# University-Industry Relations and Entrepreneurship

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**Abstract:** Formal or informal relations between academia and industry have become more frequent and visible. Asides from a quite conspicuous political motivation that has, in more recent times, consistently pushed towards more close relations between higher education institutions or public research organisations and enterprises, there are a number of several other reasons, most notably those related to knowledge creation and exploitation, that have contributed to draw the attention on collaborative or cooperative agreements between members of academe and industry. This paper attempts to systematize and synthesize the now vast literature on the subject. It focuses on the relationships between forms or modes of academia and industry cooperative channels and their implications on knowledge production and exploitation. It explores their contribution to the concept of entrepreneurship, contextualising the mechanism of creation of spin-off firms from university research, and other subtle or more hidden forms of entrepreneurial behaviour. It presents relevant statistics on the phenomena, describing the main empirical findings and their most important contributions, and highlighting the main arguments that underpin the theoretical debates.

**Keywords:** University-industry relations, knowledge production and exploitation, entrepreneurship

## 1. Introduction

This paper explores the phenomena of university-industry relations (UIR) and its relationship to entrepreneurship. The first three sections draw on theoretical concepts from different areas to contextualise the phenomena. The two following sections describe several relational processes concerning interactions between researchers in the university and in the firm. The remaining sections, building on the previous ones, explore the notion of entrepreneurship in the context of university-industry relations and highlight the main debates concerning this theme.

## 2. Quantitative indicators of trends in university-industry relations

Increasing connections between academia and industry are visible in several indicators. Statistics on the percentage of total expenditure on R&D performed by the Higher Education sector that is financed by the Business sector (OECD 2003), including the EU15 countries plus Canada, Japan and USA, show a percentage of 2.2% in 1981 and a percentage of 5.5% in 2001. There is a wide diversity between countries, and the percentages vary from 1% to 13%. The USA is on the middle of the league. During the 1980 decade, there is a very rapid rate of increase (averaging 15% per year) and during the 1990s and 2001, the rising trend persists but at a slower and declining rate (about 4.5% per year). The pattern of growth during the first period is probably related to the spread of policy initiatives that supported increasing university-industry relations, whereas the pattern of growth during the last period is tentatively related to natural constrains or opportunities that limit the usefulness and growth of UIR. The ensuing discussion will elaborate further on that aspect.According to several reports (OECD 1997; OECD 2000) both the relative and the absolute number of publications co-authored by industry and university researchers are also increasing. The number of scientific papers that is cited by patents is also increasing, showing the impact that academic research is having on industrial inventive activity. Technological innovation makes increasing use of academic research output but the intensity and the degree of connection seems subject to considerable variability across fields. The number of firms that are created base on university research (spin-off firms) is also growing.

## 3. University-industry relations and social network theories

The advantages of having relationships with a wide variety of actors in diverse institutional settings have long attracted the attention of scholars (Freeman 2004). There are a few sociological concepts that help explain the mechanisms of information diffusion and knowledge exchange within or across networks. Granovetter (1973) proposes the concepts of strong and weak ties. A strong tie

represents a person with whom there is a regular interaction, and a weak tie represents a person with whom there are sporadic or punctual contacts. The source of much of new information that a person receives comes from weak ties, while strong ties are important in terms of day to day social interaction and support. Weak ties are the source of new ideas or new perspectives at looking at old problems. Strong ties are relevant in the exchange of complex information and conducive to the exchange of detailed and thick information (Ahuja 2000). Another conceptual perspective is the distinction between networks as bridges and networks as structural holes (Burt 1992). Elements of a network may connect differently and with different persons. If a person knows another person in a network but a third person only knows the second, there is a not yet realised potential of connection between this last person and the first one. This configuration was defined by Burt as a structural hole, meaning the connection potential between elements or groups of elements that are not connected. There are elements that are better positioned than other to bridge and broker these gaps in the structure of the network, either to their own advantage or based on mediation and arbitration (Obstfeld 2005). This discussion highlights the advantages of university-industry relations (UIR), in terms of the enhancement of the opportunities for new approaches to technological bottlenecks or opportunities faced by industry, and by opening new avenues of research for members of academia. Researchers in industry and researchers in academia have very different perspectives, experiences, and sensibilities and, in this sense, the two communities have inherent knowledge production advantages by creating communication channels and patterns of cooperation.

## 4. University-industry relations and economic theories of innovation

The discussion concerning UIR is related to the quest for optimal allocation of resources for knowledge production between public (e.g. universities) and private institutions (e.g. firms). In terms of economic theory, the concern is to maximise the social returns of that investment distribution. The discussion is complicated by the fact that knowledge has a public good nature that affects the way private and public returns are appropriated. Public goods are characterised by non-rivalry and non-excludability, meaning that is difficult, or impossible, to assure exclusive access to them, as well as to have exclusive fruition of them. The nature of knowledge is conducive to a division of labour between basic research and applied research. Basic research, whose outcome is generally codified, and whose appropriability is low should be performed by public institutions. The applied or goal oriented research, which implies, in general, an emphasis on tacit (non-codifiable) knowledge, which is more easily appropriated by the producer of that knowledge, is performed by profit seeking institutions. Under this linear perspective, the motivation for private firms to enter into relationships with universities would be to get access to basic knowledge, since the incentive of firms to invest internally in basic research would be too low.

If a non linear perspective of the process of knowledge creation and exploitation is adopted, other economic motivations may surge for firms to enter into relations with university. There are explicit links and feedback loops between basic research and applied or goal oriented research (Rosenberg and Nelson 1994). As such, firms need, or are obliged by the very nature of the process of technological development, to engage in basic research activities in order to fully exploit technological opportunities. Firms have to build a minimum, or at least attain a threshold, of internal capacities in order to be able to absorb and integrate profitably in their own product or service portfolio knowledge generated externally (Cohen and Levinthal 1990). Firms contribute to scientific advancement when generating innovative solutions to technical bottlenecks faced in their design or production phases (Kline and Rosenberg 1986), and through the development of new scientific instruments (Shinn 2005). The division of labour between public and private entities and the reasons for firms and universities to interact are thus more complex than a simple linear perspective would lead us to believe.

## 5. From collaboration in scientific networks to university-industry relations

Informal networks between individual researchers and between laboratories situated in different institutional settings or in different countries are as old as organized science and are inherent to the existence of “communities” of scientists and engineers belonging to the same discipline or working in the same or related field. Collaboration between scientists has been rising (Moed, Glänzel et al.

2004) and this trend may be related to changes in the organization of scientific work. There is a multiplication of team work after the mid twentieth century, related to public investment in large research projects. Team work has evolved to giant research projects, or "big science" as it is often called, of which the most common examples are related to high energy physics and aerospace research. Large projects in the field of molecular biology and biomedical research (e.g., the Genome project) have also introduced a truly networked and distributed form of organisation. Teamwork seems to represent a new paradigm in the organisation of scientific research, and marks a discontinuity with earlier research practices (Beaver 2001).The trend in scientific collaboration is not divorced from the trends in university-industry cooperation. The practice of team-work has spread out to include participants that are external to the university. A bibliometric study, spanning a period of two centuries, on the collaboration between scientists (Wagner-Dobler 2001), seems to indicate that collaboration (measured by co-authorship) increases in scientific fields that become, with time, more applied (to industrial applications). Collaboration intensity is not due to funding or specialization (which are commonly advanced causes) but by the application potential of theoretical science. That conclusion is in accordance with other empirical results, showing that the intensity of university-industry is sector specific, and is greater, for instance, in the biotechnology, ICT or aerospace fields (Faulkner and Senker 1994; Senker, Faulkner et al. 1998; NSF 2001), sectors in which there has been a huge increase in commercial applications.

University responsiveness to social needs are also evident in the study by Meyer-Krahmer (Meyer-Krahmer and Schmoch 1998), whereby the science-based sectors have, in this case, the lowest intensity of cooperation. This pattern is tentatively explained by the industrial structure of the country, which is highly specialized in fields which require much fewer inputs from science (e.g., the mechanical sector or a more traditional chemical sector). Patterns of university-industry interaction, strongly reflecting country-specific industrial structure characteristics, are evident in other studies (Sanchez and Tejedor 1995; Mansfield and Lee 1996; Leydesdorff 2004).The growth and spread of knowledge-intensive firms has revived and accentuated the importance of UIR and academic entrepreneurship, and specifically, the role of research and development within the network knowledge relationships (Bania, Eberts et al. 1993; Swann and Prevezer 1996; Owen-Smith, Riccaboni et al. 2002; Wilkinson and Young 2002; Miotti and Sachwald 2003; Roijakkers and Hagedoorn 2006).

## 6. Motivations for university-industry collaboration

Asides from the theoretically-based sociological or economic arguments that contextualise university-industry interactions, there are a number of other commonly advanced causes to explain the rise in UIR. They include the increase in multidisciplinarity and complexity of scientific and technological knowledge and the prohibitive costs of some projects, which extend beyond the capacities or competencies of any given institution, laboratory or discipline. Advances in information and communication technologies are also referred as an important cause for the rise in collaborative activities. Bonaccorsi and Piccaluga (Bonaccorsi and Piccaluga 1994) propose, from the point of view of the firm, a classification of the motivations for entering an university-industry relation, which is corroborated in many other studies (Feller and Roessner 1995; Sanchez and Tejedor 1995; Feldman, Feller et al. 2002; Leydesdorff 2003):

- Obtaining early access to scientific breakthroughs.
- Increasing the predictive and applied power of science; includes modelling, training.
- Delegating selected development activities; includes risk sharing, cost saving.
- Lack of resources; e.g., getting access to laboratories and equipment.

From the point of view of the university, the motivations for establishing UIR are not so explored in the literature, but seem to fall in the following categories (Lee 1996; Azagra-Caro, Archontakis et al. 2006):

- Knowledge motivations; to access or to interact with knowledge developed externally, in firms or other institutions, and to engage in oriented research.
- Political motivations; policies have been set up to encourage scientific collaboration, motivated by the belief that collaboration maximizes public investment in research funding.

- Financial motivation; the policies referred above have included a diminishing amount of government direct, structural funding of universities, as mechanisms to increase and encourage universities to self-finance through interactions with industry.

A comment is due in the first point, because the widespread notion in the literature is still that UIR are unidirectional relations, where industry is seeking knowledge from university, and not bidirectional, as it seems to be more the case (Meyer-Krahmer and Schmoch 1998). That would explain why UIR are less intense in regions where industry is less developed (Sanchez and Tejedor 1995), and why size of firm seems to be an important determinant of university-industry interaction (Fontana, Geuna et al. 2006). Large firms have generally built a stock of knowledge that is unique in many ways. Complementary between different research orientations seems to drive the exchange of knowledge in the common interests of both parts. This perspective is in line with sociological explanations.

## 7. University and the entrepreneurial function

All the above described phenomena reflect a university institution that is substantially engaged in external contacts, is responsive to external demands and expectations, is quite aware of global trends in technological developments and their potential applications and is willing to involve itself in active transfer and/or exchange of knowledge, motivated by a complex set of factors, of which the financial one is not the sole one. Rosenberg (Rosenberg and Nelson 1994) notes that the bulk of research that is done at the university is basic research, but that does not mean that it is not influenced by important technological problems or objectives. Furthermore, the bulk of research is done in the engineering or otherwise applied disciplines. The concept of entrepreneurship, when applied within the framework of the university setting, is normally associated with the capacity of the university to encourage the so-called spin-off firms that are created and nurtured by the university in order to exploit some concept or technology originating from its research groups. However, within the context of the university institution, this seems to be a narrow approach to use the concept of entrepreneurship. The concept of entrepreneurship involves two dimensions: original initiative and wealth creation. Throughout the paper, we have seen that the university has been, in general terms, and asides from regional or national differences, deeply involved in the activity of production and exchange of knowledge for the sake of economic development and wealth creation. The spin-off firm mechanism of knowledge transfer is but one of a plethora of other mechanisms to diffuse and create new applied knowledge. We have mentioned only the more direct forms of interaction of university and industry, but there are more mechanisms, albeit indirect, from which the economic impact and influence of university can be assessed.

The formal mechanisms (joint labs, spin-off firms and contract research) represent only the tip of the iceberg (OECD 2000). The more common formal mechanism is contract research. Licensing has gained increased acceptance. Most universities have implemented policies to exploit their intellectual property holdings, and have established technology transfer offices (Mowery and Nelson 1999). However, the majority of UIR are established trough informal contacts and channels (mobility of researchers, co-publications, conferences, exhibitions & specialised media, informal contacts within professional network, flow of graduates to industry). The recent policy and literature focus on formal modes of UIR has somehow diverted the attention from the importance of informal mechanisms in the process of knowledge exchange and application. Responses to a large survey on R&D performing firms in the USA (Cohen and Levinthal 1990) "…suggest that the contribution of public research to industrial R&D is principally via research findings, and this contribution is far greater than that of prototypes [built cooperatively]…" (p.8). The authors also found that the preferred channels for the information flow between academia and industry were related to those of "open science", namely publications, public meetings and conferences. Geographic proximity is an important determinant of UIR (Mansfield and Lee 1996), which is probably due to the fact that many, if not most, UIR are established on the basis of personal and close interactions (Feldman, Feller et al. 2002). The definition of entrepreneurship is generally linked to the recognition of an opportunity and the willingness to explore it. However, in the context of the university, the mechanism by which that opportunity is explored is not necessarily limited to the creation of (spin-off) firms. The above discussion about UIR highlights the varied approaches by which an opportunity may be commercialized (in the sense that it enters the market). Decisions made by faculty members reflect the diverse possibilities and mechanisms by which research results are

disseminated (Renault 2006) and "…this decisions are entrepreneurial in nature as they reflect an individual's recognition of an opportunity to commercialize an innovation" (p.228). In a strict sense, an entrepreneurial attitude may be exclusively linked to the capability, or at least the intention, of creating a company. In a more broad sense, it is useful and legitimate to consider other behaviours that contribute to market diffusion of research results.

A broader and more differentiated view on the concept of entrepreneurship within the academic context is proposed by several authors (Louis 1989; Laukkanen 2003). In a study of life science scientists in US universities, a continuum of entrepreneurial behaviour is proposed (Louis 1989), composed by five types of academic entrepreneurship: 1) large scale science, meaning the creation and funding of large scale groups or laboratories; 2) Supplemental income augmentation, which includes consultation practices, private practices, or the "lecture circuit; 3) Industrial support for university science; 4) patenting, as an extension of searching and signalling commercial opportunities, and 5) Direct commercial involvement, with the formation and ownership of firms, and potential involvement of university facilities and graduate students (p.115). The emerging characteristics of large scale science require and provide researchers with management skills and attitudes that are similar to those of the private sector (Etzkowitz 1983). Another relatively new and now widespread organizational form, the research centre, represents a "…shift of the university towards business formats" (Etzkowitz and Kemelgor 1998), whereby centre directors perform similar roles to that of CEO, liaising academe, industry and government. Research centres are multidisciplinary, cutting across traditional departmental barriers and scientific areas. They are created also to explore (albeit not commercially) a new perceived (scientific or technological) opportunity. Along with science parks and incubator facilities, centres are one of the new organisational forms, "...which is emerging as a driving force for industrial and social innovation" (p.280).

The creation of firms whose products are based on the research developed at the university seems to be a logical extension of the forms listed above. It is a most extreme form of entrepreneurial attitude within academia, and it is surely the most controversial, as it is the least compatible with traditional academic values. The factors that determine the universities' stance towards entrepreneurship are not clear. There is the debate between whether there is an entrepreneurial university, or rather individual entrepreneurs within the university. One the one hand, there are suggestions (Kassicieh, Radosevich et al. 1996) that institutional variables might affect academic entrepreneurship (for instance, IPR policies, formal polices supporting entrepreneurial activity, etc). On the other hand, there are evidences that individual and group values and norms, namely at the departmental or centre level, are the main determinants of entrepreneurial behaviour. Individual personal beliefs about the role of the university in commercializing technology seem to be the main determinants, according to a study of faculty behaviour towards academic entrepreneurship (Renault 2006). The author also contends that "…whatever the university policies may be, the important decisions in academic career…are made at the department level. Therefore, if the department is lukewarm about technology transfer, this will affect the behaviour of the professors." (p.237). These conclusions are in line with those reached at by an earlier study (Louis 1989). The author suggests that individual characteristics determine the entrepreneurial behaviour linked to consultancy or large scale projects, while group characteristics determine the entrepreneurial behaviour linked to firm creation or patenting. Favourable attitudes towards university polices according credit to technology transfer activities seem to be rising (Lee 1996) although not so to activities that are more directly linked to direct commercialization of results by means of firm creation, and apparently there seems to be no significant differences in this attitude between researchers of different scientific areas (Renault 2006), at least within the engineering and life sciences disciplines.

Funding pressures are always referred as an important factor behind the entrepreneurial behaviour of university, and the numbers presented above seems to suggest more than a coincidence between reduced funds from government and the increase in the proportion of external funding. Research funds and contract research with industry seem to be the main contributors to this rising trend, and there is no clear cut evidence on the financial benefits of licensing or firm creation activities. Geuna (Geuna and Nesta in press) puts some strong doubts on the advantages of deepening the entrepreneurial (in the strict sense) university. Regarding the additional funds that

universities were supposed to obtain from intellectual property rights and equity investments in start-up firms, the authors point to the fact that most university's technology transfer offices do not generate positive net incomes. Investing in start-up firms based upon (university) patents is a very uncertain and risky business, and the typical success rate is rather low. Some authors defend that to increase this success rate, a proper institutional environment, that addresses typical university rigidities, should be created (Debackere 2000).

## 8. Additional debates on the implications of the redesign of the university mission

Current debates on the changing mission and expectations that fall upon the university institution, and the impacts it may have, fall on the capacity of the university to sustain both long term indirect support of economic growth, through the generation of new knowledge, and short term direct support of economic development, trough technology transfer mechanisms. It seems important to maintain a high systemic diversity in order to sustain an environment rich in opportunity and integrative capacity. This assertion can be extrapolated to the university setting to contextualise the entrepreneurship function, which is important as it introduces systemic diversity within the university environment and an otherwise absent integrative dimension. There are approaches that defend an anti-differentionist stance (Gibbons 2000), arguing that the contemporary knowledge production process proceeds in a way that the distinction between the mission and roles of different actors are disappearing or fading away, predicting the collapse of the university and scientific disciplines and specialties. Etzkowtiz and Leydesdorf (Etzkowitz and Leydesdorff 1998), although not denying distinct roles for each institution, propose a deeper integration between three broad categories of actors (university, industry, government). Although acknowledging the different roles and missions of each broad category of actors, the authors defend that the character and culture of each actor are being mutually absorbed by the other(s), and all are loosing their distinctive features. Arguing for a more entrepreneurial university they propose that the normative structure of science should change from the notion of "communalism" to the notion of "capitalisation".

Shinn (Shinn 2002) says that the above mentioned reasons lack a historical perspective on the relations between university and other actors, wrongly assuming that collaboration dynamics is a recent phenomena. He proposes the notion of "transversality" to describe and explain the behaviour of groups of technologists, active for at least two decades and responsible for the development of radically new devices and instrumentation, that operate at the interface between established institutions, "…both sustaining instituted differentiations and divisions of labour and violating them" (p.612). He further adds that collaboration has become gradually more important because there is a growing cognitive and organizational fragmentation (Shinn 2005). Vavakova (Vavakova 1998) argues that there is a political drive behind the claims for a redesign of the mission of the university that creates an imbalance between the private and social returns of research activity. The author says that excessive redesign of the university mission will lead to reduction of knowledge available as a public good and the manipulation of the public research agenda by private interests.

Nelson (Nelson 2001) echoes the concerns about the availability of public knowledge that can be jeopardised by the privatisation of university knowledge, and reaffirms the contribution to economic development that universities have historically made (either in the past or recently), through their research activity and through mechanisms of open science, exemplifying with the cases of the biotechnology and ICT sector, which draw heavily on the competencies developed at universities. He warns that the university, by tending to increase the privatisation of its own knowledge output, and effectively starting or tending to use the same weapons of private entities, is entering a dangerous terrain that may eventually affect and overhaul its whole structure, rationale and support. Others authors (Gulbrandsen and Smeby 2005) argue that a high research productivity and a commitment to the university ethos of open science and communication is compatible with an entrepreneurial attitude and the exploration of knowledge through other means and channels.

## 9. Conclusion

University-industry collaboration has risen in recent years. Network and cognitive advantages have been determinants of this trend, which has been politically encouraged. Causes seem to be related to changes in the scientific and technological landscape and the ensuing opportunities perceived by the market and the search for competencies that universities can provide in times of change. Entrepreneurship presupposes an exploration of new opportunities for the sake of wealth creation and economic development. The university has historically been responsive to demands for opportunities, albeit in peculiar ways, and has contributed, directly and indirectly, to economic development and wealth creation, adopting several mechanisms that promote or facilitate knowledge transfer or exchange. The entrepreneurial stance of the university should be viewed in this broad context. Several mechanisms and attitudes, asides from the creation of firms, have been and are used in the diffusion and market penetration of knowledge. An excessive emphasis on the mission of the university to satisfy immediate societal knowledge needs may compromise other missions, notably the fundamental knowledge production function that underpins future innovation and economic development. A balance between the three main functions of the university must be reached. Promoting diversity and variability is fundamental to maintain an opportunity rich environment, for the present and for the future.

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