ON ACADEMIC ENTREPRENEURSHIP¹⁰

INTRODUCTION

The rise in the number of spin-offs from universities in Europe, which has taken place since the 1990s, is often linked to the professionalization of Technology Transfer Offices (TTOs) at these universities. With the support of public funds, TTOs have stimulated a range of entrepreneurial activities by academics, spanning invention disclosures to patent applications, the generation of licensing income, and the involvement of academics in the founding of spin-offs (Siegel 2006; Clarysse, Wright et al. 2007; Wright, Clarysse et al. 2007).

The US Bayh-Dole Act of 1980, and its European counterparts, by encouraging universities to patent inventions funded by government agencies, marked the beginning of notably greater professionalization of the TTOs at the different universities (OECD 2003; Siegel, Waldman et al. 2003; Rothaermel, Agung et al. 2007). Meyer (2003) suggests that the professionalization of the TTO increases the degree to which academics are involved in entrepreneurial activities. Although earlier academic work suggested a strong link between the efficiency of the TTO and the entrepreneurial activity of the academics at the different universities, more recent empirical work does not find a clear impact of the TTO office. For example, Stuart and Ding (2006) highlight the social structural antecedents, i.e. the specific normative beliefs, which prevail at the department and university about entrepreneurial activity, as strong determinants of academic entrepreneurship. In this study, whether or not a university had a specific TTO did not have a consistent and significant impact on the likelihood of academics to engage in commercial activities. Bercovitz and Feldman (2008) build upon these results and conclude that the social environment mediates the individual attributes of academics, such as exposure to entrepreneurial activities in previous universities, which might explain why certain academics are more likely to engage in entrepreneurial activities.

¹⁰ This chapter is co-authored with Bart Clarysse and Ammon Salter and it is published in *Research Policy* (2011), 40(8), pp. 1084-1093

Yet, surprisingly, the literature on academic entrepreneurship makes very little reference (one exception is Mosey and Wright, 2007) to the individual attributes which the wider entrepreneurship literature have repeatedly put forward as the central determinants of entrepreneurial activity and success. There is, for instance, a vast literature on habitual or serial entrepreneurs, which claims that entrepreneurial experience is a very good predictor of future start-up activity (Ucbasaran, Westhead et al. 2006; Hsu 2007). This literature on habitual entrepreneurs is in line with the equally large literature on entrepreneurial intent, which puts entrepreneurial self-efficacy (the belief one has in his/her own competencies to start a company) as a consistent predictor of the intent which people have to become entrepreneurs or undertake entrepreneurial activities (Souitaris, Zerbinati et al. 2007; Fini, Grimaldi et al. 2010). Both streams suggest that confidence, either through experience or through personality, is a strong determinant of the probability that one will undertake entrepreneurial activities. A third stream of literature in the field of entrepreneurship refers to 'opportunity recognition' defined as the identification of a chance to combine resources in a way that might generate a profit. Entrepreneurial opportunities are defined as objective situations that entail the discovery of new means-ends relationships through which new goods, services, raw materials, and organizing methods may be sold at a profit (Casson 1982; Shane and Venkataraman 2000; McMullen, Plummer et al. 2007; Haynie, Shepherd et al. 2009). Opportunity recognition appears to be a strong predictor of subsequent entrepreneurial activity (Shane 2003). For instance, Baron and Ensley (2006) show that skills in opportunity identification increases the probability that an individual will become an entrepreneur. This is because people need the capacity to identify opportunities prior to engaging in entrepreneurial efforts. Moreover, Nicolaou et al. (2009) in their study of twins show that these opportunity recognition skills can, in part, be explained by genetic differences. This indicates that this ability is partly innate, and therefore somewhat impervious to social pressures and environmental context.

In short, various streams in the literature on entrepreneurship tend to emphasize individual level attributes such as experience and opportunity recognition skills as critical explanations of entrepreneurial activity. In contrast, the extant literature on academic entrepreneurship has pre-dominantly focused on social environmental factors to explain entrepreneurial behavior, while not addressing these individual attributes. This is reflected in the recent empirical literature focus on the importance of local (departmental) and university level social contexts to explain entrepreneurial behavior of individual academics (Stuart and Ding 2006; Bercovitz and Feldman 2008), while the pre-2005 literature highlighted the

crucial role of TTOs in stimulating entrepreneurial behavior (Colyvas, Crow et al. 2002; Clarysse, Wright et al. 2005). Since the European versions of the Bayh-Dole Act have been put in place, TTOs have increased in size and have continued to professionalize their activities. As a result, their role has been focused both on assisting academic spin-offs and improving the social desirability of engaging in commercial activities within university departments.

In this paper, we argue that academic entrepreneurship literature has underestimated the importance of individual differences between academics, while at the same time it has overestimated the role that TTOs have played in stimulating entrepreneurial behavior. To examine this question, we draw from a rich dataset, which includes 1,761 academics from 90 UK universities across a wide range of disciplines and departments. Our results suggest that the ‘opportunity recognition capacity’ of the academics, which we call entrepreneurial capacity, is the single most important variable explaining their engagement in entrepreneurial ventures. The social environment of the university and the professionalization of the TTO amplify the impact of entrepreneurial capacity, but have no, or only marginal, direct effects after controlling for the entrepreneurial capacity of the individual academic.

In doing so, our study makes three contributions to a richer understanding of the nature of academic entrepreneurship. First, unlike prior studies, our research design allows us to assess individual-level and organizational-level factors - individual and jointly – that shape academic entrepreneurship. Second, the study offers the rare opportunity to gauge the role of TTOs as a facilitator (or blocker) of individual level predispositions towards new venture creation. Third, since we use data from a wide range of disciplines, universities and departments, we are able to investigate the general properties of academic entrepreneurship, rising above the tendency in the current literature to focus on particular disciplines or institutions. Because we are able to both measure individual and organizational level issues, we can compare the impact of the policy measures that were implemented following the increased alertness among policy makers in Europe about the commercial potential of universities, inspired by the Bayh-Dole Act.

The paper unfolds along the following lines. We begin with a literature review and we draw upon results from our interviews with technology transfer managers and faculty involved in starting new ventures to develop a conceptual framework about the individual faculty member’s decision to engage in entrepreneurial ventures. The second section of the paper introduces the data and the methodology. The third part of the paper presents a

discussion of the empirical results. We finish with a discussion section and reflect upon the conclusions from this study.

LITERATURE REVIEW AND HYPOTHESES

The literature on academic entrepreneurship has mainly focused on how technology transfer offices can create a structural environment which facilitates the creation of academic spin-offs (Clarysse, Wright et al. 2005; Wright, Clarysse et al. 2007) and/or improves the entrepreneurial culture within the department. Clarysse et al. (2005) have shown how various levels of support at the level of the TTO determine both the amount of, and the kind of, companies which are started by academics in the universities in which they are active. Stuart and Ding (2006) and Bercovitz and Feldman (2008) have analyzed the role of organizational stimuli in an indirect way by looking at the importance of the social environment in explaining the degree to which scientists in biotech and medical departments are likely to engage in entrepreneurial activities. However, none of these studies takes the individual attitudes of academics into account. They assume that creating a supportive environment can result in higher levels of academic entrepreneurial activity in a relatively straightforward way. Although Bercovitz and Feldman (2008) find that an entrepreneurial social environment will increase the likelihood that a particular scientist in that domain will also engage in entrepreneurial activities, it is difficult to know whether this finding is the product of a selection effect, whereby academic entrepreneurs are attracted to departments where this activity is supported. In this respect, as they admit, their study is inconclusive about whether the social environment will have the same effect for academics with low degrees of entrepreneurial capacity or whether only scientists with a relatively high degree of entrepreneurial capacity will tend to join such a department in the first place. In a different context, Kraatz and Moore (2002) suggest that it is a combination of the two.

Within the wider entrepreneurship literature, scholars consider individual differences to be the critical factor explaining who becomes an entrepreneur (Shane and Venkataraman 2000). Nicolau et al. (2008) show that individual differences matter, regardless of whether entrepreneurship is measured as self-employment, starting companies, owning one's own business, or being involved in the firm start-up process. They show that the individual differences account for close to 60% of the variation even after taking into consideration environmental effects such as income, education, marital status and race. Two main factors seem to explain differences between individuals: genetic differences and experience (Shane 2010). Nicolau et al. (2009) show that genetic differences may account for over 60% of the

differences in the individual tendency to become an entrepreneur. Most of this can be related to the differences in ‘opportunity recognition capacity’, the ability to spot, recognize and absorb opportunities among individuals. Nicolau et al. (2009) show that the same genes are responsible for explaining entrepreneurial capacity (measured as opportunity recognition skills) in individuals as those that account for entrepreneurial activity itself. However, Shane (2010) shows that the genetic factor is more significant in explaining entrepreneurship among women than men. He argues that direct experience in entrepreneurial activities is a good substitute within male populations in explaining entrepreneurial activity. Shane’s findings are in line with the literature on habitual and serial entrepreneurs (Ucbasaran, Westhead et al. 2008), which highlights that the likelihood of starting of new firm increases significantly if an individual has already been involved in the founding of a previous one, regardless of the outcome of that previous company. Also the psychological view in entrepreneurship attributes some importance to experience, which they consider to be a good indicator of self-efficacy (Ajzen 1991).

We can summarize the above findings as follows. First, mainstream entrepreneurship literature attributes a central role to individual differences followed by the social context in explaining the tendency to become an entrepreneur, regardless of whether the entrepreneurial activity is seen as starting a business on your own, being involved in a start-up or becoming self-employed as a career choice. The literature on academic entrepreneurship in contrast has highlighted the efficiency and professionalization of the TTO to explain changes in entrepreneurial activity at different universities. Studies before 2005 almost exclusively looked at the direct impact of TTO activities on spin-out activity at universities. The more recent studies have also focused on indirect influences such as the local social context at departmental level as explanations of entrepreneurial activity among scientists. Despite the abundant entrepreneurship literature, little reference has been made to individual characteristics as possible indicators of entrepreneurial activity. A second, though less important shortcoming is that the more recent studies on academic entrepreneurship have focused on entrepreneurial activity in one particular domain, namely life sciences and biotechnology. The choice for a single domain is inspired by the fact that these studies want to focus on the role of the local social environment and thus want to minimize the heterogeneity at the more general environmental level. However, at the same time, it introduces a bias towards a very specific scientific domain, usually in a selected number of leading universities.

Entrepreneurial capacity, which we define as the skill which individuals have to spot, recognize and absorb opportunities, has been put forward in the entrepreneurship literature as a necessary individual characteristic to become an entrepreneur (Shane and Venkataraman 2000; Nicolaou, Shane et al. 2008). Entrepreneurially oriented individuals identify opportunities that might lead to new venture ideas that can be commercialized and show a general interest in pursuing these opportunities and/or ideas. To be an entrepreneur is to act on the possibility that one has identified an opportunity worth pursuing (McMullen and Shepherd 2006; Companys and McMullen 2007). Moreover, Nicolau et al., (2009) have shown that more than half of the variation in entrepreneurial capacity can be traced back to genetic differences between individuals, which is, in turn, unrelated to the environment in which these individuals have grown up or to the environment in which they currently operate. Therefore, we can infer that academics who have a high degree of entrepreneurial capacity will be more actively involved in entrepreneurial initiatives that spin out from the university.

Hypothesis 1: Academics with a high degree of entrepreneurial capacity (capacity to recognize opportunities) will be more likely to be involved in entrepreneurial initiatives created by others or in founding entrepreneurial ventures themselves.

The second individual characteristic that we explore is entrepreneurial experience. In the entrepreneurship literature, ‘experience’ is generally associated with a belief in entrepreneurial skills. In other words, entrepreneurs who have been involved in start-ups before – labelled as habitual or serial entrepreneurs (Westhead and Wright 1998) – are considered to have a greater belief in their own entrepreneurial potential, regardless of the outcome of their entrepreneurial efforts (Sitkin 1992; Shepherd 2003). Increasingly, the learning literature points to negative experiences as very intensive learning events, which might be of equal value as positive ones. McGrath and MacMillan (2000) provocatively asserted that serial or habitual entrepreneurs might have a ‘*entrepreneurial mindset*’ that prompts them to search continuously for new opportunities. Various sources show that the prevalence of serial entrepreneurs ranges from 40% in Sweden (Wiklund and Shepherd 2008) to levels as high as 61% in the states (Schollhammer 1991) with 51% in Great Britain (Ucbasaran, Westhead et al. 2006). This means that once an individual is involved in a start-up activity, the chances that he/she will be involved in a subsequent one are quite high, irrespective of the outcome of the previous one. The mechanism used to explain this is, what the psychology literature refers to as, self-efficacy. Once you have set up a business or once

you have been directly involved in such a founding process, you know what to expect and you can better evaluate your own skills. Shane (2010) shows that a lack of experience among females explains why the genetic differences in females prevail as explanations of their tendency to become an entrepreneur in comparison to the male population. In short, the experiences which individuals have, either directly as founders or indirectly through being involved in start-up activities by students or colleagues, is expected to have an impact on their own tendency to become entrepreneurs. Thus:

Hypothesis 2: Academics who have entrepreneurial experience will have a greater entrepreneurial self-efficacy, which leads to their subsequent involvement in entrepreneurial initiatives created by others and/or in founding entrepreneurial ventures themselves.

Whereas we introduced the individual characteristics of academics as explanations of entrepreneurial activity, a number of studies such as Kenney and Goe (2004), Bercovitz and Feldman (2008) and Stuart and Ding (2006) have highlighted the role of the local social environment in stimulating entrepreneurial behavior among academics. Both studies illustrate empirically that the local social context explains why academics make the transition from pure science to commercial activities related to their research. Stuart and Ding (2006) focus on the direct contacts between academics and coauthors who have an entrepreneurial record as a stimulus for engaging in entrepreneurial activities. Bercovitz and Feldman (2008) focus more on the entrepreneurial attitude of colleagues and the head of the department. Both studies focus solely on academic entrepreneurship in the medical and biotech domains. This choice allows them to use very detailed proxies of the local social context variables, but also implies that the findings might not easily be generalized to other fields such as engineering and physical sciences. Since local social context is an important explanatory element of entrepreneurial intent, we expect that the influence of that environment can, however, be generalized across fields. Therefore, we argue:

Hypothesis 3: Academics who operate in a context where academic entrepreneurship is stimulated will have greater likelihood of being involved in entrepreneurial initiatives created by others or in founding entrepreneurial ventures themselves.

Hypotheses 1 and 2 emphasize individual characteristics of academics. Since entrepreneurial capacity has a strong genetic basis, it is likely that TTOs have very little

impact on this. Even entrepreneurial experience can only be rarely stimulated by TTOs, although they might assist in setting up various programs which increase the entrepreneurial enthusiasm of academics and hence stimulate them to be involved in start-ups of others and cumulate entrepreneurial experience over time (Souitaris, Zerbini et al. 2007). They might also indirectly play a role in providing role models and therefore increase the social acceptance of being involved in commercial activities. However, the question remains whether TTOs, which have emerged following various Bayh-Dole legislative initiatives in various European countries since the mid 1990s also have a direct impact on academic entrepreneurship, after controlling for individual level variables and the social context. In Europe and the UK more specifically, the change in laws and regulations about who owns the intellectual property of research results, which are based on public funding, was accompanied by significant investments in creating TTO (Technology Transfer Offices) in the different universities. Most countries have set up specific public schemes where universities can apply for money to co-finance or seed finance the set up of such a TTO office. For instance, in the UK, universities have received around £700 million in constant value since 2000 for such efforts, which is equivalent to around £5,000 per academic. The initial distribution of that public money correlated closely with the size and quality of the university applying for it.

The TTOs that were created were expected to increase the commercial returns to be earned from university research. To do so, they developed activities to stimulate invention disclosures among the researchers, to protect inventions from copying and to assist researchers in the contractual and marketing part of their research. The general output measures that are used to benchmark the efficiency of a TTO against their colleague TTOs are the 'number of patent applications' filed by the university (Thursby and Thursby 2002); the level of income through contract research and the number of research based spin-offs, which are created at the university (Wright, Clarysse et al. 2007). Thursby and Thursby (2002) have empirically shown that patent applications increased in US universities after the creation of central TTOs in these universities. Moray et al. (2009) have empirically shown that the number of contracts, the size of these contracts and the money generated through industry contracts has increased significantly at Belgian universities after the creation of central TTOs at these universities in the 1990s. Wright et al. (2007) suggested that the number of research based spin-offs has also increased since central TTOs were created, but empirical evidence on this remains inconclusive as data on research based spin-offs and their performance has greatly improved since the creation of these TTOs. As a result, one is not

sure whether the number of spin-offs has increased in reality or whether the increased number on the list only reflects the fact that statistics have improved since the creation of these TTOs.

Meyer (2003) has shown that although the initiatives that were taken by central TTOs may not have led to the creation of more high growth oriented spin-offs, they have increased the entrepreneurial intent of academics. Similarly, Bercovitz and Feldman (2008) found that academics who were familiar with TTO activities in their PhD or post-doctoral period were more likely to get involved in entrepreneurial activities later on in their career because they had become familiar with the business norms and skills that are needed to be successful in commercializing research. The main conclusion from this research is that TTOs, regardless of whether they have been able to create more successful companies, have supported the creation of an environment in which academics feel more comfortable in undertaking entrepreneurial activities. This is likely to be especially true for academics that were trained in the period that TTOs have become active. It is also in this period that expectations for venture creation among academics become a wider public policy goal, with explicitly targeted funding. Therefore, we hypothesize:

*Hypothesis 4: Academics who started their career **after** the creation of a central TTO at the university are more likely to get involved in entrepreneurial initiatives created by others or in founding entrepreneurial ventures themselves*

In Hypothesis 4, we suggest a direct impact of the emergence of central TTO offices on the entrepreneurial activity of academics that are working in the shadow of the TTO. However, we might also expect an interaction effect between the academic's entrepreneurial capacity and the efficiency and/or professionalization of the TTO. If a TTO is efficient in its operations, then one would expect it to facilitate the creation of a venture, which then amplifies the impact of the efficiency of the TTO, and, in turn, the degree to which academics at the university get involved in starting a venture. There is increasing empirical evidence that the commercial results, which can be realized through spin-offs, are a multifold from the ones that are derived from selling licenses (Wright, Clarysse et al. 2007). Therefore, TTOs have extensively invested in supporting the setting up of entrepreneurial ventures. For instance, TTOs usually organize pre-seed capital to be invested in potential spin-offs (Clarysse and Bruneel 2007). Academics, who want to start a new business, therefore have access to capital. In addition, they offer incubation services, which make it possible for academics to stay within the familiar setting of the campus while setting up the new business. They also offer a

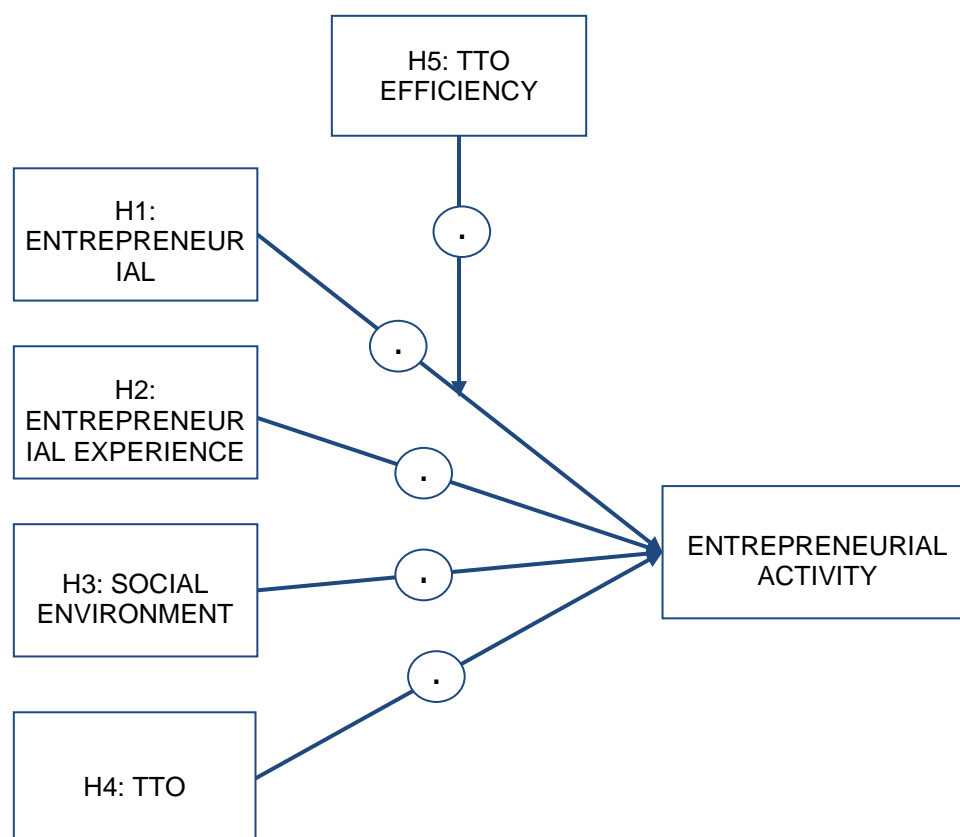
variety of advice and coaching activities towards the academics and help in finding experienced managers from industry to help support the new firm. So, one could expect that for academics with a high degree of entrepreneurial capacity, the barriers to effectively start up their own business or get involved in a start-up would be significantly lower.

A central TTO office is thus expected to not only to stimulate entrepreneurial activity directly, but also to amplify the direct relation which we hypothesized between the entrepreneurial capacity of an academic and his/her involvement in starting new businesses that emerge from universities. Thus,

Hypothesis 5: The efficiency of the TTO will amplify the likelihood of an entrepreneurial oriented academic to become involved in entrepreneurial initiatives created by others or in founding entrepreneurial ventures themselves

Figure 9 summarizes our overall conceptual framework, indicating the expected relationships between individual, social and TTO efforts on the decision of an academic to be engaged in a new venture.

Figure 9: Hypothesized Model, impact of entrepreneurial capacity, experience and organizational support on academic entrepreneurship



DATA AND METHODOLOGY

Sample Frame and Sampling Process

To test our conceptual framework presented in Figure 1, we draw upon a range of integrated and rich datasets. The most important of these is a questionnaire survey of 6,200 academic researchers in the United Kingdom. This sample frame of academics includes the principal investigators and co-investigators who received grants from the UK Engineering and Physical Sciences Research Council (EPSRC) in the period 1992-2006. The EPSRC is the largest funding body for research in the UK (it distributed £740 million of research funding in 2008) and funds research in all fields of engineering, mathematics, chemistry, and physics. The EPSRC encourages partnerships between researchers and third parties, such as private firms, government agencies, local authorities, non-profit organizations etc. Therefore, in the grant portfolio we can observe a mixture of collaborative (involving industrial or non-industrial partners) and response mode grants. The selection process for these grants is based on peer review. The questionnaire was administered electronically between April and September 2009: a letter of endorsement sent by the Chief Executive of the EPSRC was included in the invitation to participate in the survey. An email containing a personalized link to access the survey was sent a few days later, followed by two emails and a telephone reminder to non-respondents. This yielded a total of 2,194 completed questionnaires - a response rate of 36%.

The survey was designed to capture university researchers' attitudes to collaboration with industry and their entrepreneurial activities. A draft version of the questionnaire was tested during a pilot study conducted with 30 academics at Imperial College London. We merged the information obtained through the survey with additional secondary data. First, we matched our sample with the population of academics included in the Research Assessment Exercise (RAE) conducted in 2008 (HEFCE, SFC et al. 2008). The RAE assessed the quality of research in universities and colleges in the UK: 2,344 submissions were made by 159 Higher Education Institutions (covering the period 2001-2007). The RAE was conducted jointly by the Higher Education Funding Council for England, the Scottish Funding Council, the Higher Education Funding Council for Wales and the Department for Employment and Learning of Northern Ireland and the quality profiles obtained are used to determine the amount of research-related grants given to UK higher education institutions. We assigned individuals in our sample to the unit of assessment they belonged to in the RAE, obtaining additional information about the size of the unit of assessment, the amount and nature of

funding received in the last seven years, the quality of the research performed in the department.

Second, we matched the universities included in our sample with the data collected by the Higher Education Funding Council for England (HEFCE) through the Higher education-business and community interaction survey (HE-BCI) conducted in 2008 (covering the years 2005-2007). The annual HE-BCI survey examines the exchange of knowledge between universities and society in a wider sense: it collects financial and output data per academic year at university-level on a range of activities, from the commercialization of new knowledge, through the delivery of professional training, consultancy and services, to activities intended to have direct social benefits. From this source, we collected information about the different streams of funding universities receive, and the magnitude of their commercialization efforts (such as number of patent applications, revenues from intellectual property and number of spin-offs created).

Estimation Method

To empirically investigate the determinants for academics to be involved in entrepreneurial activities, we use an event (survival) analysis techniques: more specifically, we use the semi-parametric specification called the Cox model (Cox 1972). Event models are used to analyze the relationship between the time that passes before an event occurs and one or more covariates. The Cox model is a general semi-parametric model in which no assumption about the distribution of survival times is made: estimates are obtained through partial likelihood methods based on the ordering of events. As we are dealing with tied data (multiple observations register the event of interest at some point in time, t_j), we approximate the partial likelihood function with the Breslow method (Breslow 1974).

We can outline our model as:

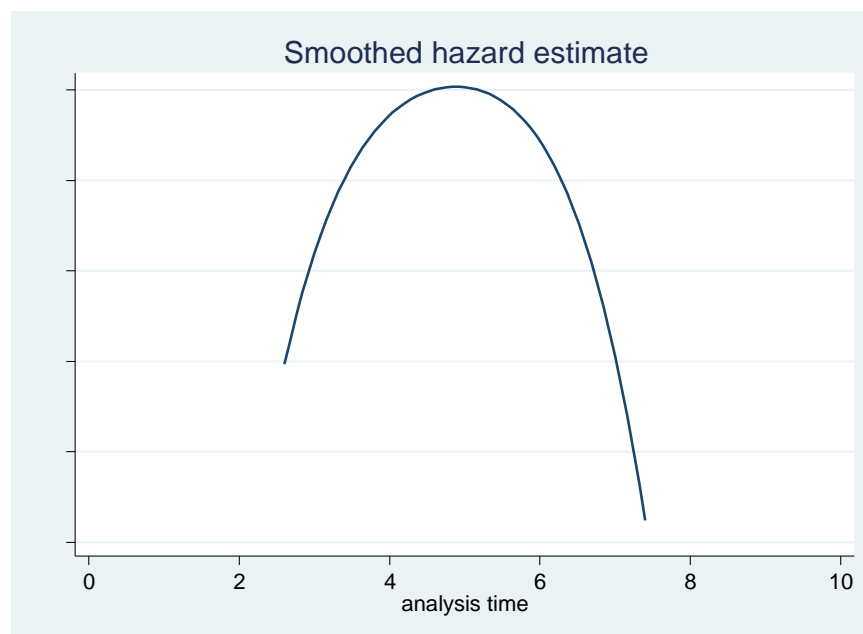
$$h(t) = h_0(t) \exp(X_i\beta)$$

where $h_0(t)$ is the baseline hazard (this corresponds to the case in which all the covariates equal zero) which is shifted by an order of proportionality with changes in X (representing the vector of covariates).

The *event* in our model is the creation of a company by an academic (self reported in the questionnaire). The analysis period starts at $t_0=2000$ and we observe all the individuals in our sample (1761) until $t=2009$. Academics may present three different categories of entrepreneurial activity: they may have not created any company in the period 2000-2009,

they may have created one company in the period 2000-2009, or they may have created multiple companies in period 2000-2009. Different to most survival models, individuals in our study do not exit the sample after the event has occurred as they may be involved in several commercial ventures.

Figure 10: smoothed baseline hazard function (gauss) of the event ‘creation of a company’



Without introducing any covariates, we can estimate the baseline hazard function based on the data displayed in Figure 10. We can derive from this baseline hazard function that an academic in our sample typically gets involved in the creation of a company between 4 and 6 years after entering the observation sample. Before that, it is very unlikely that he/she gets involved in entrepreneurial activities and after 4 to 6 years the chances that he/she is involved in a start-up significantly decrease again.

Variables

Dependent Variable. As explained above, the dependent variable is the baseline hazard rate for each individual in each year of observation. The hazard rate represents the researcher’s decision to either get involved in a newly founded venture as a director or as a co-founder. The dependent variable captures the event of becoming an academic

entrepreneur. For every year in the sample the variable can take value 1 if the researcher started a company in that year, 0 otherwise. In the overall sample, 16% of the academics are involved in start-ups in the period of our study. This figure is marginally higher than found in other studies, in part reflecting the seniority of our sample of academics.

Entrepreneurial Capacity. To test hypothesis 1, we introduce a first independent variable in our analysis, which is the researcher's *entrepreneurial capacity*. The construct entrepreneurial capacity is based upon Nicolau et al. (2008) and Nicolau et al. (2009). It consists of three items: (1) 'I frequently identify opportunities to start-up new businesses (even though I may not pursue them)'; (2) 'I frequently identify ideas that can be converted into new product or services (even though I may not pursue them)'; (3) 'I am generally not interested in ideas that may materialize into profitable enterprises (reverse-coded)'. The respondents were asked to rate these items on a 5-point Likert scale going from 'strongly disagree' to 'strongly agree'. The final measure is an average of the three scores given: the Cronbach Alpha for the construct obtained is 0.8, with well above standard thresholds for new and short scales. Overall, the average self-reported entrepreneurial capacity of an academic is 2.9 (see Table 11).

Social Environment. Several studies have shown that social influences increase the likelihood that an academic will become an entrepreneur (Kenney and Goe 2004; Krabel and Mueller 2009), typically refer to the availability of show cases and best practices in the direct environment of the academic as main motivators. For instance, Stuart and Ding (2006) show that proximity to other academics who have started new spin-offs significantly increases the likelihood that a focal scientist will engage in entrepreneurship. In other words, having academics who have successfully started spin-offs does have a positive impact on others. Kim and Miner (2007) further show, in a review of the literature on vicarious learning, that having both positive *and* negative showcases in the close proximity is a good indicator of vicarious learning. Regardless of whether there is a direct contact between the academics who are involved in the spin-offs or not, the existence of these spin-out companies in the local setting is a source of learning and norm creation.

In line with this, to measure the social environment, which prevails at the university where the academic is employed, we measure the number of *spin-offs* created by this university in the same year. This data has been included in the model as panel data: every individual is observed in nine periods (2001 – 2002 – 2003 – 2004 – 2005 – 2006 – 2007 – 2008 – 2009) and the number of spin-offs changes according to the period. Therefore, each entry in the model corresponds to a combination researcher-period. The data on spin-offs

from universities is derived from the HE-BCI survey: data are available from academic year 2002/2003 to academic year 2007/2008. As our analysis spans other years, we have used the data of the closest year to fill in the missing values in the data.

We assume that if a university generates a large number of spin-offs in a given year, this reflects a strong social appreciation of this kind of commercial activity at the university in this period. As shown in Table 11, an average UK university generates on average between three or four spin-offs per year. However, the standard deviation is quite high and the maximum number of spin-offs was 25.

Entrepreneurial Experience. The variable *past ventures* measures how many commercial companies the researchers were involved (as entrepreneurs) before 2000. 28% of the academics we observe between 2000 and 2009 had a venture before that period.

TTO presence. As mentioned above, all UK universities have started to create central TTO offices from the middle of 1990s. By the end of the 1990s, almost all UK universities had created these offices, partly financed by government funding, and started to develop best practices. So, academics who started their academic careers at a postdoctoral level after this period of TTO emergence and expansion are likely to have familiarized themselves with the activities of a TTO. To capture this transformation in the climate for academic entrepreneurship in the UK in the late 1990s, we have introduced in the model an additional variable at the individual level. The dummy variable *TTO* takes a value of 1 for researchers who have been awarded a PhD after 1998 and a value of 0 for researchers who have been awarded a PhD before 1998. 18% of the academics in our survey have received their PhD after 1998, indicating that most of the sample were trained before the emergence and expansion of UK TTOs.

TTO efficiency. To measure the efficiency with which a TTO operates, we include the number of *patent applications* of that university as a proxy, related to the number of employees at the TTO office. Thursby and Thursby (2002) have shown that the efficiency of the TTO directly results in an increase in patent applications at the level of the university. Other output measures such as income from licenses or contract research depend much more on the quality of the underlying research base at these universities, the socio-economic environment in which the universities are located and the overall prestige of the university. In line with the proxy for entrepreneurial efficacy, this variable changes over time for each of the universities in the sample. An average UK university applies for 42 patents a year and has a TTO office with 38 employees. Again, the standard deviation is quite large and the

maximum patent applications, which we noted in a given year was 185, while the largest TTO office employed 240 people (see Table 11).

Control variables. We include several control variables in the estimation. First, Stuart and Ding (2006) have shown that whether an academic works at a top 10 university in the US or not, explains the degree of entrepreneurial activity of that academic. In the UK, there are clearly four universities, which have consistently outperform the rest in terms of science and technology, so we include a dummy variable capturing these universities, namely University of Cambridge, University of Oxford, Imperial College London and University College London. We also control for the department's *research quality*, which has been indicated by Bercovitz and Feldman (2008) as an explanation of entrepreneurial activity of academics. This variable is measured as the percentage of staff rated 'internationally leading' and 'international excellent', which is a signature measure of research quality used for allocating funding in the RAE. In the entrepreneurship literature, it is often found that women have less probability of starting a business than men. Given this, we include a gender dummy to capture whether the academic is male or female. Overall, only 13% of our respondents are female. Control variables related to demographic characteristics have been reported by the respondents, while control variables on universities and departments have been extracted from the Research Assessment Exercise and the HEBCI survey.

Table 11: Descriptive statistics (chapter 5)

Variable	Mean	Std. Dev.	Min	Max
[1] Gender	0.13	0.33	0	1
[2] Department quality	62.29	15.47	10	95
[3] Top university	0.19	0.40	0	1
[4] Entrepreneurial capacity	2.93	1.00	1	5
[5] University spin-offs	3.24	4.03	0	25
[6] Entrepreneurial experience	0.15	0.51	0	5
[7] TTO	0.18	0.39	0	1
[8] University patent applications	41.60	44.71	0	185
[9] Professor	0.54	0.50	0	1

Table 12: Correlation Matrix (chapter 5)

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
[1] Gender	1.00								
[2] Dept. quality	0.00	1.00							
[3] Top university	0.06	0.42	1.00						
[4] Entrepr. capacity	-0.07	0.01	0.00	1.00					
[5] Univ. spin-offs	-0.01	0.20	0.21	0.02	1.00				
[6] Entrepr. experience	-0.07	0.04	0.07	0.23	0.04	1.00			
[7] TTO	0.14	0.05	0.01	0.03	-0.02	-0.09	1.00		
[8] Univ patent applications	0.03	0.43	0.70	0.00	0.18	0.02	0.00	1.00	
[9] Professor	-0.12	0.00	0.01	0.03	0.01	0.12	-0.40	0.00	1.00

RESULTS

Table 13 provides the results of our model. Model 1 is the baseline model. The gender control variable is statistically significant and negative (the coefficient is lower than 1). This means female academics have 40-50% less chance of being engaged in an entrepreneurial venture than their male equivalents. Also the quality of the research department plays a role. Academics who work at research departments with a high research status have a slightly higher chance of being involved in entrepreneurial venture. This result confirms that academic excellence and commercial outputs are often complementary to one another (Stuart and Ding 2006; Bercovitz and Feldman 2008). Yet, being employed at a top university does not make a significant difference in chance of being involved in an entrepreneurial venture.

Table 13: Estimation model

VARIABLES	(1)	(2)	(3)	(4)
Gender	0.465** (0.125)	0.641 (0.174)	0.679 (0.185)	0.714 (0.194)
Department quality	1.016** (0.005)	1.015** (0.005)	1.014** (0.005)	1.013* (0.005)
Top university	0.900 (0.161)	0.766 (0.142)	0.662+ (0.161)	0.669+ (0.162)
Entrepreneurial capacity		2.568*** (0.206)	2.243*** (0.246)	2.188*** (0.240)
University spin-offs		1.026+ (0.015)	1.022 (0.015)	1.023 (0.015)
Entrepreneurial experience		1.313*** (0.091)	1.269*** (0.089)	1.203* (0.087)
TTO			0.545** (0.111)	0.795 (0.176)
Univ. patent applications			0.987+ (0.007)	0.987+ (0.007)
Entrepr. capacity*patent app.			1.004* (0.002)	1.004* (0.002)
Professor				2.033*** (0.323)
Scientific discipline	yes	yes	yes	yes
Observations	13,892	13,892	13,892	13,892

Notes: Hazard ratios reported instead of coefficients, seEform in parentheses *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$

Model 2 adds the two individual level variables and the nested social environment variable. These variables correspond with Hypotheses 1, 2 and 3: (1) entrepreneurial capacity; (2) entrepreneurial experience and (3) social environment. Hypothesis 1, which links the entrepreneurial capacity of an individual academic to his/her entrepreneurial activity, is confirmed in this model. Each change on the entrepreneurial capacity scale of one unit increases the chance that the academic will eventually get involved in an entrepreneurial venture by a staggering 157%. In line with hypothesis 2, we analyzed the entrepreneurial experience of an academic by using his/her involvement in previous entrepreneurial initiatives as a proxy. Again, we find that this variable is positive and significant, indicating the impact of having been involved in entrepreneurial initiatives before increase the probability of being involved in these initiatives in the future, thus confirming Hypothesis 2. In particular, being a serial or habitual entrepreneur increases the likelihood of getting

involved in a next entrepreneurial venture by close to 30%. To test Hypothesis 3, we used the spin-offs that were generated in a given year in the academic's home university as a proxy to reflect the social environment, which prevailed at that university in that year. In line with other studies on social environment, we find a positive and significant impact of the social environment on the probability that an academic will create his/her own business. However, the impact of this environment is much weaker than the impact of the entrepreneurial capacity of the academic.

Model 3 adds the TTO level variables. First, we hypothesized that academics that had been familiar with TTO activities at the beginning of their career would have a higher propensity to engage in entrepreneurial activities during their academic career. This hypothesis is in line with the social learning hypothesis, which was put forward by Bercovitz and Feldman (2008). However, we find little empirical support for this hypothesis. On the contrary, academics that have received their PhD *after* 1998 have a much lower probability of being involved in a venture than those that have received a PhD before 1998.

Model 4 also includes a robustness check to analyze the counter-intuitive result of the test of Hypothesis 4 in Model 3. In that model, we find that academics that received their degree after 1998 have a lower chance of being engaged in entrepreneurial activities than those who received their PhD before. An alternative explanation for the negative sign might be that academics that answered our survey stay connected with the university in a particular role, even after founding a company or stay full time academics while being involved in the board of these companies. Therefore, we may miss those researchers who leave the academic community to be more directly involved in their new ventures. We might expect that tenured academics have more possibilities to engage themselves in commercial activities while staying at university than their non-tenured colleagues, who still have to publish actively to build their tenure profile. In order to capture this question, we include a dummy variable to measure whether the academic in a given year had already achieved the status of professor or not. We find that professors are twice as likely to engage in entrepreneurial activities than their non-tenured colleagues. After controlling for professorship, we also find that the TTO variable, which distinguishes between those who have received their PhD after and before 1998, is no longer significant. However, the sign remains negative. So, the result does not change our initial findings with respect to Hypothesis 4.

Finally, we hypothesized that the interaction between the efficiency of the TTO at a given university (proxied by the number of patent applications in a given year in relation to the number of employees at the TTO in that year) and the entrepreneurial capacity of the

academics would increase the likelihood that academics would get involved in entrepreneurial activities. In other words, we expected that the TTO would facilitate the process of entrepreneurial activity for those academics that are already likely to get involved in entrepreneurial activities. We indeed find a positive relation between the interaction term of the TTO's efficiency and the entrepreneurial capacity of an academic. However, this relation is only marginally significant, so Hypothesis 5 only receives weak support.

Overall, we can conclude that the hypotheses which link the different predictors of entrepreneurial intent to entrepreneurial activity of individual academics receive strong support, while the hypotheses which relate the role of the TTO to the entrepreneurial activity of an academic receive little or no support.

DISCUSSION AND CONCLUSIONS

Explaining why academics become involved in entrepreneurial ventures is a domain that has received increasing levels of interest from academics and practitioners. Most papers of the first generation of studies, i.e. published before 2005, have tried to use university-level factors, such as development of the TTO, to explain the rise in the number of entrepreneurial ventures that spin-out of these universities. In general, these studies are empirically driven exercises and remain poorly linked to the wider entrepreneurship literature. Indeed, these university-level studies have often ignored the role of the individual academic in the process of spin-off creation, while more recent studies have tried to explain social mechanisms that lead individual academics to engage in entrepreneurial activities. Two of these studies (Stuart and Ding 2006; Bercovitz and Feldman 2008) have more specifically shown that the (local) social environment in which an individual operates plays an important role in explaining his/her entrepreneurial activity.

This paper extends the literature in two important ways. First, we offer a link between the individual-level explanations of entrepreneurial activity that are found in the entrepreneurship literature and the emerging literature on academic entrepreneurship. Our analysis looks at the social environment surrounding the academic in line with the academic entrepreneurship literature, but also at individual-level characteristics such as entrepreneurial capacity and experience. Although entrepreneurial capacity, defined as the capacity to identify, recognize and absorb opportunities, and entrepreneurial experience, in terms of previous involvement in entrepreneurial activities, have been identified as determinants of the tendency to become an entrepreneur in the mainstream entrepreneurship literature, they have been ignored by the literature on academic entrepreneurship. By including these variables in a

model of academic entrepreneurship, we helped to realign the literature on academic entrepreneurship with the wider literature on entrepreneurship. Second, by exploring the role of the TTO as an additional explanation in this model, by both showing the potential direct impact of the TTO and its indirect interaction with the individual level variables, we are able to integrate the TTO level and individual levels. This combination allows us to gain insights into whether and how TTO efforts shape individual-level entrepreneurial behavior.

The results of the analysis have important implications. First, they suggest that among the individual-level variables, the opportunity recognition capacity of an academic is by far the most important variable to predict whether an academic will get involved in entrepreneurial activities or not. Although most emphasis has been put in the literature on explaining how the social norms in a particular department contribute to the eventual engagement of a particular academic in an entrepreneurial venture, these social norms have much less predictive power than the individual entrepreneurial capacity of the academic, which appears to be to a large extent genetically imprinted. In addition, by showing that an academic who has already been involved in entrepreneurial activities is more likely to be involved in subsequent entrepreneurial activity, the results suggest that individual attributes might play a much larger role than initially thought in drivers of academic entrepreneurship.

Second, our results suggest that the role of the TTO in increasing the entrepreneurial activities of academics appears to be rather limited, or even non-existent. The efficiency of a TTO or even the mere presence of a TTO has often been used to explain why particular universities were able to produce so many research-based spin-offs. This might be a plausible finding, if we only take spin-offs into account which are based on a formal transfer of technology and, in which the TTO has a major stake. However, if we take a wider range of the start-ups into account, regardless of whether they are officially listed as spin-offs or not and regardless of whether there is a formal IP relation between the spin-off and the university, we find that the presence of a TTO plays little role in shaping academic venture creation, and that the efficiency of the TTO is only of marginal value.

This finding raises questions about the overall efficiency of TTOs in commercializing results through entrepreneurial ventures. Many of these TTOs adopt best practices, which focus on assisting the transfer of technology to industry, including new companies under the assumption that academics have an entrepreneurial capacity. TTOs spend most of their time protecting technology and formalizing the contractual relations around this technology. Much less effort is put into the development of a social environment, which stimulates entrepreneurial activities among academics such as entrepreneurship training,

entrepreneurship seminars etc. and little or no effort at all is put into attracting individuals with a high level of entrepreneurial capacity at the universities. This is an important issue in the light of the central topic of how the Bayh Dole Act has affected technology transfer activities. In Europe, the Bayh Dole Act was not only a regulatory framework, which had changed. It also formed the basis of a number of initiatives that were taken by various governments to support the development and professionalization of TTOs.

In the case of the UK, various schemes for supporting university technology transfer were extended and enhanced in 1999 to provide direct support for university's 'third stream' activities (Mustar and Wright 2010). The first of these programs, Higher Education Reach Out to Business and the Community Initiative (HEROBAC), was launched in 1999 and was later succeeded in 2002 by the Higher Education Innovation Fund (HEIF), which included four subsequent rounds of funding. These programs began by allocating funding to universities on the basis of competitive tender, but in 2003 they moved to block funding based on performance measures. Overall, the UK government has provided almost £700 million pounds (in constant 2003 prices) in direct support to English universities for third stream activities from 2000 to 2008, with another £340 million pounds committed for the 2009-2011 period (PACEC 2009). Funding within HEROBAC and HEIF have included support for a range of commercial activities, including commercial venturing by academics, personal exchanges between university and industry and university patenting. However, the majority of these funds have been used to build up and extend the efforts of the universities' TTOs.

Our findings of the salience of individual characteristics are consistent with Lockett and Wright (2005), who question the role of TTOs if the universities do not undergo a structural change. It is clear that universities have created TTO offices of considerable size and scope, and have very high expectations about the commercial results that these TTO offices might generate through entrepreneurial ventures. However, the universities, which have invested so much in the TTOs, made little or no attempt to attract entrepreneurially oriented academics as tenured professors or to recruit entrepreneurially oriented individuals in an academic career. Nor was entrepreneurship a core subject in the doctoral education of PhD students, especially of those aiming for an academic career. Yet, it is exactly the entrepreneurial capacity of the academic, which seems to be the most predictive factor of his/her entrepreneurial behaviour.

Limitations and future research

This study presents some limitations which can open up avenues for future research. Following previous research in this field (Nicolaou, Shane et al. 2009) we assume that entrepreneurial capacity is determined by genetic predisposition and it is therefore exogenous to the entrepreneurial behaviour itself. In this respect, our definition of entrepreneurial capacity largely overlaps with the definition of opportunity recognition and therefore suffers from the empirical problem that it is possible to know that an opportunity was recognised only by observing the final outcome. Given our research setting, we are not able to disentangle the share of ability to recognize opportunities which is linked to genetic factors and the part which is influenced by entrepreneurial behaviours themselves. Future research should take into consideration the possibility of an iterative feedback between being engaged in an entrepreneurial venture and entrepreneurial capacity.

POLICY RECOMMENDATIONS

There are a number of policy recommendations, which can be derived from this study. First, it is very clear that the individual attributes of the academics employed at a particular university are very important in explaining institutional levels of entrepreneurship. The university's potential for commercializing its research results through entrepreneurial ventures is liable to depend on its ability to attract and retain academics with high levels of entrepreneurial capacity. Given the importance of this individual level, the creation and efforts of TTOs is of modest or little use in itself unless such a creation is backed up by changes in the hiring and promotion practices of the university itself. This suggests that one of the implications of the Bayh-Dole and its European counterparts may be to make the university itself a more attractive place for individuals with a high entrepreneurial capacity to work. In this sense, the effect of these policies may be to deter self-selection of individuals with high levels of entrepreneurial capacity away from academic careers. Of course, this outcome is somewhat distant from the original intentions of these laws to change the culture of academics towards industrial engagement and commercialization.

Second, it is clear that the analysis that once an academic is tenured, he/she is more likely to engage in entrepreneurial activities. This may be so because early career researchers may wish to focus on meeting their universities tenure requirements in terms of publication in the formative part of their career. A significant involvement in a commercial venture may distract them from these efforts. Second, given the slow pace of tenure processes in many European universities, it may be that early career researchers exit academic life altogether in

order to express their entrepreneurial intent. One implication of these findings is that if a university wants to stimulate involvement in entrepreneurial activities, they should ensure that promotion and tenure decisions reward such efforts. They should also seek to make decisions about promotion within a reasonable time span. Since, in many European universities, the process to obtain a full professorship can last over decade for even the most talented researcher, this is an important issue. With such a long gestation period to a professorship, it may be that many entrepreneurial academics turn away from academic careers as their efforts are unrewarded or unappreciated by their universities.

Third, we found that academic excellence, reputation and entrepreneurial activity go hand-in-hand. This means that attracting entrepreneurial academics does not mean that these academics will need to sacrifice their scholarship. The underlying quality of the research at the department remains highly important to explain the potential of starting new businesses based upon that research. So, changing career and recruitment practices does not imply that academic norms should be devalued. Only, these environments might be made more attractive to potential academics with a high degree of entrepreneurial capacity.

CHAPTER SUMMARY

This chapter focuses on the relationship between individual and organizational attributes in determining academic entrepreneurship. Using a large-scale panel of academics from a variety of UK universities from 2001-2009, the chapter shows that individual level attributes and experience are the most important predictors of academic entrepreneurship. The academic's social environment plays an influential, but less prominent role than individual level factors. Finally, results show that the activities of the TTO play only a marginal and indirect role in driving academics to start new ventures. The contribution of this chapter is to enrich understanding of the nature of academic entrepreneurship by incorporating individual attributes which the wider entrepreneurship literature emphasizes as being central determinants of both entrepreneurial activity and success. Moreover, this study offers the possibility to gauge the role of TTOs as facilitators (or blockers) of individual-level predispositions towards new venture creation.

CHAPTER 7 - IN GOOD COMPANY: THE INFLUENCE OF PEERS ON INDUSTRY ENGAGEMENT BY ACADEMIC SCIENTISTS¹¹

INTRODUCTION

There is broad agreement that interactions between public science and industry contribute significantly to innovation in products, processes and services (Mansfield 1991; Cohen, Nelson et al. 2002; Murray 2002; Toole and Czarnitzki 2009). Simultaneously, academic science itself often benefits from interactions with industry as many academics work in fairly applied fields, such as medicine and engineering (Nelson and Rosenberg 1994), and problems in industry have traditionally served as a powerful stimulus for progressing both basic and applied science (Rosenberg 1982; Stokes 1997). Interaction can take many forms, from joint research, contract research and consulting to more directly commercial activities such as the founding of university spin-out firms (Louis, Blumenthal et al. 1989; Agrawal and Henderson 2002; Cohen, Nelson et al. 2002; Shane 2002; D'Este and Patel 2007; Toole and Czarnitzki 2010).

While interaction within industry has long been common practice in industry (Mowery 2009), in the last thirty years the emergence of novel technological opportunities, such as in biotechnology or computer science, have driven renewed interest in the conditions that facilitate university-industry interaction (Mowery, Nelson et al. 2001). As governments have increasingly come to see universities as 'engines of economic growth' (Feller 1990), and universities themselves seek to mobilize additional resources via commercialization and industry collaboration, a considerable body of research has addressed the question of what drives individual academic researchers to engage in such interaction. Authors have predominantly focused on the role of individual characteristics, including demographic attributes, social capital, experience and professional status, and organizational factors, such as the attributes of universities (Owen-Smith and Powell 2001; Di Gregorio and Shane 2003; Lockett and Wright 2005; Link, Siegel et al. 2007; Boardman 2008).

The extant body of work has yielded interesting results yet remains relatively silent on an important aspect that may drive participation in industry engagement, which is academics' local work context. Universities are professional bureaucracies (Mintzberg 1979) that are

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strongly decentralized in a sense that little directive or socially relevant influence is exerted by the university as such. Rather, academics belong to departments which operate relatively independently, with their respective academic disciplines being their primary audiences. Recognizing this crucial aspect of the organization of scientific work, authors have started to explore how academics' immediate work context, i.e. their department, shapes their involvement in industry-related activities (Louis, Blumenthal et al. 1989; Stuart and Ding 2006; Bercovitz and Feldman 2008). This research has suggested that academics, though often seen through the lens of their individual achievements, are highly susceptible to the attitudes and behaviors of their work colleagues, the prevailing local norms and the local leaders. These insights parallel findings on entrepreneurial behavior, indicating that individuals' immediate work colleagues exert considerable influence on transitioning them towards founding a firm (Nanda and Sorensen 2010).

The emerging research stream on local social influences on academic scientists' behavior has produced promising insights but questions remain about the precise mechanisms that make the social context relevant for industry engagement. For instance, we know little about whether local effects are exerted by a common culture, or norms, collective learning and imitation, or hierarchical imposition of policies. In this paper, we contribute to the debate by arguing that local *peers* play a key role in determining academics' individual behaviors. In other words, individuals are strongly influenced by the behavior of their workplace peers, that is colleagues of the same rank. We develop hypotheses to test the idea that these peer effects are generated by two distinct mechanisms. The first mechanism is social learning, indicating that individuals reduce uncertainty by following the behavior of their peers (Bandura 1977; Nanda and Sorensen 2010). The second is social comparison whereby individuals choose local peers to act as a reference group (Hyman 1942; Ibarra and Andrews 1993). While social learning is an indication of cooperative attitude, the incidence of social comparison suggests that rivalry is also at play, and that individuals compare themselves with their colleagues in order to advance their careers in a competitive professional environment.

We test our hypotheses using multi-source data on 1,371 academic scientists in a range of disciplines, in UK universities. In doing this, we make a particular effort to address the so-called reflection problem common to econometric studies of peer effects (Manski 1993) which can result in spurious correlation. The reflection problem states that evidence of peer effects is likely to be overstated in studies where the average behavior of a group is translated as explaining individual behavior. We undertake several tests to rule out possible alternative explanations for real endogenous peer effects.

Our study highlights the extent to which industry engagement is shaped by the behavior of the focal individuals' peers. We are able to pinpoint the precise nature of social influence and simultaneously to exclude a variety of other mechanisms that may be responsible for generating behavior alignment in local work contexts. We show that individuals look to their immediate peers for their orientation, both collaboratively via learning as well as more competitively via social comparison. At the same time, we note the absence of effects exerted by local social norms in informing individuals' engagement behaviors implied by some previous research. Our results suggest that there are two, potentially substitutable paths that determine industry engagement by academics, or discretionary behavior in professional environments more generally. One path is represented by the accumulation of experience with respect to the behavior in question; the other rests on perceived competition amongst individuals. Our findings have interesting implications for how specific behaviors might be promoted within local work contexts by universities.

THEORY BACKGROUND

Academics have different degrees of autonomy over specific aspects of their job roles. For instance, the allocation of teaching duties is an area where many academics enjoy less discretion compared to other areas of academic activity. However, academia is unique in allowing individuals to engage proactively in a wide range of diverse activities, from becoming a start-up entrepreneur, to acting as a government advisor, to taking on a role in civil society. Chief amongst the work areas where academics have considerable discretion is engagement with industry partners. While teaching and conducting research were the traditional mainstays of academic work, in recent years, individual academic's engagement with industry has become important for faculty, university managers, and policy-makers (Markman, Siegel et al. 2008). Increased regard for industry engagement has been driven partly by new technological opportunities, such as biotechnology and computer science (Mowery, Nelson et al. 2001), and the way that universities have responded to them. Governments regard universities as 'engines of economic growth' (Feller 1990) and seek to encourage universities to be entrepreneurial by engaging with industry. In addition, universities are making their own concerted efforts to build technology transfer functions and enhance their receptivity to industry activities (Owen-Smith 2003; Ambos, Mäkelä et al. 2008; Markman, Gianiodis et al. 2009).

For the individual academic, these developments have resulted in increased opportunities to engage in discretionary behaviors (Rothaermel, Agung et al. 2007). Engagement with

industry takes many different forms and therefore affords individuals with opportunities to ‘craft’ their jobs by actively shaping both the tasks and the relationships around them (Wrzesniewski and Dutton 2001). While the decision to found a company and perhaps to abandon university employment in order to become an entrepreneur is an extreme variant of this behavior, it is more common for academics continue with their research careers and engage with industry in ways that may include patenting and licensing, collaboration and consulting (Owen-Smith and Powell 2001; Agrawal 2006; Link, Siegel et al. 2007; Perkmann and Walsh 2008). Engagement in any of these latter types of activity involves personal initiative and effort to approach and win industrial partners. Academics also have more freedom to decide about engagement with industrial partners than over their teaching loads and which courses should be offered. Autonomy is an important antecedent of any discretionary behavior because it allows the choice to adopt the behavior or not, which may not be possible in more structured work situations (Grant and Ashford 2008). In addition, at many universities, engagement with industry does not count towards career advancement in the same way as the almost universally used measures of publication and other research-related outputs.

Extant work looks at what determines individual industry engagement behavior at universities. While a number of studies explores the role of individual-level factors in informing academics’ engagement, there is a stream of research that suggests that the social environment in which individuals operate plays an important role. Louis et al. (1989) found that local norms were more powerful predictors than individual characteristics in terms of engagement with industry. Being embedded in an academic department with a culture that is supportive of entrepreneurial activities can help counteract the disincentives created by a university environment that does not recognize such efforts (Kenney and Goe 2004). Using a sample of US-based life scientists, Stuart and Ding (2006) found that the more university and divisional colleagues and co-authors were involved in private sector firms, the more likely an individual academic would be entrepreneurial.

This work has shifted attention away from individual characteristics towards considering how the local social environment may stimulate proactive behavior among academics. A qualitative study on university patenting by Owen-Smith and Powell (2001) provides a graphical illustration of how successful commercialization by immediate peers and the ensuing prestige, affected the aspirations of other individuals. Thus, incidences of success can be powerful forces for work colleagues, providing role models and pointing to the feasibility of commercialization behavior (Kassicieh, Radosevich et al. 1996; Wright, Birley et al.

2004). Bercovitz and Feldman (2008) confirmed the presence of such peer effects in their study of medical researchers, which found that individuals were more likely to disclose inventions if their departmental colleagues of similar seniority did so as well.

These studies have generated important insights into how academics' social workplace environments shape their industry engagement but we lack knowledge about the specific mechanisms underlying this effect. We develop a framework that emphasizes the role of peers. A peer group is a specific type of reference group which the individual takes into account when selecting a behavior amongst several alternatives (Hyman 1942; Kemper 1968). An individual's peers are of similar rank and have similar attributes to the individual, and belong to his or her immediate social context. The influence of peers on individual behavior has been documented in many different empirical settings, including neighborhoods (Dietz 2002), education (Coleman 1966; Jackson and Bruegmann 2009), movie sales (Moretti 2011), health plan choices (Sorensen 2006), and workplace contexts (Lazega 2000; Nanda and Sorensen 2010).

HYPOTHESIS DEVELOPMENT

In developing our hypotheses about how an academic's engagement with industry is influenced by peers, we consider departmental colleagues of similar rank as the salient peer group for the academic's work-related behavior. The department is a central organizational feature of academic life and is constituted by the community of immediate work colleagues. Although departments may be composed of smaller units, 'the department' is the principal locus of decision-making in academia (Alpert 1985). Working in a department imposes obligations and responsibilities on academic staff, such as sharing teaching workloads, participating in departmental committees, and the like. Hiring, promotion, and applications for tenure are normally decided at department level before consideration by the university organization. Within the same university, departments may differ about expectations related to scholarship, organizational citizenship behavior, approaches to commercialization, etc. In this context, there are two mechanisms that lead to individuals being influenced by the behavior of their peers.

First, individuals look to their peers for cognitive orientation, and adopt behaviors through vicarious learning (Bandura 1977; Manz and Sims 1981; Nanda and Sorensen 2010). Peers operate in the individual's immediate proximity, hence their actions are extremely visible and they provide models of how to pursue opportunities and resolve problems. Academic careers involve investment in discipline-relevant knowledge and adoption of the

modus operandi of academia (Stephan and Levin 1992). The proximity of departmental colleagues to the individual allows their behavior to be easily observed, providing opportunities for learning and validating assumptions about how to act (Manski 2000). Peers may actively support this learning process by sharing experience and guiding colleagues. New ideas require early support, nurture and examination, all of which local colleagues can provide, which will give signals about the potential scientific value of the idea (Oettl forthcoming). Since in the early stages, many new ideas can be expressed only incompletely (Zucker, Darby et al. 2002), face-to-face communication with trusted local colleagues can provide a low-cost and efficient mechanism to assess the value and viability of an early stage scientific idea.

Like pure scientific work, working with industry and commercializing research also require specific skills, which differentiate individuals (Owen-Smith and Powell 2001). Methods and techniques in novel areas of science and technology often develop locally because they are incompletely codified, and the tacit knowledge is shared with departmental colleagues (Agrawal 2006). Making contact with potential industrial partners, managing relationships well, and recognizing the economic or technological value of scientific findings are non-trivial activities that require skill and experience. Learning from others about how to engage with industry partners and from their experience, encourages individuals to engage in similar behavior. Especially in conditions of uncertainty, referent others are used to establish a more accurate view of reality and make judgments about the desirability and feasibility of a specific behavior (Turner 1982).

A second peer effects mechanism is comparison with a chosen reference group (Hyman 1942; Merton and Kitt 1950; Ibarra and Andrews 1993). The peer group provides a standard or check point that can be used to evaluate a situation, and particularly the individual's position in it (Shibutani 1955). Peer groups can be a yardstick for ambition, based on the desire to relate to and be accepted by a group. Individuals tend to compare themselves with others whom they consider as having similar attitudes or abilities, and their aspiration are influenced by what they perceive to be the level of achievement of the reference group (Festinger 1954). In academia, this means that junior members of faculty will compare themselves to colleagues with similar experience, rather than to senior colleagues who are out of reach in terms of current levels of achievement. Engaging with industry is one area that is likely to involve comparison with a department reference group. Attracting industry funding for personal research projects, or engaging in lucrative consulting projects, are activities where outcomes are uncertain; comparative self-evaluation with peers can be useful to build

confidence. Individuals observe their colleagues and establish individual ambitions based on emulating the observed behavior. Self-categorization theory (Turner, Hogg et al. 1987; Hogg and Abrams 1988) suggests that uncertainty promotes in-group identification and makes the members of an individual's peer referent group the focus of social comparison. The above considerations lead us to hypothesize that:

H1. The extent of an academic's engagement with industry is positively associated with the extent of industry engagement of their departmental peers.

H1 describes an alignment between individual behavior and the aggregate behavior of the peer group and describes two possible mechanisms that generate this alignment. In order to establish whether both mechanisms are at work, we investigate how peer group effects are reinforced or reduced by the characteristics of focal individuals. Examining how individual characteristics moderate alignment with peer behavior will allow us to infer which mechanisms are at work.

First, we consider the individual's previous professional experience and stock of knowledge accumulated from previous learning. Academics with previous experience of working in industry will be more familiar with the world of industrial research and able to benefit from a wider range of resources and information relevant to collaboration with private firms. These individuals face less uncertainty in collaborating with industry compared to colleagues with no previous experience. For instance, previous experience provides superior knowledge on the benefits that can be expected from engagement with an industry partner, such as access to a broader range of research problems which may promote the combination of scientific discovery with technological innovation. Individuals with industry experience will be more familiar with the needs of industrial partners and their approach to establishing and managing research projects (Mansfield 1995); they will be better able to cope with the tensions between satisfying academic and industrial objectives (Boardman and Bozeman 2007). Inexperienced individuals may find it difficult to reach agreement with industrial partners about the focus of the research project and the timing and nature of dissemination of research findings. Resolving these issues involves a learning process which, for those with no previous experience of working with industry, can be facilitated by departmental peers. Mimicking the behavior of peers can substitute for industry experience. If academics' susceptibility to peer behavior is moderated by the extent of their previous industry

experience, we have support for the assumption that peer effects in academic departments are driven by learning mechanisms. We hypothesize that:

H2: The effect of an individual's departmental peers on the extent of his/her industry engagement is negatively correlated with the individual's number of years of experience of working in industry.

Next, we consider the impact of the second peer effect mechanism, i.e. the comparison process. A characteristic likely to influence individuals' propensity to take behavioral cues from their work peers is their own seniority within the organization. The influence of seniority on the individual's susceptibility to peer effects is likely to indicate the presence of social comparison in generating this peer effect. Individuals at the beginning of their careers are more concerned about advancement than more senior colleagues (Baldwin and Blackburn 1981; Jacobs, Karen et al. 1991). Professional competition in academic science is fierce, and success depends heavily on what the individual achieves in the early stages of his or her career. The choice of junior colleagues to engage in specific discretionary behaviors therefore is often informed by the desire to advance their career prospects. Competition for jobs exists among people at similar stages in their careers; therefore, for each individual the local peer group is representative of the broader reference group constituted by these candidates. Individuals will compare themselves to local colleagues of the same ranking and use them as a benchmark when selecting their own behaviors. This comparison process will be particularly important in relation to behaviors that are highly discretionary. For some activities the existence of formal rules will be sufficient to orient individual behavior; however there are no fixed prescriptions for activities such as engaging with industry, and young academics in particular will look to their peers for clues about how to behave.

H3: The effect of an individual's departmental peers on the extent of his/her industry-engagement behavior is lower for more senior individuals.

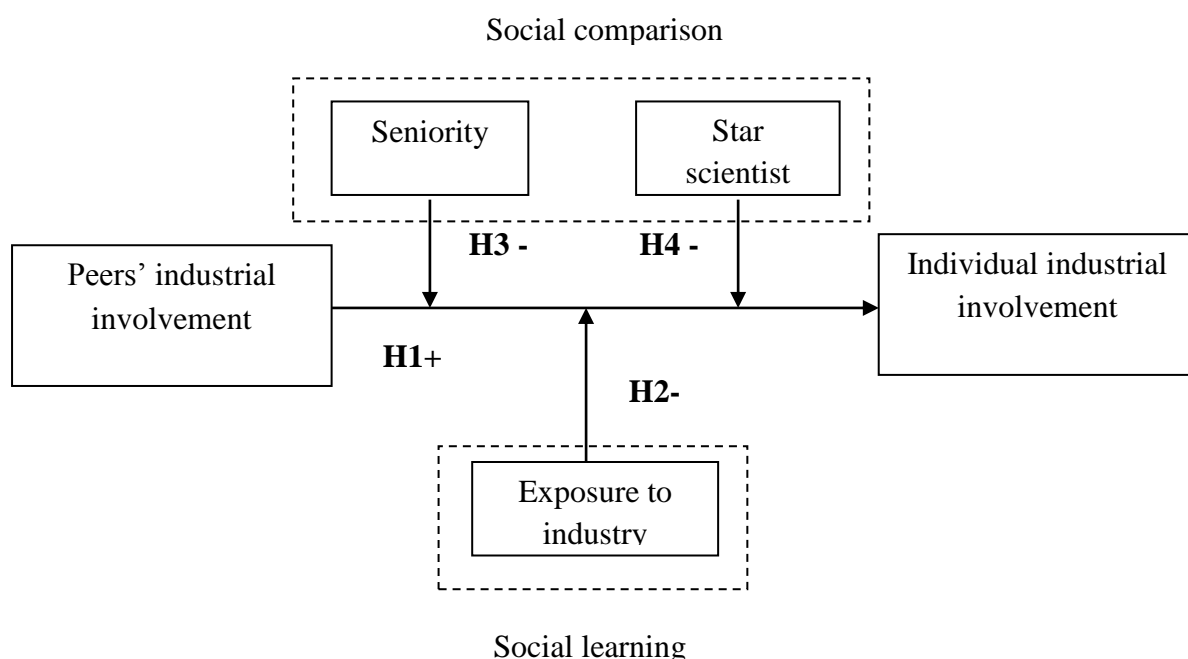
Next, we investigate how individual performance affects academics' susceptibility to peer behavior. It has been documented that a small group of highly effective researchers plays a disproportionate role within a scientific community in terms of productivity (Zucker and Darby 1996). 'Star' scientists also outperform their colleagues in terms of engagement in the commercialization of research and are responsible for a significant share of the economic activities at universities (Zucker and Darby 1996).

High performance is closely correlated to status within the scientific community. Over time, the status of stars becomes self-reinforcing because reputation attracts larger flows of resources, and provides higher visibility, resulting in more attention to the research outputs of these individuals (Merton 1968). It is likely that these excellent scientists will choose a reference group with which to compare themselves differently from their ‘average’ departmental colleagues. Social comparison often involves selective search for clues as to the similarity of peers to oneself (Mussweiler and Strack 2000). For star scientists, ‘similar others’ will likely be represented by other stars in the scientific community rather than departmental colleagues. ‘Average’ researchers will probably prefer to compare themselves with equals amongst their academic departmental colleagues. Thus average performers will tend to follow the behavior of departmental peers more than will star performers, which is further confirmation of the presence of social comparison processes underpinning peer effects in academic departments. We can hypothesize that:

H4: The effect of an individual’s departmental peers on the extent of his/her industry-engagement behavior is lower for star scientists.

Figure 11 illustrates the hypothesized model.

Figure 11: Hypothesized model, effect of peers' industrial involvement on individual academic engagement



DATA AND METHODOLOGY

Data

To explore our hypotheses, we exploited a unique dataset covering a population of 6,200 academic researchers in the UK, compiled from various sources. These include information on this population of scientists from the records of principal investigators and co-investigators who received grants from the UK Engineering and Physical Sciences Research Council (EPSRC) in the period 1992-2006. The EPSRC is the largest research funding body in the UK and, in 2008, disbursed £740m for research across all fields of engineering, mathematics, chemistry, and physics. The EPSRC encourages partnerships between researchers and third parties, such as private firms, public bodies, non-profit organizations, etc. However, for most research projects there is no requirement to have an industrial partner. The selection of projects is based solely on peer review. We used the EPSRC data to obtain information on each academic's research funding profile, including amounts of funding received. These data are comprehensive and cover all academics granted EPSRC funding in the UK over a period of 15 years.

First, we conducted an Internet-based survey of the 6,200 academics listed in the EPSRC records who were still listed as active academics on their respective university websites. The questionnaire covered various aspects of researchers' engagement with industry, such as engagement types and frequencies, and attitudes towards engagement. The survey instrument exploited items and scales deployed in previous surveys of academics (Bozeman and Gaughan 2007; D'Este and Patel 2007; Link, Siegel et al. 2007) and included several questions exploring individuals' attitudes towards engagement and entrepreneurship. A draft version of the questionnaire was pilot tested with 30 academics at Imperial College London. The final questionnaire was administered to the whole population between April and September 2009; it was introduced by a covering letter signed by the Chief Executive Officer of the EPSRC, followed a few days later by an email containing a personalized link to access the survey. Two further emails and telephone reminders were sent to non-respondents. We obtained a total of 2,194 completed questionnaires, corresponding to a response rate of 36%.

Second, we drew on data collected from a survey administered to the same population in 2004 (D'Este and Patel 2007) which also asked about the frequency of engagement with industry; 735 individuals answered both waves of the survey.

Third, we matched our sample with the population of academics included in the 2008 Research Assessment Exercise (RAE) (HEFCE, SFC et al. 2008). The RAE was a

government-mandated program to assess the quality of research of all universities and colleges in the UK. The assessment was carried out via disciplinary panel reviews of the publications, research environment, and research ranking of each department. The results were used as the basis for determining the allocation in subsequent years of research funding to universities not allocated via competitive bids for grants. RAE submissions contain information on ‘units of assessment’, usually departments or similar units. These submissions contain rich information about the character of the department, including the size of the unit of assessment and the amount and nature of funding it received in each of the previous seven years. We used this information to develop measures of the departmental environment of each individual in our sample.

Fourth, we matched the universities included in our sample with data derived from the government’s Higher Education-Business and Community Interaction Survey (HE-BCI) conducted in 2008, covering the years 2005-2007 (HEFCE 2008). This annual survey examines the exchange of knowledge between universities and society. It collects university level financial and output data on a range of activities, from the commercialization of new knowledge, through the delivery of professional training, consultancy, and services, to community-oriented activities.

Fifth, to capture details on respondents’ scientific productivity, we used bibliographic information collected from ISI Web of Science, including number of an individual’s journal articles, number of citations, names of the journals, and associated disciplines.

Our final data source was Eurostat (2003) which provides information on the university region (NUTS2 level), including Gross Domestic Product (GDP), business Research and Development (R&D) expenditure, and patent applications. These data are informative about the regional economic context in which academics operate; some local environments offer greater opportunities than others for industrial engagement.

We performed several checks on the sample used for the analysis to ensure its representativeness of the population being studied. First, to check the reliability of our response pool, we conducted some tests on the response population, looking for sources of bias in our sample. In particular, we analyzed whether there were differences in the typology of university of affiliation of the respondents compared to the rest of the sample. We performed a Wilcoxon-Mann-Whitney test and found no significant difference. Second, because only grant holders were targeted, there was a risk of sample selection bias since non-grant holders might behave differently in terms of engagement with industry. Since we did not have information on academics who had not received a grant in the period 1992 to 2006,

as a proxy for non-grant holders we used the group of academics in our survey who had not received a grant in the previous five years (2000 to 2006). We compared their level of involvement with industry with that of academics who had received a grant in 2000-2006 and found no statistically significant difference.

Dependent variables

Our dependent variable captures academics' industry engagement behavior through the construction of an index. The individual *industrial involvement index* (III) is a modified version of the index developed by Bozeman and Gaughan (2007). We used information from our survey data on types and frequencies of academics' industry engagement to construct the index (see Table 14). This list covers a broader range of industry engagement forms than captured in previous studies of peer effects on academic entrepreneurship because it includes a range of teaching, research, and consultancy engagements with industry.

Table 14: Types of researchers' interaction with industry

Type of interaction (j)	Frequency % (b _j =1)
Attendance at conferences with industry and university participation	82.7
Attendance at industry sponsored meetings	63.6
A new contract research agreement	58.0
A new joint research agreement	57.5
Postgraduate training with a company (e.g. joint supervision of PhDs)	47.7
A new consultancy agreement	47.6
Training of company employees	30.4
Creation of new physical facilities with industry funding	17.3
Creation of a commercial venture	3.74

Table 15: Coding of occurrences of researchers' engagement with industry

Questionnaire answer (category)	0	1-2	3-5	6-9	>10
Occurrence (<i>b_j</i>)	0	1	1	1	1
Volume of interaction (<i>T_j</i>)	0	1.5	4	7.5	10

The III was constructed as follows. First, for every type of industry engagement we established whether the researcher had collaborated or not ('occurrence', denoted by *b_j*); see Table 15 for how we coded response items. We computed frequency of each type of engagement for the whole population:

$$f_j = \frac{\sum_{n=1}^N b_{n,j}}{N} \quad (1)$$

where j is the type of industry engagement, n is the individual and N is the total sample ($N=1,895$). We constructed the index by multiplying the actual number of interactions declared by each academic for each channel (T_j) and the frequency of its non-occurrence ($1 - f_j$), and summed the scores.

$$III_n = \sum_{j=1}^9 T_j \cdot (1 - f_j) \quad (2)$$

The index takes account of the ‘difficulty’ and infrequency of certain activities such as the creation of new physical facilities relative to others such as attending industry sponsored meetings. We extend the measure proposed by Bozeman and Gaughan (2007), using more granular information that takes account of the actual number of occurrences of different types of engagement for every individual, as opposed only to occurrence.

Independent variables

Our main independent variable expresses departmental peers’ industrial engagement. Following Bercovitz and Feldman (2008), we define peers as an individual’s departmental colleagues of the same academic rank. We assume that to the extent that faculty members in a certain position (e.g. professors) socialize primarily with their academic equals, their choices related to collaboration with industry are likely to be influenced by the actions of other members of the faculty of the same rank. Moreover, it is relevant to look at individuals of the same rank in order to avoid confounding effects deriving from authority-based relationships.

Peers’ engagement is an average of the industrial involvement of peers (not including the focal individual). These data are taken from our survey and matched with the RAE unit of assessment question about individuals’ departmental affiliation. Meaningful measures of peer behaviors require information on at least one researcher other than the focal individual. We therefore excluded individuals where there were no responses from peers, which left 1,344 valid observations. The average size of cohorts per department was 11 individuals, which helped to ensure that our results were not driven by the views and behavior of single researchers in small departments.

To analyze the social learning component of peer effects, we interacted the main independent variable with number of years of work experience in the private sector (*industry experience*). Individuals who have been exposed to the *modus operandi* of industry in other contexts will be less reliant on peers when deciding about collaboration with private companies.

Furthermore, to explore the social comparison mechanisms of peer effects, we interacted the main independent variable with the researchers' *academic age* (or number of years of experience as a researcher, defined as their age minus their age when being awarded their PhD). We also interacted peers' engagement with a dummy variable for *star* scientists. In line with the literature on star scientists (Zucker and Darby 1996; 2001; Azoulay, Zivin et al. 2008), we define star scientist as those academics who are in the top 1% of the distribution of citations in their discipline and who are in the top 25% of the distribution of grants received from the EPSRC in our sample.

Control variables

We included a range of control variables to account for individual, department, university, and regional level effects on a researcher's experience with industry. A first group relates to the academic's individual characteristics. We included demographic characteristics such as *gender* and *academic rank* (coded as a dummy variable indicating professor status) (Link, Siegel et al. 2007). We used a dummy variable for a British doctoral degree (*British PhD*), and a proxy for the quality of the institution awarding the PhD degree (*elite PhD*), coded as a dummy variable indicating whether the institution is part of the Times Higher Education Supplement (2004) list of worldwide top universities. This was based on information from the survey responses. We also controlled for researchers' quality and productivity. We included the total amount of research funding received from EPSRC in the period 2000-2006, standardized by the average level of funding of other researchers in their discipline (*individual grants*). We controlled for the scientific productivity of researchers in the same period of the grants (2000-2006) by including the number of publications on the ISI Web of Science identifying the researcher as an author (*publications*). We also included a variable for *intrinsic* motivation to be an academic researcher. Adherence to the traditional academic norms of openness may influence scientists' attitudes to collaboration. A study of 98 US professors conducted by Renault (2006) indicates that agreement with the values of academic capitalism (as opposed to Mertonian values) is a strong predictor of involvement with industry. Finally, we controlled for scientific discipline by introducing a dummy variable (*basic discipline*) identifying the disciplines mathematics, chemistry, and physics.

A second group of variables was related to department's characteristics, taken from the RAE 2008 database. We included in the regressions research income received between 2005 and 2007 from industry per Full Time Equivalent (FTE) staff (*department industry funds*). Although we were unable to observe the formal rules governing industry collaboration in a

department, we believe that the amount of funding received from private companies is a good proxy for these norms since we would expect that departments heavily funded by industry would encourage their members to engage in collaboration with industry. We controlled for *department research quality* measured as the percentage of staff rated ‘internationally leading’ and ‘international excellent’, which are the measures of research quality used for allocating funding in the RAE. These measures help to capture the opportunities for industry engagement offered by the individual’s department.

The third group of variables captured university characteristics. We controlled for institutional involvement in commercialization and collaboration activities by stock of *university patents* per FTE, and income received from industry per employee in the period 2005-2007 as *university industry funds*. These measures account for the level of commercialization efforts in the university as a whole, and the degree of institutionalized support for these activities. Individual engagement may be enhanced by a formal support infrastructure and institutional incentive mechanisms (Landry, Amara et al. 2006). We assessed the profile of the universities in the sample by introducing measures of their quality based on their RAE 2008 score (*university research quality*), and incorporating a dummy for *group* (Russell Group, Red Brick, 1994 Group, New Universities) to account for the strong institutional differences between groups of universities in the UK. Large, and high quality universities may offer more opportunities for industry collaboration than small, less good quality universities (Owen-Smith and Powell 2001).

The fourth group of variables is for the regional level. We identified the regions (NUTS2 or 37 UK regions) in which the universities in our sample were located and included measures for economic and innovation activity. We included variables for Gross Domestic Product (in € millions) (*region GDP*), business R&D expenditure (in € millions) (*region R&D*) and the number of EPO patent applications per million of inhabitants (*region patents*). These measures help us to account for different levels of demand for academic knowledge in the local environment (Krabel and Mueller 2009).

Identification strategy

Empirical analysis of peer effects can produce spurious correlations and suffer from the identification problem described by Manski (1993). We dealt with these methodological issues as follows.

First, we addressed the possibility that local sorting processes for hiring and retaining academic staff and individual self-selection into departments might bias results. Keen

collaborators with industry may self-select into or get hired by departments where commercialization efforts are more common. To rule this out we used information on those individuals in our sample who, according to their grant records, moved between universities by extracting the researchers' two most recent affiliations. We also gathered information on the level of commercial activity in the departments of origin and destination of each mobile researcher based on amounts of funding from industry sources according to RAE records. If a researcher moved for industry engagement related reasons, we would expect some variation in the level of commercial activity between the original and the destination departments. Comparison of the values for each respondent based on a Wilcoxon signed-rank test, we found no statistically significant difference between the levels of income received from industry by the department of origin and the destination department ($z = -1.538$, $\text{Prob} > |z| = 0.1241$).

It would seem that researchers do not move based on the external engagement profile of a department, which is strong evidence against the presence of a sorting problem in our analysis. The result held when we performed the analysis on the subsample of 'highly engaged' academics (those in the top 25% or top 10% of the industrial engagement index distribution). The data show that academics move because of the research quality of the university and the department. The same test applied to the difference in the quality of the origin and destination universities, and the difference in quality of the departments involved, showed statistically significant differences (in both cases the destination is of higher quality on average).

Second, the peer effect we seek to measure should be a true endogenous effect by which the propensity of a person to behave in some way varies with the behavior of the group to which s/he belongs. Simple observation of a correlation between individual and group behaviors may in fact hide other mechanisms at play. A correlation effect may be due to unobservable characteristics, which influence the behaviors of both the individual and his or her peers. Individuals may behave similarly to the group because of their similar individual characteristics. We addressed this problem by including detailed information on departments, universities, and regions. Moreover, we conducted an additional analysis aimed at reducing the effect of shared unobservable contextual characteristics on individual behavior, following Bercovitz and Feldman (2008). To this end, we included an independent variable in our model measuring researchers' engagement in the 'outside peer group', i.e. members of the same department but of different rank. We defined *outside peers' engagement* as the average industrial engagement index of the outside peer group. This allowed us to investigate whether

an individual's decision to engage was driven by unobservable departmental characteristics rather than imitating peers. To take account of outside peers, we required information on at least one additional individual, in the same department but of a different rank, which reduced the number of our observations to 1,192.

Third, there are exogenous (contextual) effects: the propensity of an individual to behave in some way may change with the exogenous characteristics of his or her peers (Manski 2000). For instance, industry collaboration behavior may be based on the characteristics, such as age and gender, of co-workers. To control for this possibility, we computed the average academic age of the focal individual's peers (*academic age peers*) and included it in one of the models.

Fourth, average group behavior may be influenced by the behavior of the individual member, introducing a 'reflection problem' (Manski 1993; 2000). It has been suggested that reflection problem can be alleviated by examining peer effects on the basis of attitudes and perceptions rather than manifest behaviors: this makes it easier to differentiate between preference interaction and expectations interaction (Manski 1993; 2000). We performed an analysis using a perception variable measuring the extent of the benefits of industry engagement perceived by the individual's peers. We operationalized extent of perceived benefits from industry collaboration as the total number of single benefits indicated by the individual as 'important' or 'very important' in the questionnaire (items reported in Table 16). The list of benefits builds on D'Este and Patel (2007) and refers to both the personal and professional benefits from working with industry. This information allowed us to construct the *peers' benefits* measure based on the average number of benefits perceived by the individual's peers in each department, excluding the focal individual. By using subjective evaluations of the benefits on industry collaboration engagement, we were able to mitigate some of the measurement issues associated with the reflection problem (Manski 1993).

We conducted another analysis to address the issue of reflection by isolating the behavior of recently recruited academics. In his analysis of social learning and health plan choice, Sorensen (2006) assumes that the health plan choices of *newly hired* employees are influenced by co-workers but not vice-versa. Our data allowed us to perform an analysis making a similar assumption. Since 523 of the individuals in our sample had responded to the 2004 survey we were able to identify individuals who had moved universities between 2004 and 2009 (52 individuals). They were labeled *movers* and assumed to be influenced by the behavior of their new colleagues but not vice-versa since the observation period was too short for the reflection mechanism to occur.

Table 16: Researchers' motivations for engaging with industry

Motivation	% of respondents ¹
Source of additional research income	69.7
Increasing the likelihood of application of my research outside academia	66.6
Raising awareness of problems that industry confronts	59.3
Building and sustaining your professional network	53.0
Keeping abreast of research conducted in industry	51.9
Getting inspiration for new research projects	50.8
Feedback from industry about viability of research	46.1
Access to materials or data necessary for research	40.1
Training of postgraduate students	34.5
Helping students to find employment in industry	33.6
Access to research expertise of industry employees	30.0
Improving the understanding of foundations of particular phenomena	24.4
Access to state-of-the art equipment, facilities and instruments	18.4
Seeking proprietary knowledge (e.g. patents)	12.3
Source of personal income	10.8

¹Percentage of respondents indicating 'very important' or 'crucial' on the survey.

Estimation

We employ an ordinary least squares (OLS) model to investigate the impact of peers' behavior on individual industry collaboration. To use this kind of model, we must assume that the dependent variable is normally distributed: we therefore employ the natural logarithm of the individual industrial involvement index. To address the possible problem of heteroskedasticity, we use robust standard errors. Another assumption of OLS is that standard errors are independently and identically distributed; however, this may be violated. If errors are clustered (i.e. if observations within a certain group are correlated in unknown ways), the OLS estimates will be unbiased but the standard errors may be wrong, leading to incorrect inferences. Since the respondents in our sample are affiliated to different disciplines, we can expect some group correlation which we are not able to observe; therefore we clustered errors by scientific discipline. As a robustness check we clustered errors also by department and university; the main results were unchanged.

RESULTS

Tables 17 and 18 present the descriptive statistics and correlations for all the variables employed. Correlations generally were low to moderate indicating that multicollinearity was not a problem in the estimations. The variance inflation factor (VIF) for the main specification was 2.43, which was well below the value of 10 commonly recognized as indicating multicollinearity. The appropriateness of using weights for the industrial involvement index can be gauged from the pattern of academics' engagement across different disciplines. Some activities are more common than others. For example, nearly 83% of respondents attended conferences with industry participation, while just 17% were involved in the creation of physical facilities, such as laboratories, with industry partners, and only 3% had started a company. Another 8% of our sample had not engaged with industry in any form and a small proportion of individuals did not perceive any important benefits from industry engagement. Seeking additional research funding was seen as the most important driver for industry collaboration.

Table 17: Descriptive statistics (chapter 6)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Individual engagement	1371	4.47	4.46	0	33.97
Gender	1371	0.11	0.31	0	1
Academic age	1371	21.07	9.87	1	60
Academic rank	1371	0.54	0.50	0	1
Industry experience	1371	2.77	5.26	0	45
Star	1371	0.08	0.31	0	3
Intrinsic motivation	1371	3.35	0.80	0	4
British PhD	1371	0.84	0.37	0	1
Elite PhD	1371	0.42	0.49	0	1
Individual grants	1371	1.00	2.04	0	27.28
Publications	1371	25.03	27.04	0	393
Basic discipline	1371	0.39	0.49	0	1
Russell Group	1371	0.62	0.49	0	1
Red Brick Universities	1371	0.18	0.38	0	1
Group 1994 Universities	1371	0.19	0.40	0	1
New Universities	1371	0.03	0.16	0	1
Dept. industry funds	1371	179925.80	125988.20	3416.90	993625.1
Dept. research quality	1371	0.63	0.15	0.11	0.95
Univ. patents	1371	0.25	0.30	0	1.24
Univ. industry funds	1371	24.08	23.69	1.15	142.81
Univ. research quality	1371	2.68	0.19	1.75	2.98
Region GDP	1371	73013	55213.52	17116.70	193751.90
Region R&D	1371	1.78	0.97	0.93	4.29
Region patents	1371	76.48	58.33	0.07	198.89
Peers' engagement	1371	4.34	3.27	0	33.97
Outside peers' engagement	1229	4.23	3.20	0	33.97
Peers' academic age	1371	18.82	8.91	0	49
Peers' benefits	1371	6.08	2.70	0	15

Table 18: Correlation Matrix (chapter 6)

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]
[1] Gender	1																									
[2] Academic age	-0.15	1																								
[3] Academic rank	-0.12	0.49	1																							
[4] Industry experience	-0.07	0.17	0.07	1																						
[5] Star	-0.03	0.34	0.20	0.15	1																					
[6] Intrinsic motivation	0.10	0.00	0.05	-0.08	0.02	1																				
[7] British PhD	-0.05	0.16	0.05	0.09	0.08	-0.01	1																			
[8] Elite PhD	-0.02	0.05	0.04	0.00	0.12	0.04	0.14	1																		
[9] Individual grants	-0.05	0.15	0.20	0.05	0.17	-0.02	0.10	0.07	1																	
[10] Publications	-0.05	0.18	0.29	0.00	0.28	0.05	0.05	0.08	0.16	1																
[11] Basic discipline	-0.01	0.06	0.04	-0.11	-0.01	0.01	-0.05	0.13	-0.01	0.13	1															
[12] Russell Group	0.00	0.03	0.04	-0.09	0.10	0.07	0.00	0.19	0.07	0.13	0.09	1														
[13] Red Brick Univ.	-0.04	0.01	-0.04	-0.03	-0.03	0.03	0.06	0.01	-0.02	0.01	0.01	0.35	1													
[14] Group 1994	-0.04	0.00	-0.02	0.05	-0.05	-0.04	-0.01	-0.08	-0.06	-0.04	0.05	-0.66	-0.23	1												
[15] New Universities	0.01	-0.02	0.00	0.03	-0.03	0.02	0.06	-0.03	-0.02	-0.04	-0.09	-0.18	-0.06	-0.07	1											
[16] Dept. ind. funds	-0.04	0.07	0.07	0.04	0.06	0.07	0.03	0.06	0.09	0.23	0.24	0.25	0.09	-0.11	-0.08	1										
[17] Dept. res. quality	-0.01	0.00	0.00	0.03	0.13	0.01	0.02	0.16	0.10	0.07	-0.20	0.46	0.12	-0.16	-0.22	0.15	1									
[18] Univ. Patents	0.05	-0.02	-0.02	-0.01	0.06	0.00	-0.05	0.11	0.02	0.02	0.00	0.24	-0.22	-0.25	-0.03	0.14	0.18	1								
[19] Univ. ind. funds	0.04	0.01	0.01	0.08	0.05	-0.05	0.03	0.03	0.04	-0.02	-0.12	-0.04	-0.15	-0.12	-0.05	0.07	0.07	0.49	1							
[20] Univ. res. quality	-0.02	0.04	0.01	-0.05	0.16	0.05	-0.03	0.29	0.05	0.13	0.14	0.60	0.01	-0.09	-0.42	0.24	0.61	0.32	0.05	1						
[21] Region GDP	0.10	-0.03	0.00	-0.04	0.04	0.05	-0.05	0.14	0.00	-0.04	0.05	0.18	-0.22	-0.13	-0.03	0.05	0.08	0.62	0.25	0.32	1					
[22] Region R&D	-0.01	0.03	0.02	0.05	0.09	-0.02	0.03	0.09	0.06	0.09	-0.06	-0.06	-0.20	0.05	-0.05	-0.01	0.15	-0.19	0.31	0.18	-0.24	1				
[23] Region patents	0.03	0.03	0.02	-0.04	0.11	0.05	-0.01	0.23	0.04	0.10	0.11	0.27	-0.23	0.00	-0.06	0.05	0.31	0.19	0.05	0.60	0.42	0.48	1			
[24] Peers' engagement	-0.02	0.09	0.27	0.11	0.06	0.00	0.10	-0.05	0.08	0.11	-0.25	-0.06	0.00	-0.02	0.00	0.09	0.03	0.01	0.22	-0.09	-0.07	0.08	-0.09	1		
[25] Outside peers' eng.	0.01	-0.08	-0.30	0.07	-0.04	0.00	0.06	-0.07	-0.06	-0.07	-0.22	-0.13	-0.04	-0.01	0.08	0.04	-0.04	0.06	0.21	-0.13	-0.02	0.03	-0.10	0.10	1	
[26] Peers' academic age	-0.10	0.43	0.65	0.03	0.14	0.06	0.06	0.02	0.13	0.22	0.04	0.04	0.02	-0.03	0.03	0.05	-0.04	-0.05	-0.01	0.01	0.00	0.01	0.06	0.16	-0.11	1

Table 19 presents the results of our econometric analyses. Model (1) is a baseline model with the individual industrial involvement index as the dependent variable. Academic age has a negative and statistically significant effect on the level of engagement with industry, indicating a possible cohort effect. As observed by Bercovitz and Feldman (2008), the longer ago that the researcher completed his formal training, the lower the likelihood of collaboration with industry because, in the past, university engagement with industry was less relevant or even discouraged. Being a professor (*academic rank = 1*) has a positive and statistically significant effect: this finding is in line with previous research (Link, Siegel et al. 2007) and suggests that more experienced academics control more organizational resources and have greater license to engage in proactive behaviors such as collaboration with industry. Experience of working in the private sector (*industry experience*) is also positive and significant, which is also in line with previous research (Audretsch 1998). Being intrinsically motivated to be an academic is positively and significantly related to individual engagement with industry: this perhaps indicates that academics who adhere to the norms of public science collaborate with industry in order to advance their research agendas (D’Este and Perkmann 2011). Academics who attended UK universities are significantly more likely to engage with industry than those trained abroad, but a PhD degree from a high-status university (*elite PhD*) does not seem to have any effect. Being a high-performing scientist (*star*) is not significant in the regression, contradicting somehow the published literature which has reported that being highly productive in academic terms increases the likelihood of being involved in collaboration or commercialization activities (Zucker and Darby 1996). Analyzing more in depth the scientific productivity of the researchers, the amount of EPSRC grant funding received is not statistically significant, while the number of publications is positively correlated to industrial engagement, which is in line with previous research on academic inventors (Agrawal and Henderson 2002; Azoulay, Ding et al. 2007; Breschi, Lissoni et al. 2007; Fabrizio and Di Minin 2008). Affiliation to a basic discipline has a negative and significant effect on industry engagement, confirming previous results (Link, Siegel et al. 2007). None of the department level variables has a significant effect. The quality of the university is negatively and significantly correlated with individual engagement: better universities receive more government funding and more funding from a wider spectrum of other sources and therefore are less reliant on industry to finance research projects. None of the regional level variables is significant in the regression.

Table 19: Regression results for individual industrial engagement

VARIABLES	(1)	(2)	(3)	(4)	(5)
Gender	-0.0381 (0.044)	-0.0428 (0.042)	-0.0375 (0.043)	-0.0360 (0.045)	-0.0322 (0.045)
Academic age	-0.0073** (0.002)	-0.0061* (0.002)	-0.0060** (0.002)	0.0008 (0.003)	0.0003 (0.003)
Academic rank	0.2360*** (0.041)	0.1296** (0.035)	0.1304** (0.035)	0.1206** (0.033)	0.1219** (0.033)
Industry experience	0.0242*** (0.004)	0.0231*** (0.004)	0.0324*** (0.007)	0.0233*** (0.004)	0.0309*** (0.007)
Intrinsic motivation	0.0968** (0.028)	0.0934** (0.027)	0.0911** (0.026)	0.0936** (0.027)	0.0917** (0.026)
British PhD	0.2217** (0.070)	0.1936* (0.069)	0.1905* (0.071)	0.1887* (0.069)	0.1865* (0.070)
Elite PhD	-0.0719 (0.048)	-0.0691+ (0.039)	-0.0660+ (0.037)	-0.0674+ (0.036)	-0.0649+ (0.035)
Star	-0.0946 (0.089)	-0.0806 (0.088)	-0.0800 (0.090)	0.0234 (0.127)	0.0213 (0.131)
Individual grants	0.0142 (0.018)	0.0130 (0.016)	0.0128 (0.016)	0.0126 (0.017)	0.0125 (0.017)
Publications	0.0033* (0.001)	0.0030* (0.001)	0.0029* (0.001)	0.0030* (0.001)	0.0029* (0.001)
Basic discipline	-0.3231* (0.135)	-0.2386* (0.096)	-0.2362* (0.094)	-0.2395* (0.097)	-0.2375* (0.095)
Department industry funds (per employee)	0.0000 (0.000)	0.0000 (0.000)	0.0000 (0.000)	0.0000 (0.000)	0.0000 (0.000)
Dept. research quality	0.1324 (0.270)	0.0777 (0.179)	0.0674 (0.180)	0.0743 (0.176)	0.0659 (0.177)
University patents	0.0380 (0.126)	0.0683 (0.104)	0.0634 (0.104)	0.0631 (0.105)	0.0596 (0.105)
University industry funds (per employee)	0.0037* (0.002)	0.0020 (0.001)	0.0021 (0.001)	0.0020 (0.001)	0.0021 (0.001)
Univ. research quality	-0.4457+ (0.224)	-0.3577* (0.156)	-0.3415* (0.154)	-0.3712* (0.149)	-0.3567* (0.146)
Region GDP	0.0000 (0.000)	0.0000 (0.000)	0.0000 (0.000)	0.0000 (0.000)	0.0000 (0.000)
Region R&D	0.0151 (0.051)	0.0222 (0.042)	0.0228 (0.042)	0.0195 (0.042)	0.0202 (0.042)
Region patents	-0.0002 (0.001)	-0.0003 (0.001)	-0.0003 (0.001)	-0.0003 (0.001)	-0.0003 (0.001)
Peers' engagement		0.0554*** (0.010)	0.0623*** (0.012)	0.0915*** (0.014)	0.0945*** (0.015)
Academic age * Peers' engagement				-0.0015** (0.000)	-0.0014** (0.000)
Star * Peers' engagement				-0.0207+ (0.013)	-0.0202+ (0.015)
Industry experience * Peers' engagement			-0.0019* (0.001)		-0.0016+ (0.001)
Constant	1.8112** (0.502)	1.4480** (0.352)	1.3908** (0.346)	1.3348** (0.364)	1.2962** (0.362)
Observations	1,371	1,371	1,371	1,371	1,371
R-squared	0.195	0.242	0.244	0.247	0.248

Notes: Ordinary Least Squares, robust standard errors clustered by discipline. University groups included.
 One-tailed test for main variables, two-tailed tests for control. ⁺p<0.10, *p<0.05, **p<0.01, ***p<0.001

Model (2) builds on the previous base specification but includes a variable for the level of peers' engagement. The explanatory power of the model increases significantly with the addition of the main independent variable: R^2 increased from 0.195 to 0.242. The influence of industry engagement of an individual's peers is positive and significant, suggesting that the actions of a researcher are affected by the behavior of the other researchers of the same rank in his department, as predicted by H1. All the control variables maintain the same effect as in the baseline.

In model (3) we introduce the first moderator, previous industry experience, which resulted in significant improvement in the model's explanatory power. The interaction term is significant and negative: individuals who spent longer periods of time working in private companies are less influenced by their peers when choosing their engagement behavior. H2 is therefore confirmed, indicating that having been exposed previously to the industrial logic is a substitute for social learning from academic colleagues. In Model (4) we test H3 and H4 by adding two moderators. First, the interaction term between academic age and peers' engagement is negative and significant as expected. Younger individuals rely more heavily than their senior colleagues on social comparison with their peers when deciding about engaging with industry. Second, the interaction term between *star* and peer's engagement, as expected, is also negative and significant: high-status individuals do not compare themselves with their departmental peers and therefore are less conformist and more willing to engage in deviant behaviors. Again, the change in R^2 is positive and significant. We find therefore that the social comparison component of peer effects seems particular relevant in our setting. Finally, in model (5) we test the full model. The signs are consistent with the previous specifications, and we observe a statistically significant increase in R^2 . As a robustness check, we calculated an alternative specification of the main model that included university dummies and region dummies instead of the variables at the university and regional level. The main results are unchanged.

Table 20 presents an analysis to test for possible sources of spurious correlation. Model (1) presents the main model testing the influence of peers' behaviors on individual behaviors for reference. To check for unobserved heterogeneity, which might explain the correlation between behaviors for other reasons than peer imitation, in Model (2), along with the main independent variable, we introduce an additional variable measuring outside peers' engagement. In this specification, the coefficients of the main independent variable and the controls remain unchanged, while the coefficient of the outside cohort engagement variable is

not significant. This suggests that our results are driven by the identified peer effects, and not by some characteristics of the department that we cannot control for.

To rule out the possibility of contextual (exogenous) effects in the analysis, in Model (3) we introduce the average academic age of the peers of the focal individual. As expected, the coefficient of academic age peers is not significant: individual decisions related to industrial engagement activities are not influenced by an exogenous characteristic of the individual's co-workers.

Models (4) and (5) address the problem of reflection. Following Manski's (1993; 2000) suggestion we test the effect of peers' *perceptions* of the benefits from industry engagement (as opposed to manifest behaviors) on a focal individual's engagement behavior. We find the effect of peers' perception of benefits on individual industry engagement to be positive and significant, reinforcing the presence of genuine peer effects. Model (5) is a standard analysis of the subsample of researchers who moved universities between 2004 and 2009. The coefficient associated with peers' behavior is significant and positive, providing additional support for the argument that individual behavior is shaped by peers' behavior and not vice versa, assuming that recent movers are more likely to be influenced by their colleagues and that the time frame is too short for the mean behavior of the group to be influenced by these new colleagues.

Table 20: Regression results for tests for the identification problems

VARIABLES	(1)	(2)	(3)	(4)	(5)
Gender	-0.0428 (0.042)	-0.05 (0.039)	-0.04 (0.043)	-0.05 (0.042)	0.11 (0.256)
Academic rank	0.1296** (0.035)	0.14** (0.034)	0.13** (0.038)	0.14*** (0.034)	-0.22 (0.325)
Academic age	-0.0061* (0.002)	-0.01* (0.002)	-0.01* (0.002)	-0.01** (0.002)	0.02+ (0.011)
Industry experience	0.0231*** (0.004)	0.02*** (0.003)	0.02*** (0.004)	0.02*** (0.004)	0.00 (0.024)
Intrinsic motivation	0.0934** (0.027)	0.09** (0.023)	0.09** (0.027)	0.09** (0.027)	0.14 (0.128)
British PhD	0.1936* (0.069)	0.18* (0.067)	0.19* (0.069)	0.19* (0.069)	0.17 (0.245)
Elite PhD	-0.0691+ (0.039)	-0.04 (0.035)	-0.07+ (0.038)	-0.06 (0.039)	0.28+ (0.145)
Star	-0.0806 (0.088)	-0.09 (0.084)	-0.08 (0.088)	-0.07 (0.086)	0.15 (0.344)
Individual grants	0.0130 (0.016)	0.01 (0.016)	0.01 (0.016)	0.01 (0.017)	0.04 (0.082)
Publications	0.0030* (0.001)	0.00* (0.001)	0.00* (0.001)	0.00* (0.001)	-0.00 (0.006)
Basic discipline	-0.2386* (0.096)	-0.22* (0.086)	-0.24* (0.096)	-0.21* (0.088)	-0.35* (0.152)
Department industry funds (per employee)	0.0000 (0.000)	0.00 (0.000)	0.00 (0.000)	0.00 (0.000)	0.00** (0.000)
Dept. research quality	0.0777 (0.179)	-0.04 (0.170)	0.08 (0.182)	0.11 (0.163)	-0.91 (0.904)
University patents	0.0683 (0.104)	0.08 (0.107)	0.07 (0.105)	0.06 (0.106)	0.05 (0.865)
University industry funds (per employee)	0.0020 (0.001)	0.00 (0.001)	0.00 (0.001)	0.00+ (0.001)	-0.00 (0.019)
Univ. research quality	-0.3577* (0.156)	-0.38* (0.131)	-0.36* (0.157)	-0.31+ (0.156)	-0.85 (1.469)
Region GDP	0.0000 (0.000)	0.00 (0.000)	0.00 (0.000)	0.00 (0.000)	0.00+ (0.000)
Region R&D	0.0222 (0.042)	0.01 (0.040)	0.02 (0.042)	0.02 (0.042)	0.38 (0.228)
Region patents	-0.0003 (0.001)	-0.00 (0.001)	-0.00 (0.001)	-0.00 (0.001)	-0.01* (0.003)
Peers' engagement	0.0554*** (0.010)	0.06*** (0.011)	0.06*** (0.010)	0.05*** (0.010)	0.13* (0.045)
Outside peers' engagement		0.01 (0.008)			
Peers' academic age			-0.00 (0.002)		
Peers' perceptions of benefits				0.02* (0.008)	
Constant	1.4480** (0.352)	1.52*** (0.245)	1.45** (0.346)	1.21** (0.370)	1.55 (3.316)
Observations	1,371	1,229	1,371	1,371	52
R-squared	0.242	0.241	0.242	0.247	0.672

Notes: Ordinary Least Squares, robust standard errors clustered by discipline. University groups included. Two-tailed tests.

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

DISCUSSION

Our analysis suggests that academics' engagement with industry is strongly informed by the behavior of their departmental peers. Observing colleagues' behaviors exerts significant peer pressure on individuals to emulate such behavior. Furthermore, we found that the influence exerted by peers is moderated by the focal individuals' industry experience, academic age, and academic standing. Individuals with experience of working in industry are less susceptible to the influence of their peers because they already possess knowledge about collaborating with firms. In turn, more junior individuals are more likely to be influenced by peers in deciding about their industrial engagement as they seek to learn in order to further their careers. Finally, star performers are less influenced by local peers and look farther afield for reference points for competing professionally. Peer effects are therefore not only a function of individuals' desire to learn but also their eagerness to socially compare themselves against relevant others, whereby star scientists are less likely to compare themselves against their local colleagues, in contrast to lower-profile individuals.

Our study makes several contributions. First, we add to work on university-industry relations and commercialization of university technologies. For a long time, researchers have been interested in what drives academic scientists to work with industry and hereby possibly contribute to the transfer of knowledge and technology from university to industry (Louis, Blumenthal et al. 1989; Mansfield 1995; Owen-Smith and Powell 2001; Murray 2002; Siegel, Waldman et al. 2003; Haeussler and Colyvas 2011). A recent stream in the literature highlights that individuals' behavior is strongly informed by the social context in their universities or departments (Stuart and Ding 2006; Bercovitz and Feldman 2008). Our study contributes to this body of work by identifying the precise mechanisms by which this local context influence occurs. We have highlighted that the bulk of this social influence is due to one department-level factor, i.e. peer effects. When deciding to proactively engage with industry – as this is effectively discretionary behavior, academic scientists mimic the average behavior of their departmental work colleagues who are at a similar stage in their careers. We show also that there are two mechanisms that produce this effect. One is social learning where scientists learn from observing colleagues' behaviors and the outcomes of colleagues' efforts and subsequently emulate these behaviors. The other is social comparison where scientists compare themselves with relevant others, such as their departmental peers. While social learning is a co-operative activity, social comparison suggests an element of rivalry and competition motivating scientists' collaboration strategies. In other words, academic

scientists may decide to engage with industry because they aspire to achieve their colleagues' performance levels, for instance to improve their career prospects. While previous research has explored various facets of competition in academia, such as the race for priority in publishing (Hagstrom 1974) and the struggle for resources (Merton 1968), our findings suggest that competition may also affect academic scientists' proactive efforts to collaborate with industrial users of their research. By demonstrating this link between industry engagement and academic career progress, one may conclude that industry engagement appears to be more closely aligned with academics' professional progression within the world of science than is suggested by studies viewing engagement as somehow removed 'third mission' (Etzkowitz 2003).

Our study also provides a view of academic engagement with industry that is broader than academic entrepreneurship which is often emphasized as the most visible and impactful mode of scientists interaction with the private sector. Much of the research on university-industry relations has highlighted the incidence and impact of entrepreneurial activity by academic scientists, resulting in the filing of patents and the founding of academic spin-offs (Agrawal and Henderson 2002; Shane 2002). While certainly important as a means of technology transfer, patents and licensing represent only part of the information transferred out from a university (Agrawal and Henderson 2002). Using our industry involvement index, we are able to capture collaboration behaviors that are far more common than the types explored in other studies. In many disciplines, large numbers of academic faculty routinely participate in collaborative engagement with industry via joint research, consulting, or contract research (Louis, Blumenthal et al. 1989; Gulbrandsen and Smeby 2005; D'Este and Patel 2007). Characterizing these as engagement behaviors allows us to take into account the fact that academics may exploit them for reasons other than to act entrepreneurially. These reasons may include resource mobilization for their academic research projects, as well as sources for new ideas that may shape their research agendas (Rosenberg 1982; Mansfield 1995). Engagement behavior is a broader category that may include entrepreneurship but encompasses all types of activities with industry that academics may undertake at their own discretion.

Furthermore, our study contributes methodologically to the study of university-industry relations by providing accuracy in testing peer effects. We attempt to overcome the challenges of testing claims about the influence of peers in several ways. First, we use a large comprehensive dataset characterizing the activities of individuals and their peers. We cover a broad segment of the population of academic researchers, exploring the determinants of

industry collaboration across a broad range of channels, including consulting, contract research, joint research and training of company employees. This allows us to develop insights that are applicable to widely practiced activities rather than to relatively rare activities such as entrepreneurship. Second, in testing peer effects, we address the problem that correlation between peers' behavior and individual engagement with industry may be spurious and suffer from several identification problems - a challenge common to all studies of group effects on individual behavior (Manski 1993). On one hand, we exclude the possibility of presence of contextual interactions by showing that individual behaviors do not vary with exogenous characteristics of the group members. On the other, we separate the impact of peer effects from the influence of common unobservable characteristics by including rich information about the environment in which these academics operate. Furthermore, we distinguish between different groups of colleagues, following the idea proposed by Munshi and Myaux (2006) and Sorensen (2006) according to which estimated peer effects should be stronger when the social group is defined more narrowly. Finally, we address the reflection problem. Previous work has predominantly focused on manifest behaviors when attempting to establish the impact of local social contexts (Louis, Blumenthal et al. 1989; Sorensen 2006; Stuart and Ding 2006; Bercovitz and Feldman 2008; Nanda and Sorensen 2010). Our approach moves in the direction of Manski's suggestion (Manski 2000) and adds to these works by separately considering the impact of peers' perceptions and behaviors on individual actions. Moreover, we perform our analysis on a restricted sample of researchers of whom we know the recent career history, and are hence able to carry out our analysis on individuals who have recently moved – these are less susceptible to the reflection problem because of the limited time of interaction. By doing so, we speak directly to the concern that peers effects may be overestimated because of simultaneity issues.

Finally, our results also have implications for the study of professional services organizations because, in many respects, academic departments have features in common with practice areas in these organizations. Universities, like other professional services firms, are professional bureaucracies (Mintzberg 1979) where highly skilled individuals work relatively autonomously with groups and 'clients' external to their organizations. For all these organizations, many discretionary behaviors of employees are crucial for acquiring external resources and getting the job done. Our study suggests that individual behavior is shaped to a great extent by peers in the immediate work environment. Learning from and comparing with peers appears to have a major influence on an individual's decision to engage in behavior which is not unequivocally prescribed by organizational policies. In this context, note that the

influence of ‘outside peers’, i.e. local colleagues who are either more junior or senior than the focal individual, is not important. This means that individuals are strongly oriented towards what they perceive to be their generalized other, suggesting that immediate peer groups represent opportunities for generating professional identities which in turn inform individuals’ attitudes and behaviors (Ibarra 1999).

IMPLICATIONS, LIMITATIONS AND FUTURE RESEARCH

Understanding the social mechanisms that lead academics to engage with industry contributes to the wider issue related to how universities and organizations in general, should be managed, and specifically with respect to the promotion of proactive behavior by organization members. Our findings suggest that there may be no direct incentive that senior members, such as heads of university departments, can offer to encourage employees to behave proactively in relation to seeking engagement with industrial partners. Similarly to what happens when we observe the tension between bureaucracy and entrepreneurship (Ruef and Lounsbury 2007), proactive behaviors cannot be dictated. Because organizational members are influenced mostly by same-level peers, attempts to promote (or discourage) engagement would need to consist of collective influence on organizational members which, in turn, would stimulate emulation by peers and result in a virtual cycle of mutual reinforcement. A cultural approach to framing industry engagement positively and emphasizing its complementarities with academic work more generally, would appear appropriate to nurture the former aspect, while greater transparency would enable individuals to view their colleagues’ behavior and promote emulation. Hiring policies need to take account of the fact that employing faculty with experience of working with industry may increase the likelihood that departmental colleagues will mimic this behavior. Owen-Smith and Powell (2001) suggested that industry engagement requires considerable skills and therefore is a learned practice, developed through experience and social exchanges with colleagues. It would seem that junior academics are more susceptible to local peer pressure than senior academics, suggesting that the above insights will be helpful for department heads keen to stimulate proactive behavior.

This study has some limitation which can open avenues for future research. First of all, we rely on survey data to construct the activities not only of the focal individuals but also of the members of their department of affiliation. While we possess information on a large number of researchers, we cannot ensure a complete representativeness of the departments. Future research should rely on universities’ archival data in order to construct precise

measures of departments' engagement activities with industry. Similarly to many scholarly contributions on the measurement of peer effects, the main limitation of this study is represented by the sorting problem. Despite our attempts to control for the level of engagement in the department of origin compared to that of the department of destination (for academics who moved between different institutions), we cannot determine with our data if the first location of academics was determined for reasons completely exogenous to commercial involvement. It is indeed possible that the first choice of location is determined by the preference of researchers to affiliate with a department which is closer to them in terms of engagement with industry, and that all subsequent moves are between departments similar to the original one. Future research should use career history data in order to assess if academics are sorted into departments because of their preference for commercialization activities, and panel data to analyze the dynamics of the departments' behaviour when a new faculty member joins the group.

CHAPTER SUMMARY

This chapter analyses the role of social context on academics' industry engagement activities. The analysis tests the idea that peer effects are generated by two distinct mechanisms: social learning (indicating that individuals reduce uncertainty by following the behaviour of their peers), and social comparison (indicating that individuals choose local peers to act as a reference group). Particular efforts are made to address the so-called reflection problem common to econometric studies of peer effects on individual behaviour, which can result in spurious correlation. This chapter shows that individuals look to their immediate peers for their orientation, both collaboratively via learning as well as more competitively via social comparison. While recognizing the importance of individual (demographic and psychological) factors for explaining an individual's behaviour, this chapter contributes to the literature on university-industry relations and commercialization of university technologies in two ways. First, it highlights the importance of the local social environment in influencing an individual to depart from the routines prevailing in the organization. Second, it identifies the precise mechanism by which this local context influence occurs.

CHAPTER 8 – CONCLUSION

In this thesis I investigated the microfoundations of the interaction between universities and industry. In particular, I have highlighted how individuals' perceptions of the benefits and costs of collaboration, their personality characteristics and the social pressures they are exposed to, influence their engagement with industrial partners.

This thesis seeks to make several contributions to the literature. First, it contributes to the debate on the individual determinants of academics' industrial engagement. Since the early 1990s, the literature has shifted from an organizational-level perspective to a deeper analysis of the individuals involved in the technology transfer process, the focus has been mostly on demographic characteristics or academics' scientific productivity. In this thesis, I have investigated the role of some individual features which are less observable (and as a consequence more difficult to measure), such as personality traits and perceptions, which are likely to influence how academics approach collaborative activity. Understanding the role of academics' traits and perceptions is important because it acknowledges the crucial role of individual volition in the phenomenon of university-industry interaction. My research shows that university researchers react differently to the possibility of collaborating with industry, and their decision ultimately is informed by their personal evaluation of the benefits and costs of engagement. Moreover, while increasing our theoretical understanding of academics' involvement in technology transfer, this thesis informs policy on how more efficient strategies could be devised to promote collaboration between universities and industry.

Second, I contribute to the debate on the role of social context in scientists' behaviour. The more recent literature takes account of the social influence explaining academics' decisions to engage with industry. In this thesis I have investigated the mechanisms underlying the effect of peer behaviour on individual behaviour. This is central to understanding the antecedents to academic engagement in highlighting which individuals are most likely to be susceptible to peers' influence, and through which mechanisms.

Third, from an empirical perspective, previous studies on academics' involvement with industry have focused on relatively narrow fields, notably the life sciences or medical disciplines. However, the life sciences may be atypical, given that patents play a smaller role than in many other industries, and firms often prefer to work with university researchers using collaborative forms such as consulting or joint research (Cohen, Nelson et al. 2002;

Nelson 2004). In this thesis, I have focused on a wide range of disciplines in the physical and engineering as well as the life sciences, encompassing both basic and applied areas. This wider focus helps our understanding of the mechanisms at play in different scientific disciplines and makes the results more generalizable.

Finally, in this research effort I have aimed to cover a broad segment of the engagement activities of academic researchers. Previous research tends to focus on single aspects of academic entrepreneurship – defined variously as filing invention disclosures, patenting, or involvement in spin-off companies. However, these types of academic entrepreneurship are relatively rare events even within leading universities (Agrawal and Henderson 2002). Hence, I have explored the determinants of industry collaboration across a broad range of channels, including consulting, contract research, joint research and training of company employees. This has allowed the development of insights that are applicable to widely practised activities rather than to relatively rare activities such as academic entrepreneurship.

LIMITATIONS AND FUTURE RESEARCH

The analyses that form this thesis have some limitations, both empirical and theoretical, which point to several avenues for future research.

Empirically, different forms of academic engagement leave different traces. Academic entrepreneurship can be measured by counts of university spin-offs or company directorships maintained by academics. Information on patents is accessible via public patent directories: recent research has successfully identified university-invented patents that are not assigned to universities as well as patents assigned to universities (Thursby, Fuller et al. 2007; Lissoni, Llerena et al. 2008). Academic engagement, such as joint research projects, consultancy and training activities, is empirically more difficult to detect because it includes collaboration instances that may not be documented by generally accessible records. Researchers have tried to proxy for industry engagement using co-authorship between university researchers and industry scientists (Liebeskind, Oliver et al. 1996; Katz and Martin 1997; Murray and Stern 2007). This procedure however is likely to under-represent collaborations that are more applied in nature and do not result in publications, such as contract research or consulting assignments.

Being aware of these issues, I decided to collect information on collaboration by asking academics directly for information, via surveys. This approach was necessary also because certain information is not formally codified, such as personality traits and individual

perceptions. It is clear that relying on self-reported information raises certain challenges which may weaken the quality, reliability and validity of research results.

A first issue is the reliability of self-reported measures of behaviours, perceptions and characteristics. If as scholars we are interested in exploring questions related to these individual characteristics, we generally rely on information provided directly by individuals, although other strategies are possible, such as obtaining data through experiments or inferring psychological information from secondary or archival data. When gathering these data through surveys, it is important to frame the relevant questions so that non-response rates and response bias are minimized. Questions related to sensitive issues may be ignored, resulting in high non-response rates, while response bias is likely to be caused by respondents' desires to present themselves in a favourable light (Catania 1999). Individuals are also liable to under- or over-report behaviours when asked to recall events from the past. For these reasons, it is important to measure these individual variables through items and scales that have been well tested and are grounded in theory. In this thesis, I adopted an interdisciplinary approach that takes account not only of the body of research in management and economics on this topic, but also of related streams of research in sociology and psychology. This allowed me to make use of well-established scales and concepts from other disciplines and to employ them to analyse the context of university–industry interaction.

Non-response bias can occur if non-responders present some specific characteristics that influenced their decision not to respond to the questionnaire. It could be argued that since the surveys constructed for this thesis were intended to measure university-industry engagement, individuals who did not collaborate with firms would decide not to address the questionnaire. This is a legitimate concern in relation to all the information that requires voluntary disclosure from the individuals analysed. In the covering letter to would-be respondents I explained that the questionnaire was addressed to all researchers, independent of their experience of collaboration with industry. In the Italian survey, 18% of respondents did not participate in any collaboration with industry; in the UK survey, 10% of respondents did not report any instances of collaboration in years 2006 and 2007. Also, as described in Chapter 2, I employed several statistical techniques (such as comparing characteristics of potential participants with those of respondents, comparing early and late respondents) to understand the possible extent of non-response bias. While these tests did not reveal any major biases, they are not conclusive evidence of complete representativeness of my sample. However, a possible lower response rate of non-collaborators would mean that results in this study are rather conservative.

Surveys are also liable to suffer from biases related to sample selection. Sample selection bias is a systematic error due to non-random sampling of a population, in which some members of the population are less (or more) likely to be included than others because of their characteristics. In my data several sources of this bias may have been present. In the case of the Italian survey, respondents come from universities with active TTOs, and from disciplines with clear linkages with industry. In the case of the UK survey, scientists interviewed are all EPSRC grant holders: they are therefore more senior and scientifically more productive than the average UK researcher, and mostly come from a limited set of disciplines related to engineering and physical sciences. The possible presence of sample selection bias raises questions about the external and internal validity of results. Ideally, sampling procedures should ensure population representativeness and avoid sample bias; however, this may be unfeasible because of cost and time considerations. Choosing to target a particular group to analyse has some benefits and costs for the research.

On the positive side, choosing a population on which I possessed rich information (such as ESRC grant holders) gave me the opportunity better to characterize the individuals in the population. Working with a sample of limited size allowed me to collect and link information from a wide range of sources (see Chapter 3) to the individuals who responded to the survey. Since much of the data collection was done manually, this would have been impossible with a very large sample, for example, a census of all academics in a country. A sample of limited size also made it possible to contact the researchers several times to ensure a satisfactory response rate.

On the negative side, sample selection bias means that results may not be representative of the whole population. While I employed several statistical techniques to ensure results were not driven by some exogenous characteristics of the researchers which were influencing selection of the sample studied (see Chapter 3), I cannot generalize my findings to the whole population of academics in Italy or the UK. However, as my interest in this thesis was to explore the mechanisms behind university-industry interactions, it is appropriate to study academics who are active in research and who are able to mobilize different kinds of resources.

Future research should ensure population representativeness and also limit selection bias. For instance, the disciplinary scope of the surveyed population could be broadened, and more universities and disciplines could be targeted. The central practical challenge for researchers will be to generate large lists of researchers that are either reflective of the whole population or of a random non-biased sample. When trying to measure observable behaviours

or outcomes (such as number of joint research contract or consultancies), future research should try to collect objective information. Records held by universities on industry contracts would be ideal sources of information, but present two major challenges. First, they are not readily available because they are often considered commercially sensitive by university administrators. Second, analysis would need to be restricted to a limited number of institutions (or even to a single case) since these data are difficult to standardize across a large number of universities. These difficulties could be mitigated through a large effort undertaken at national (or international) level, as in the case of STAR METRICS in the US, a federal and research institution collaboration to create a repository of data and tools to assess the impact of federal R&D investments (<https://www.starmetrics.nih.gov>). To date, no similar exercise has been carried out in the UK or in Italy.

Another problem is lack of longitudinal data. My thesis is based on cross-sectional data, which poses limitations in terms of inferring causal relationships between variables. I mitigated this problem by complementing the information collected through the survey with information contained in different datasets and including a time dimension wherever possible (such as with publication data or RAE data). I decided not to use both waves of the UK survey in this thesis (Chapters 5 and 7) because it was not appropriate (Chapter 5: self-monitoring is a trait which is relatively stable over an individual's lifetime) or because it would have reduced the sample available for analysis, compromising statistical significance (Chapter 7: in order to construct groups, it is necessary to have a rather large sample of observations). When possible, such as in Chapter 6, I exploited the panel nature of part of my data (venture creations and records on universities' commercialization activities). While a new generation of studies using panel data on academic patents and publications takes account of the time dimension (Stuart and Ding 2006; Azoulay, Ding et al. 2007; Breschi, Lissoni et al. 2007; Azoulay, Ding et al. 2009), this has yet to be accomplished by research on academic engagement using survey data. Future research should conduct repeated surveys, or at least administer subsequent surveys containing some identical questions, across a comparable population of researchers, in order to improve the reliability of inferences on causal relationships.

A related issue is the problem of possible self-selection. This concern is particularly relevant when trying to gauge the effect of the environment or of social groups on individual behaviour. In the absence of a time element, it is difficult to understand whether academics adopt certain behaviours *because* of their environment, or if they deliberately choose to operate in a group (or an organization) whose characteristics resemble their own. To identify

more clearly the different mechanisms influencing individual behaviour, future research should take into account the career histories of researchers. Cohort studies that follow academics with initially similar characteristics over time, would help to determine causality relationships and to separate the role of the environment or characteristics developed later in researchers' careers, from selection effects.

Finally, this research does not explore the consequences of academic engagement. The impact of academics' engagement with industry on scientific productivity should be a major topic in the debate on university-industry interaction. This debate so far has ignored the impact on teaching-related activities and has tended to focus only on the effects of academic patenting and entrepreneurship on the rate, direction and quantity of science (Agrawal and Henderson 2002; Breschi, Lissoni et al. 2007; Fabrizio and Di Minin 2008; Azoulay, Ding et al. 2009; Larsen 2011). However, the phenomenon of university-industry interaction includes a rich mixture of mechanisms which often apply to most academic researchers, as opposed to patenting and entrepreneurship. It is clear that each of these mechanisms of interaction with industry require different levels of time and effort on the part of an academic. Thus, knowledge transfer efforts potentially could shift researchers' efforts away from teaching and long-term oriented basic research, towards commercial, applied research with a short-term orientation, reducing academics' scientific productivity and endangering the universities' educational and scientific missions.

Future research should analyse various aspects of the possible consequences of academic engagement, such as its impact on education activities, its impact on research productivity and the relationship between academic engagement and commercialization. This last feature is important because some types of collaboration may complement commercialization outputs while others may be neutral or even compete with them. Knowing more about the relationship between academic engagement and commercialization would also inform policy debates by clarifying whether policies designed to stimulate entrepreneurship also stimulate academic engagement, or whether more focused policy approaches are needed.

POLICY IMPLICATIONS

The results of this thesis should provide some interesting reading for policy makers and university administrators.

Many policy initiatives in this area are motivated by the idea that Europe is suffering from an 'engagement deficit' compared to the US. The message behind the so-called

European Paradox (made official through the publication by the European Commission in 1994 of the *White Book on Innovation* (CEC 1994) and often relabelled to fit single national contests) states that Europe produces research comparable to the US, but is unable to translate this research into successful technological innovation. This idea has pushed European policy makers to reconsider the way public research is structured and to put more emphasis and support on research, which, in turn, can more easily and more successfully enter national innovation systems.

Some of these efforts have been directed to improving interactions between university and firms, under the assumption that a better interface between academia and industry would facilitate the flow of basic research and ideas to the development and innovation stages. This has been identified by the European Commission as one of the six priorities for European universities in the immediate future (EC 2003). Given the difficulty to measure these flows, policy makers have channelled attention to activities that leave more evident trails: patenting and entrepreneurship. As a result, most policy initiatives are designed to encourage and support these two specific activities.

It is important to point out also that a large proportion of the evidence supporting the existence of an ‘engagement deficit’ is the result of misinterpretation of the data available on university-industry interactions in Europe. As evidence to compare awareness to commercial opportunities among university researchers in different countries was (and still is) very weak, low levels of patenting by European universities has been used as an indicator for lack of general academic engagement. There are several indications however that statistics on university patenting in Europe are biased by the fact that universities often do not appear as the applicant on patents, even when their researchers are involved as inventors (Geuna and Nesta 2006; Giuri, Mariani et al. 2007; Lissoni, Llerena et al. 2008).

My thesis highlights that academics engage in a wide range of industry engagement activities, other than the more easily observable patenting and creation of start-ups. From a policy perspective, it is important to recognize that different transfer or collaboration mechanisms exist, that they may generate different benefits, and that they require different support structures and incentive mechanisms. First, as individual discretion seems the main determinant of academic engagement with industry, it is important that policy makers and university administrators understand what are the driving forces of individual academics’ willingness to collaborate with industry. The discourse around the ‘engagement deficit’ ignores the fact that in reality collaboration with industry is an activity that is quite widespread among academics and often is driven by research-related motivations, such as

acquiring additional funds for the laboratory or getting inspiration for new research projects. If we treat universities as monolithic organizations where individuals respond in the same way to the same set of incentives, we overlook the importance that the affordance of autonomy plays in incentivizing and guiding researchers' behaviours. We should instead recognize that individual characteristics and motivations are central to determining who ultimately will engage with industry.

In addition, to shape university practices and structures at the organizational level, policy measures should be addressed to individuals and the groups in which they work. For instance, in my thesis, I show that knowing about the benefits associated with collaboration increases academics' willingness to participate in knowledge transfer activities. Thus, increasing awareness of the opportunities for collaboration and fostering individual-level engagement skills would appear to be potentially powerful for driving increased volume and quality of university-industry relations. I highlighted also the influence of peer effects for stimulating individuals' collaboration activities, both through social learning and social comparison. Creating a favourable social environment for university-industry collaboration by attracting individuals interested in developing those kinds of relationships should increase the university's potential for commercializing its research. This might be achieved by ensuring that hiring, promotion and tenure decisions reward collaboration and commercialization without sacrificing scholarship.

Given the focus on patenting and entrepreneurship in the discourse on university-industry interaction, there is a strong emphasis on the role of TTOs or liaison offices for promoting and facilitating academics' engagement with industry. TTOs have often been considered formal gateways between universities and industry and government funding to encourage technology transfer and collaboration have been directed mainly to developing and strengthening TTOs. These structures are very important for assisting academics in their technology transfer and research commercialization activities: by establishing a formal framework for collaboration between researchers and companies, they ensure that universities benefit from the interaction (Siegel, Veugelers et al. 2007). Some authors note the aggressive commercialization strategies and inadequacy of staff of some TTOs, as a result of extremely rapid growth due to large influxes of funds, such as those channelled through HEIF, and point to the barriers they create for firms looking to collaborate with universities on research projects (Fabrizio 2007; Valentin and Jensen 2007). However, others highlight the importance of TTOs for facilitating the creation of connections between researchers and firms (Siegel 2006; Clarysse, Wright et al. 2007; Wright, Clarysse et al. 2007).

Nonetheless, the increased influence of TTOs can create two sets of problems. First, as previously discussed, concentrating on organizational mechanisms can make university administrators overlook the role of individual volition in determining academic engagement patterns in their institutions. Second, focusing almost entirely on TTOs generates an organizational focus within the university on formal commercialisation mechanisms, that is, patenting, licensing and entrepreneurship. The results from the research in this thesis show that the role of these structures for stimulating academic entrepreneurship is rather limited, and depends crucially on individuals' predispositions towards entrepreneurship. University administrators may need to reconsider the role played by their TTOs, and revise their views on what constitutes a good measure of TTO performance. If the involvement of researchers in entrepreneurial activity ultimately is a function of their individual characteristics and personal perceptions, TTOs might be more effective at fostering entrepreneurship by creating a favourable social environment and making academics aware of the opportunities for engagement and the benefits that can be derive from it, rather than focusing only on facilitating technology transfer from a legal and commercial point of view.

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APPENDIX

IPGC Survey of University Researchers 2009

A. University-industry interactions

1. How important are the following reasons for your involvement in interactions with industry? Please select the appropriate responses.

	Not at all importa nt	Not very import tant	Some what import tant	Import tant	Cru cial
Source of personal income	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Source of additional research income	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Keeping abreast of research conducted in industry	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Raising awareness of problems that industry confronts	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Building and sustaining your professional network	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Seeking proprietary knowledge (e.g. patents)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Increasing the likelihood of application of my research outside academia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feedback from industry about viability of research	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Access to materials or data necessary for research	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Access to research expertise of industry employees	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Access to state-of-the art equipment, facilities and instruments	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Helping students to find employment in industry	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Improving the understanding of foundations of particular phenomena	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Training of postgraduate students	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Getting inspiration for new research projects	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. How frequently have you been engaged in the following types of activity with industry in the last two years (calendar years 2007 and 2008)? Please select the appropriate response.

<i>Types of activity</i>	0 times	1-2 times	3-5 times	6-9 times	≥10 times
Creation of new physical facilities with industry funding (e.g. new laboratory, other buildings on campus)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A new joint research agreement (original research work undertaken by both partners)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A new contract research agreement (original research work done by University alone)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
A new consultancy agreement (provision of advice that requires no original research)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Training of company employees (through course enrolment or through temporary personnel exchanges)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Postgraduate training with a company (e.g. joint supervision of PhDs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Attendance at conferences with industry and university participation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Attendance at industry sponsored meetings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

3. In the past two years, what share of your research team's total research budget does industry funding account for?

Please indicate the share: %

4. How many years of work experience have you had in the private sector?

5. Please indicate the extent to which the following act as constraints to your involvement in interactions with industry.

	Not at all	A little	Modestly	Quite a lot	Very much
Absence of established procedures for collaboration with industry	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
University's Technology Transfer Offices have a low profile	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The nature of my research is not linked with industry interests or needs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Potential conflicts with industry regarding Intellectual Property Rights	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Short term orientation of industry research	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of suitable government funding programmes for university-industry joint research in specific areas	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Industry imposes delays in dissemination of research outcomes and publications	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Rules and regulations imposed by university or government funding agencies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Difficulty in finding companies with appropriate profile (e.g. highly innovative partners)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mutual lack of understanding about expectations and working priorities	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
High personnel turnover and lack of continuity in companies' research strategies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Policies adopted by the university's Technology Transfer Office	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

B. Your work: structure, interaction style and motives

6. What share of your total work time do you devote to the following activities in an average week of work? Note that the column must sum 100%

Doing research that does not involve industry	
University administration	
Teaching and related activities	
Working on research activities with people in industry (excluding consulting and activities related to the creation/management of commercial ventures)	

Consulting and activities related to the creation/management of commercial ventures	
<i>Total time of work</i>	<i>100%</i>

7. When thinking about your job as an academic, how important is each of the following factors to you? Please select the appropriate responses

	Not at all important	Not very important	Somewhat important	Important	Crucial
Salary	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Benefits	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Job security	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Opportunities for career advancement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Intellectual challenge	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Level of responsibility	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Degree of independence	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Contribution to society	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

C. Relationship with industry and support from department and university

8. Consider your level of agreement with the following statements about your working with industrial partners. Rank your level of agreement from 1 (strongly disagree) to 5 (strongly agree)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
During collaborative projects, my industrial partners usually treated my problems constructively and with care	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
My industrial partners may use opportunities that arise to profit at my expense or at the expense of the university	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Based on past experience, I cannot have complete confidence in my industrial partners to keep promises made to me	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I trust my industrial partners to treat me fairly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

I trust that confidential information shared with my industrial partners about my research results will be kept strictly private	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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9. Please indicate your level of agreement with the following statements about the supportiveness towards industry collaboration of your department and of your university. Rank your level of agreement from 1 (strongly disagree) to 5 (strongly agree)

	Department Strongly disagree → Strongly agree	University Strongly disagree → Strongly agree
My department/university is very effective in supporting collaboration with industry	① ② ③ ④ ⑤	① ② ③ ④ ⑤
My department/university is an obstacle in the collaboration with industry	① ② ③ ④ ⑤	① ② ③ ④ ⑤
My department/university rewards me for working with industry	① ② ③ ④ ⑤	① ② ③ ④ ⑤
My department/university actively encourages me to work with industry	① ② ③ ④ ⑤	① ② ③ ④ ⑤

10. Please assess the impact that the Research Assessment Exercise 2008 had on your collaborations with industry. Please select the appropriate responses.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
In preparing for the RAE I reduced my work with industry to give more time to research I could publish in basic research / discipline oriented journals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The requirements of the RAE left with little time to develop new links with industry	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The requirements of the RAE made me avoid publishing in practice-based journals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

The requirements of the RAE left me with little time to sustain my relationships with industry	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The requirements of the RAE process limited my time to develop commercial activities, such as starting a new venture	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

D. Entrepreneurial orientation and venture creation

11. Assess your level of agreement with the following statements. Please select the appropriate responses.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I frequently identify opportunities to start-up new businesses (even though I may not pursue them)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I frequently identify ideas that can be converted into new product or services (even though I may not pursue them)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I am generally not interested in ideas that may materialise into profitable enterprises	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	Yes	No
12. You are, alone or with others, currently trying to start a new business, including any self-employment or selling any goods or services to others	<input type="checkbox"/>	<input type="checkbox"/>
13. You are, alone or with others, expecting to start a new business, including any type of self-employment, within the	<input type="checkbox"/>	<input type="checkbox"/>

next three years		
14. In the past, you have been involved, alone or with others, in the creation of a new business (successful or unsuccessful), including any self-employment or selling any goods or services to others	<input type="checkbox"/>	<input type="checkbox"/>

14A. [IF ANSWERED YES TO 14] Please indicate how many:

[IF ANSWERED YES TO 12 OR 13 OR 14]

15. How important were the following factors in influence your decision to start a business?
Please select the appropriate responses.

	Not at all important	Not very important	Somewhat important	Important	Crucial
To be at the forefront of scientific and technological developments	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To challenge myself	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To develop practical application for a product from my research	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To fulfil a personal vision	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To achieve something and to receive recognition for it	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To lead and motivate others	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To have more influence in my community	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To increase my prestige among my colleagues	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To follow the example of a person I admire	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To develop and learn as a person	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To achieve greater financial security	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
To increase my personal income	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

16. Please indicate the extent to which the following have acted as barriers in your attempts to start a business. Please select the appropriate responses.

	Not at all important	Not very important	Somewhat important	Important	Crucial
Family pressure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Different career trajectory	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of resources	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of support from your university	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of support from colleagues	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Lack of mentors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Structure of the university incentive system	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Limited financial need	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

E. Commercial ventures

[IF ANSWERED YES TO 14, NUMBER OF SLOTS EQUAL TO ANSWER TO 14A]

17. Please provide the name of the companies in whose creation you have been involved.

Company name	Year of establishment	Ongoing?

18. Which of the following best fits as a description of the business model of the companies you contributed to create? Please select the appropriate response.

<i>Company A</i>	
The company provides research-based consultancy or research services to customers	<input type="checkbox"/>
The company develops intellectual property rights that can be licensed or sold to customers	<input type="checkbox"/>

The company produces and market a product and has its own production/operations facilities put in place	<input type="checkbox"/>
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19. What roles do you have performed in the companies you have been involved with creating?

	Director	Consultant	Chairperson	Manager	Member of the scientific advisory board	None
Company A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

F. Personal background

20. Year of birth:

21. Gender: Female ☐ Male ☐

21 Current academic title: **[drop down menu]**

23. Do you have a PhD? Yes ☐ No ☐

24. When did you receive your PhD? 25. Where did you receive your PhD?

26. The statements below concern your personal reactions to a number of different situations. No two statements are exactly alike, so consider each statement carefully before answering. There are no correct or wrong answers. If you feel uncomfortable in answering this question, please feel free to proceed to the next question.

	True	False
I find it hard to imitate the behavior of other people	<input type="checkbox"/>	<input type="checkbox"/>
At parties and social gatherings, I do not attempt to do or say things that others will like	<input type="checkbox"/>	<input type="checkbox"/>
I can only argue for ideas which I already believe	<input type="checkbox"/>	<input type="checkbox"/>
I can make impromptu speeches even on topics about which I have almost no information	<input type="checkbox"/>	<input type="checkbox"/>
I guess I put on a show to impress or entertain others	<input type="checkbox"/>	<input type="checkbox"/>
I would probably make a good actor	<input type="checkbox"/>	<input type="checkbox"/>
In a group of people I am rarely the center of attention	<input type="checkbox"/>	<input type="checkbox"/>
In different situations and with different people, I often act like very different persons	<input type="checkbox"/>	<input type="checkbox"/>
I am not particularly good at making other people like me	<input type="checkbox"/>	<input type="checkbox"/>
I'm not always the person I appear to be	<input type="checkbox"/>	<input type="checkbox"/>
I would not change my opinions (or the way I do things) in order to please someone or win their favor	<input type="checkbox"/>	<input type="checkbox"/>
I have considered being an entertainer	<input type="checkbox"/>	<input type="checkbox"/>
I have never been good at games like charades or improvisational acting	<input type="checkbox"/>	<input type="checkbox"/>
I have trouble changing my behavior to suit different people and different situations	<input type="checkbox"/>	<input type="checkbox"/>
At a party I let others keep the jokes and stories going	<input type="checkbox"/>	<input type="checkbox"/>
I feel a bit awkward in public and do not show up quite as well as I should	<input type="checkbox"/>	<input type="checkbox"/>
I can look anyone in the eye and tell a lie with a straight face (if for a right end)	<input type="checkbox"/>	<input type="checkbox"/>
I may deceive people by being friendly when I really dislike them	<input type="checkbox"/>	<input type="checkbox"/>

27. Would you like to receive a report of this research? Yes ☐ No ☐

28. Please add any further comments below

