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4 Academic patents, spin-offs and beyond

The many faces of scientific entrepreneurship

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1 Introduction

The present chapter discusses the notion of 'academic entrepreneurship', as it emerges from a number of recent theoretical and applied contributions to the economics of innovation and science and technology studies.

In Section 2 we put forward the proposition that contemporary science is the result of an 'entrepreneurial' effort, undertaken both by individual scientists and by the academic institutions that host them. The intensity and specific features of the entrepreneurial effort depends very much on the institutional characteristics of national academic systems, which we outline by looking briefly at the history of the US and French systems, the last one taken as the extreme example of the European case (Section 3).

In Sections 3 and 4 we examine the recent literature on university patenting and spin-off firm creation, and suggest that both commercial activities result from the broad entrepreneurial agendas of individual scientists and universities, and not merely from a few individual scientists' profit-seeking attitudes.

In Section 5 we propose a few conclusions and outline a few directions for future research.

2 'Entrepreneurship' in science

'Entrepreneurship' is quite a popular word in a number of studies dealing with the philosophy, sociology, economics and history of science. A common thread can be traced across the different authors and approaches that have used it.

2.1 Entrepreneurship as an individual features: the sociology of scientist–entrepreneurs

The contemporary sociology and economics of science describe the organization of scientific research, especially in experimental sciences, as necessarily 'entrepreneurial'. Scientists at the head of large laboratories perform a number of activities which are typical of the modern entrepreneur, such as setting up and managing increasingly complex organizations, and providing them with adequate funding and human capital. More generally, scientists with innovative research agendas have to relate frequently with agents outside the universities (especially policy-makers and industrialists), in order to find political and material support for that agenda.

The starting point of many recent essays is Robert Merton's portrait of academic scientists as individuals engaged in careers based upon peers' recognition of their contributions to the advancement of scientific knowledge (Merton 1973). In Merton's view, such recognition takes primarily the form of 'scientific credit', which is given to any scientist whose 'priority claim' over a discovery is acknowledged by the scientific community at large. Philosophers and economists of science have gone a long way in exploring how the quest for scientific credit may shape social relationships in science, and have reinforced the notion that being credited with one or more 'discoveries' (through the mechanism of bibliographic citations and, possibly, eponymy) is essential to a scientist's career (Kitcher 1993; Dasgupta and David 1994).

An even more complex view of how scientists manage their careers according to entrepreneurial criteria comes from the sociological tradition of 'science studies' (Callon 2002), and a number of related contributions to the history of science and technology (Latour 1988; Lenoir 1997).

This literature explores in greater depth the relational aspect of the scientific enterprise. Scientific facts are not merely 'discovered' by the first scientist who solves a theoretical puzzle or creates an innovative experimental routine (and thus wins the priority race). Rather, they are established by obtaining social consensus on the relevance of the topic, on the legitimacy of the theoretical assumptions, and on the solidity of experimental routines. Such consensus has to be gained both from fellow scientists (especially within one's own disciplinary field) and from other relevant actors, such as businessmen and policy-makers.

Fellow scientists can validate the contents of a scientific paper or programme by citing it as a legitimate source of information, or neglect it as irrelevant or poorly conceived. Their consensus has to be elicited either by indirect means (e.g. by choosing the best publication outlet or through a perfunctory use of paper citations) or by more direct ones, by establishing social ties through research cooperation, conference invitations and joint lobbying for economic resources from state and industry.

In this respect, businessmen and policy-makers can be instrumental in providing funds, data, scientific materials and instruments, as well as ethical validation. Participation to science policy forums, policy and ethical committees, and scientific boards of large companies are all necessary activities for senior scientists to support the activity of their laboratories.

If seen within this context, IPR management, consultancy and equity participation to spin-off companies are not simply market and market-like alternative activities, but indeed necessary steps, conditional to the scientific entrepreneur's chief goal of setting up or expanding her lab, and promoting her academic career (OECD 1999: 37).

This perspective suggests that technology transfer activities such as patenting or joining a start-up company may have deeper motivation than the immediate quest for profits. Ease of patenting and access to resources for setting up a company are welcome insofar they are instrumental in widening and thickening the scientist's network. They will be disregarded if they do not fit in the research agenda. At the same time, more research funds, or more career opportunities, although totally unrelated to any technology transfer target or firm creation objective, may naturally push more scientists to pursue the ambition of setting up their own laboratory; and it may well be that, by doing so, those scientists will reach out of the academic walls anyway.

Lenoir's (1997) portrait of German physiologists, physicists and chemical scientists in the nineteenth century confirms this view. In particular, Lenoir contrasts scientists engaged in academic careers within the boundaries of established disciplines with those whose research agendas foresee the birth of a new discipline, or require disciplinary boundaries to be re-drawn, either to allow for interdisciplinary work or to establish new hierarchies between disciplines.

Lenoir's scientist–entrepreneur first aims at acquiring superior skills and technical expertise in handling complex experimental procedures and equipment, so that other scientists will find it hard to disprove his experimental results, and will require his approval or help to validate their own findings. Then he will promote a wider agenda, which aims at proving the social benefits bestowed by the new disciplinary programme for society. Practical applications of the new scientific discipline (were it nineteenth-century organic chemistry or twentieth-century nuclear physics) are proved through patenting, licensing, consulting and the encouragement of start-ups by young colleagues and students.[3]

Thus, academic entrepreneurship, as part of the more general phenomenon of scientific entrepreneurship, proves to result from a complex bundle of strategies and incentives and career planning.

2.2 Academic entrepreneurship as an institutional feature: US vs. European universities

One of the best-known papers on entrepreneurship in academy is Henry Etzkowitz's (1983) essay on 'Entrepreneurial scientists and entrepreneurial universities in American academic science'. The 'entrepreneurial university' is there portrayed as the outcome of a revolutionary process started in the United States with the Big Science programmes launched in the aftermath of the Second World War. In a later paper, Etzkowitz (2003) suggests that, slowly but inevitably, European research-oriented universities will leave room to profit motives for their research, and turn into entrepreneurial ones such as their overseas counterparts.

On closer inspection, however, the American model of the 'entrepreneurial university' appears to be rooted much more deeply in the gradual evolution of US universities from teaching colleges of divinity and liberal arts to modern research institutions. By contrast, many contemporary efforts to promote entrepreneurial attitudes in universities outside the United States are at odds with an institutional history of central planning and control.

The US university system has been, since its early boom in the first half of the nineteenth century, a heterogeneous collection of a large number of autonomous institutions cherished by their local communities or by religious groups and individual philanthropists (Rudolph 1990). Their faculty members were neither subject to their students' control (as in Italian medieval universities) nor ever served as civil servants paid by the state, as in most European countries. Since their inception, the president and board of trustees of US colleges exercised a degree of local control which federal and state governments never managed to overcome. Attempts to centralize the university system have always been overthrown (both by the oldest private colleges and the more recent state universities), even at times when financial distress could have advised otherwise (Trow 2003). Nowadays, autonomy is one of the greatest strength of the US universities, and this is also the main background reason for their transformation into 'entrepreneurial' organizations.

Since right after Second World War, and well through the 1960s, the extraordinary success achieved by basic science applications to military technology legitimized the well-known exponential increase of federal funding of academic research. However, Vannevar Bush's famous report 'Science, the endless frontier', while presenting the case for large public funding of research universities convincingly, failed to persuade US lawmakers of the need to set up a centralized body for the administration of all funds (Graham and Diamond 1997).

Nowadays, a number of concurrent institutions still provide research grants in various fields. The National Institute of Health, the National Science Foundation, the Ministry of Defence and other governmental bodies all run projects both in separate scientific fields and in a few overlapping ones. The possibility to be financed, in certain fields, by different agencies has helped to keep alive a healthy heterogeneity of research targets (also within the same scientific field) and administration models.

All of these programmes rely on the so-called Principal Investigator (PI) principle, by which individual scientists (neither their departments nor their institutions) are made entirely responsible for a project. The PI's research record is instrumental to win the grant in order to set up or expand her own laboratory or research group. Individual scholarship, and not any political objective of equal distribution of resources, becomes the key allocation criteria for research funding. As a consequence, universities have been engaging in a race to recruit the most talented scientists, whose contribution is decisive to get public funds.

At the same time, individual scientists engage in self-promotion activities in order to win and then manage the grants. They devote their efforts not only to publishing, teaching and attending scientific meetings, but also to establishing relationships with one or more funding agencies, aiming at influencing the choice of the research topics to be funded, as well as networking at the academic level for recruiting brilliant young scientists to the ever-increasing needs of their laboratories. As employees of their universities, and not of the federal government nor of the individual states, the academic scientists are let free and possibly encouraged to engage in these typical entrepreneurial activities, as long as this enhances their university's reputation and financial health. As a result, the US academic system has witnessed in recent years an overall tendency of research teams to increase in size and complexity in all scientific fields, albeit at different rates (Adams *et al.* 2005).

Etzkowitz (1983) describes this pattern as one of diffusion of 'quasi-firms' (laboratories and research groups), whose survival and expansion depends upon chasing funds, recruiting skilled employees, managing funds, delivering results and moving up to higher-level funding agencies. PIs provide the necessary entrepreneurial effort and skills to do the job, in exchange for a large bite of the credit for the success of the scientific enterprise. Stephan and Levin (2002) offer a similar view. One cannot fail to see here a strong parallel with the redefinition of academic entrepreneurship we have proposed in Section 2.1.

The history and organization of the US system differs in many ways from the European one. These are well exemplified by French universities, whose history is one of abrupt termination and slow recreation under tight centralized control.

French medieval universities were abolished by the Revolution, as part of the wider effort to reduce the influence of the Catholic Church in education. The task of educating the technical and administrative elites was then assigned to the so-called Grandes Ecoles, modelled after the Ecole des Ponts Chaussées, founded in 1775.

After that, in 1806–8, a brand new institution was set up in order to educate a new generation of teachers, lawyers, medical doctors and the rank-and-file of public administration needed for the renovated state: the Imperial University. Its lecturers were asked to act as civil servants, organized along rigid disciplinary lines and within regional faculties under the state's control. It was not until 1896 that the regional faculties were transformed into local universities, and not until the 1970s that they gained a substantial degree of organizational (but not yet financial) autonomy (Neave 1993).

Research tasks were increasingly assigned to specialized institutes, often founded around a new discipline, such as the Institute Pasteur (1887), or under the direct control of a ministry, as in the case of various agricultural agencies. In 1939 the National Centre for Research (CNRS) was founded. Still well into the 1990s, CNRS employed over 14,000 full-time researchers, and even more were employed by the other public research organizations (PROs), as opposed to 45,000 university professors, whose research engagement was, at best, on a part-time basis.

Although since the late 1980s more and more CNRS labs have been moved within academic walls, a vertical hierarchy of labs exist, starting from those staffed exclusively by CNRS personnel (funded directly by CNRS and the Ministry of Education), followed by those staffed both by CNRS and university personnel, and down to those staffed entirely by university faculty, with no access to CNRS funds (Neave 1993; Laredo and Mustar 2001).

In recent times, French policy-makers have actively encouraged academic staff to engage in patenting and even in entrepreneurial ventures, but have also been unwilling to grant more autonomy either to the universities (which still cannot manage freely their personnel, real estate and finance) or to their researchers (whose contacts with industry are regulated in great detail). While the supposed lessons of the Bayh–Dole Act (see below) are clearly upheld, very little is retained of the lessons derived from the long US history of generous support to fundamental research, faculty mobility and university autonomy, nor from the role these features play both in promoting technology transfer and in shaping scientific entrepreneurship.

Rigidities such as those described for France are common throughout continental Europe, starting with large countries such as Germany and Italy (Clark 1993). And the cross-country similarities extend to the policy-makers' wish to imitate the US university patenting boom, and their reluctance to go beyond university IPR reform.

3 Academic entrepreneurship and university patents

Over the past 20 years, university patents have come to the attention of the academic community, of policy-makers, and more recently of the general public, as a consequence of the impressive growth registered in the number of patent applications by US universities after the introduction of the Bayh–Dole Act in 1980.

In particular, USPTO patent applications by universities have been growing at a much faster rate than those by business companies and individuals. Above all, there has been an impressive growth in the number of academic institutions entering for the first time in the patent system. Henderson *et al.* (1998) calculate that from 1965 to 1991 the number of universities patenting in the United States increased from 30 to 150. Most patents, however, remained concentrated in the hands of the major research universities: in 1991, the top 20 universities held 70 per cent of patents. Biotechnology and, later, software have been the fields where university patenting has thrived most.

A close inspection of the recent literature, however, reveals once again that this particular form of academic entrepreneurship (AE) has deep roots in the history and institutional profile of the US academic system; and that such roots are as important as the patent-based incentive scheme created by the Bayh–Dole Act, if not more.

The lack of comprehensive data on Europe makes any comparison effort extremely arduous, and the need to collect data with imaginative criteria the most urgent. The few available studies, however, tend to confirm the importance of historical conditions and institutional frameworks.

3.1 University patents before the Bayh–Dole Act

University patenting was common in US academia well before the introduction of the Bayh–Dole Act, but for a long time it was hardly associated with a profit motive, at least on the part of the university. The earliest university patents, and the first organizations dedicated to manage them, were due to academic inventors who wished to make their inventions accessible to the public at large, and return any commercial proceedings to science in the form of research grants.

Mowery and Sampat (2001) remind us of the importance, in the history of academic patenting, of Frederick Cottrell, professor at UC Berkeley, who in 1912 founded the Research Corporation, a non-profit company he endowed with his own patents, with the specific purpose of preventing the rampant monopolistic firms of the time from gaining control of the technological field of his interest, and used any proceeds to finance further academic research in a variety of fields. Apple (1989) offers a similar story for Wisconsin's Professor Harry Steenbock, who in 1925 founded the Wisconsin Alumni Research Foundation (WARF), and trusted it with his own patents in the food-processing field.

The Research Corporation, after receiving other patents by Cottrell's colleagues in various universities, went on to become the most important broker of academic patents. WARF similarly allowed the University of Wisconsin to be, for a long time, the top patenting university in the United States.

The Research Corporation and WARF have been instrumental in diffusing IPR management expertise in the US academic system. In the 1970s the Research Corporation, facing increasing costs for the management of a scarcely profitable patent portfolio, started decentralizing a number of tasks to the client universities, to which it offered training courses in IPR management and consultancy services. When, in the 1980s, the Research Corporation sold its university business to a for-profit spin-off, most universities had learnt enough to start their own technology transfer offices and exploit effectively the new opportunities opened up for them by the Bayh–Dole Act.

In Europe, only Britain had a similar experience with the British Technology Group (BTG), which was founded in 1948 (originally with the name of the National Research Development Corporation) with the specific aim of commercializing the results of British public research and re-investing the proceedings in the university system (Clarke 1985; Gee 1991).

3.2 Academic patents as a by-product of entrepreneurial science

Assessing the impact of the Bayh–Dole Act has been a major line of research in the United States. Among the many questions investigated, two are of particular interest here: did the Act really increase the number of university patents, or is it that progress in biotechnology and software (and the concurrent strengthening of IPR laws) would have led to the observed growth anyway? Did the economic incentives attached to patenting change the research pattern of universities, either by increasing the overall research effort, or by addressing it to more applied fields?

Research addressed to these questions has first investigated the kind of inventions patented by universities. The Act aimed at creating a marketplace for proofs of concepts and prototypes, to be acquired, developed and finally placed on the market. Granting IPRs to universities was necessary to overcome any potential market failure.

As argued by many studies we review below, clearly stated IPRs, along with proper contractual arrangement, can help overcoming agency problems.

Case studies by Zucker *et al.* (1998a) suggest that prominent US biotech scientists whose patents were licensed either to established or new companies, play a prominent role after licensing for the precise reason that their expertise and skills are needed to further develop the inventions. Jensen and Thursby (2001) argue that this is also the case in other fields. On a similar vein, Thursby and Thursby (2002) suggest, on the basis of survey data, that growth in university patenting and licensing may be explained by 'universities becoming more entrepreneurial' at all levels: scientists are more willing to disclose their inventions, while the university administrations have increased the rate at which disclosed inventions are patented. Academic research has not shifted from basic to applied, but commercialization efforts have become so aggressive that also inventions of minor importance have been patented. This may also explain early results by Henderson *et al.* (1998), who observe a decline in the importance of university patents (as measured by citations received) after the Bayh–Dole Act.

However, there is no complete agreement on the importance of agency problems, and the related IPR solutions, in the history of US technology transfer.

Studying the cases of Stanford, University of California, and Columbia University, Mowery *et al.* (2001) reach the conclusion that one can hardly attribute the recent historical developments to the Bayh–Dole Act. A greater influence has been possibly played by legislative changes allowing the general strengthening and broadening of IPRs, and in particular the increasing freedom to patent the results of biomedical research. Mowery *et al.* (2001) also find that academic research has not been diverted from basic targets, and criticize the methodology behind the above-mentioned papers whose findings go in the opposite directions.

Colyvas *et al.* (2002) study in depth the history of 11 blockbuster patents from Columbia and Stanford, and confirm that they do not originate from applied research, but rather from basic research aimed at the solution of practical problems. In contrast to Thursby and Thursby (2002), Colyvas *et al.* (2002) suggest that most inventions, while in need of further development for a number of applications, were of immediate use in industry for other purposes; and that the academic research leading to these inventions was, from its very beginning, already sponsored by industry or closely monitored (and influenced) by 'strategically placed people in industry'. According to this view, the Bayh–Dole Act not only did not divert academic scientists from their research interests, but also did little to promote additional technology transfer, which was already in place *before* any patent was taken.

Even the work by Zucker and colleagues, at a closer look, suggests that the latter might have been the case. The academic scientists who have exploited more effectively the opportunities offered by the new patenting regime are the so-called 'superstars', that is scientists with an outstanding publication record and an influential position in the local academic and business communities, as well as a long record in managing grants and personnel for their labs.

More recently, a number of empirical contributions have tested the hypothesis of a trade-off between commitment to scientific (basic) research and patenting by academic scientists, more often than not coming to negative conclusions.

In a cross-sectional perspective, scientists with a superior patenting performance also exhibit superior publication scores, while longitudinal analysis has revealed that inventorship of a patent has the tendency to be associated with a temporary increase in the number of publications, and not to a decrease in their quality. The most productive scientists are also those more likely to become academic inventors, as soon as they tap into a promising set of scientific opportunities.

In addition, institutional factors seem to matter a lot: other things equal, scientists whose colleagues are also academic inventors, or whose universities have a longer tradition of IPR management, are more likely to match a good publication record with some patenting activity (Azoulay *et al.* 2005).

Once again it is confirmed that, as far as individual scientists are concerned, patenting adds a further dimension to traditional forms of scientific entrepreneurship, but it does not change more traditional motivations and behaviours. Rather than pursuing patenting only for personal enrichment, scientists may disclose their research results because they hope to access further funds for their ongoing research, and support their careers within the academy. University administrators, on the contrary, are more prone to exploitative behaviour, as they chase royalties to strengthen the budgets of their institutions. Technology transfer offices may have often the additional problem to legitimize themselves by proving to be useful, as when their performance is evaluated on the basis of the number of disclosures, patents and licences they obtain.

This complexity is confirmed by studies on licensing schemes. As we noted above, licensee companies often require the commitment of scientists to develop further their inventions, so that the contract provides for output-based payments such as royalties. Thursby *et al.* (2005) explore licensing contracts more in depth, and find that they often involve explicit consulting duties for the academic scientists. The higher the importance of tacit knowledge and learning-by-doing in the application of an invention, the higher the chance that commercialization will require a direct involvement of the inventor (Lowe 2002). However, in a survey, Jensen and Thursby (2001) find also that technology transfer offices regard themselves as mediating between the requests of the university administration, which point at maximizing returns for the institutions via fees and royalties and therefore push for binding licensing-cum-consulting contracts, and those of the inventors, whose natural preferences go towards sponsored research.

3.3 Academic patenting in Europe

Research on academic patenting in Europe has been much less substantial than in the United States. The most part of it has dealt with the institutional differences between the European and the US academic systems. Discussion of these differences has served two different purposes:

1 As a possible explanation of quantitative differences in the patenting patterns by universities in the two systems.
2 As a justification for adopting different measurement criteria of academic patenting activity in the two systems.

The three most important institutional differences between Europe and the United States relate, or related until recently, to:

1 The legal ownership of IPRs over academic research, epitomized by the so-called 'professor's privilege', i.e. the exemption of academic personnel from attributing the rights over their inventions to their employers.
2 The balance between research conducted by universities and research conducted by other PROs in countries such as Germany and France.
3 The comparatively little autonomy and competencies of the European university administrations in matters of IPRs.

Until 2002, the academic (or professor's) privilege was a typical institution of the German patent law, which reflected the power achieved by academic scientists in the late 1800s. Over the twentieth century, it was also adopted by many of the countries which imitated the German academic system and science policies. In the UK, until recently, it was also a peculiar arrangement of Cambridge University.

According to a simplistic application of microeconomics, this arrangement should be expected to provide scientists with the highest possible incentives to exploit their research results via patenting. In practice, it has always achieved little, at least compared to the US tradition, as it was the result of an academic system that granted little managerial power to universities and empowered greatly individual professors as opposed to departments.

With no or little administrative support by the university, the costs and complexities of the patent system have traditionally discouraged academic scientists to actively manage their own IPRs. Lacking financial autonomy, most European universities saw little reason to obviate to this situation by arranging a transfer of the professors' IPRs to them, in exchange of royalties. Being forbidden or heavily constrained to conduct commercial activities by governmental regulations, European universities could not manage effectively a patent portfolio. And, with the exception of the BTG in Britain, no European country has ever hosted an organization such as the Research Corporation or WARF.

The academic privilege has been recently abolished both by Germany and Denmark, and Sweden is also considering abandoning it (PVA–MV 2003). Currently, IPRs from publicly funded research belong to universities in Austria, Belgium, France, Germany, the Netherlands, Norway, Portugal and Spain (OECD 2003).

However, no matter whether the national legislation imposed the academic privilege, most European universities have for long lacked the autonomy and administrative skills required in order to take advantage of their professors' patenting activities. They traditionally resisted being involved in such activities, and took the shortcut of allowing scientists engaged in cooperative or contract research with various business companies or PROs to sign blanket agreements that left all IPRs in their partners' hands.

This suggests that a large part of academic patents in Europe may simply escape the most commonly available statistics, which classify the origin of the patent according to the identity of the grantees or applicants, rather than of the inventors. If this methodological remark were true, traditional comparisons with the United States may be proved to be misleading; insofar as they exaggerate the scarcity of academic patents in Europe.

Following this clue, Meyer (2003) for Finland, Iversen *et al.* (2007) for Norway and Lissoni *et al.* (2008) for Italy, France and Sweden have re-classified patents by inventor, and matched the inventors' names with available datasets on university faculties. They found out that in both countries a significant percentage of the business companies' patents originate from academic inventors (from 3 per cent of EPO patents in Italy to 8 per cent in Finland). CNR, CNRS and VTT (the most prominent PROs of France, Italy and Finland, respectively) also hold many patents signed by academic inventors.

Attempts to measure the number of academic patents in Germany have relied on a thinner tactic, namely that of looking for the academic title 'Professor' in the inventor's field of patent applications, given that the title, in Germany, is awarded only to academics with tenured positions. Schmiemann and Durvy (2003) suggest that, according to this kind of calculation, 5 per cent of German patents at EPO can be attributed to universities. Gering's and Schmoch's (2003) calculations suggest that academic inventors' patents at the German patent office have grown from about 200 to almost 1,800 between 1970 and 2000.

Data of this kind have also been collected for individual institutions in Spain, Belgium, Denmark and, on a sample basis, for the Netherlands, the UK and a score of other European countries.

Many European countries' public research systems, however, rely extensively not just on universities, but also on a large web of public laboratories, which have often enjoyed more financial autonomy than universities and whose patenting record, as a consequence, is more open to scrutiny. Germany is a well-documented case.

Gering and Schmoch (2003) estimate that the number of German institutes' patents compare favourably to that of academic professors', especially if one takes into account their smaller budget as opposed to the overall R&D budget of universities.

A cursory look at patent statistics also confirms the importance of French PROs' patents, especially the CNRS (which also retains the IPRs over the research results achieved by teams working within universities, even when they include university staff).

All together, these early measurement attempts suggest that academic patenting in Europe is far from negligible. However, it seems due either to individual scientists' efforts to link up with business companies or to default arrangements between scientists and funding agencies or PROs. University administrations seem to play a lighter role, in line with their lack of autonomy and entrepreneurial chances and attitudes.

4 Academic entrepreneurship and firm creation

As university technology managers became more experienced in technology commercialization, it soon became clear that in many cases licensing of potentially valuable patents was not easily achievable for a number of reasons (Thursby *et al.* 2001; Jensen *et al.* 2003). First, because in many cases academic inventions were disclosed at a proof-of-concept stage, it was hard to convince a firm to take on the long and risky development work needed to bring a final product to the market. Second, in many cases, this work could not be effectively done by an external firm alone, because the tacit and know-how dimension of the knowledge involved was too high. Third, many of the most promising cutting-edge and disrupting technologies are of no interest for large incumbents and would make a good investment only for venture capitals and high-risk equity market.

At the same time, with the development of biotech companies in the United States, several successful examples of superstar scientists that had raised huge amount of capitals in the market by selling the equity of their start-ups were impressing the public opinion, and seem to suggest that academia and industry could join their effort to leverage a new generation of high-tech companies, characterized by a strong research focus.

Business angels and venture capitals were starting to knock on the universities' doors, in search not only of promising business ideas, but also of qualified consulting and peered opinions to evaluate and manage the strategic choices of their biotech portfolios.

These new opportunities were taken in good favour by US and European university administrators, who soon adapted their regulations to allow giving equity capital and branding to start-ups and to ensure job security and institutionalized temporary leave to professors on 'entrepreneurial duties'. Many technology managers saw academic spin-offs as a sort of advanced solution to technology transfer that would help finding viable commercialization strategies to growing patent portfolios (Franklin *et al.* 2001).

4.1 Early studies: academic knowledge as a non-tradable asset

Since the beginning of 1990s, many scholars have investigated the individual motivations and the rationale behind the claim for a proactive role of university-based scientists in the generation of new high-technology applications for nascent industries.

Early contributions to academic spin-off company creation tended to stress that university-based scientists own a specific set of knowledge and information, enabling them to spot valuable opportunities of investment, which would remain hidden to other people. Hence a scientist or a novel PhD student may have a comparative advantage vis-à-vis other potential entrepreneurs in the recognition of promising businesses, thanks to the idiosyncratic knowledge gained while working at a scientific discovery.

This view was supported by several pieces of empirical evidence, especially with regard to emerging high-tech industries. For instance, Zucker and Darby (1996) suggested that the most successful biotech companies were co-publishing with university professors and showed that their commercial success, in terms of the number of products developed and commercialized, was positively associated to the scientific eminence of researchers participating in the scientific board and holding equity stakes. In a later study, co-publications were also shown to explain a firm's patent citations rate, suggesting the idea that a stronger technological base would produce higher quality patent applications in fields characterized by a high strategic value of IPR assets (Zucker *et al.* 1998b). Shane and Stuart (2002) studied the probability of success of 134 new ventures exploiting MIT inventions and found that both the academic rank of the inventor and the number of MIT patents in the company portfolio were likely to increase the probability of an IPO and decrease the failure rate.

The idea underlying those early studies is deeply rooted in a linear model of science–technology relationships: in which cutting-edge science is produced by the universities and highly attached to individual researchers, hence, professors and personnel trained in the academic environment have easier and quicker foresight of technological solutions and a preferred access to business.

Besides, the attention of early studies was especially focused upon the growing US biotechnology industry and on its innovative potential, as compared to more traditional drug industry and market incumbents. Certainly the idiosyncratic features of that industry makes any generalization hard and does not justify some excess of emphasis placed on early result.

With regard to the choices on the structure of ownership, those contributions stressed that cutting-edge science is naturally attached to individuals and, because of the poor absorptive capacity of the environment, transfer could not occur through simple licensing and requires aligning professors' remuneration to the success of the venture (Audretsch 1995; Audretsch and Stephan 1999). This seemed particularly the case of newly created firms, which can be shaped on the emerging scientific culture and may be better suited to the exploitation of new and radical technologies (Henderson 1993).

In such a context, because the intellectual capital was seen as the true key asset, the founding of a firm looked like a unique means for the scientist to extract private gains from her idiosyncratic knowledge. Additionally, because the diffusion of this knowledge is naturally bounded by face-to-face interactions, many authors foresaw a lower need of engaging in enforcement and protection of IPRs (Audretsch 1995). Hence, the mantra goes that best scientists enjoy both a superior access to high-value knowledge and a stronger natural excludability leading to higher-value entrepreneurial opportunities in the selection phase and sustainable competitive advantages later on (Zucker *et al.* 1998b).

Besides, in highly incomplete informational contexts, the scientific reputation of the academic entrepreneur, or the rank of the related institution could have been used by the stakeholders as an indirect signal of the high perspective value of the venture (Shane and Khurana 2003; Stuart and Ding 2004). In the absence of more accurate information, a researcher's eminence could serve to proxy the strength of a company's technological base whereas the star scientist's research specialties would signal the future technology strategies that the company would have been undertaken (Audretsch and Stephan 1996). In a study of biotechnology IPOs, Stephan and Everhart (1998) found that the amount of funds raised and the initial stock evaluation of firms were positively linked with the reputation of the university-based scientist associated with the firm. *Ceteris paribus*, Di Gregorio and Shane (2003) found that spin-off companies from peer-universities were more likely to attract venture capitals than less prestigious ones, whereas Franklin *et al.* (2001), in a survey of key competitive factors conducted among UK technology managers, reported that the researcher's reputation was ranked immediately after their scientific preparation and that this was especially true for higher performing and more experienced universities.

4.2 Incentive problems rediscovered

Following this line of thought, at the beginning of 1990s, most academic administrations, technology managers and venture capitalists were especially stressing the technical content of university applications, which they expected to be more radical and broader in scope than innovations with purely industrial backgrounds. Nevertheless, this emphasis on the knowledge capital and on the alleged superior technological endowments eventually fades at the end of 1990s, when broader studies reported mixed evidence. For instance, Nerkar and Shane (2003) found that the top technological level of MIT start-ups reduced failure rates only in low-concentration industries. The same study also re-established the importance of industry differences in terms of patent effectiveness and appropriability regimes in explaining venture success.

In the meantime, with the help of policy-makers, an increasing number of universities had invested in (often unprofitable) technology transfer activities (Thursby and Thursby 2002), and it started to be questioned if the importance of firm creation from academia had been over-sold, possibly beyond any true economic advisability, both in terms of economic gains and of professors' intentions, which brought into play an entirely new set of problems.

As soon as profit started to become a concern of universities at the institutional level, technology managers discovered that a good technological endowment or the expectations of business profits in many cases were not enough to justify or to convince a scientist to take part in a venture, as ultimately entrepreneurship also meant risk-taking, a strategic vision and possibly a life change. Indeed 'entrepreneurial type' scientists were hard to find, a considerable mismatch of objectives between faculties, technology managers and investors was affecting transactions and several aspects of the academic culture after all seemed to be at odds with the rules of market competition (Siegel *et al.* 2003).

Despite their technological strengths, newborn firms were frequently reported to be unsuccessful because of a failure in complying with the market needs. Field studies and extensive interviews with technology managers portray scientists as individuals with a good taste for science, but with relatively naive ideas about the pursuit of market goals (Thursby and Thursby 2003c).

The knowledge-endowment argument and its related theory of entrepreneurship hence lost much of their appeal, as a stronger trade-off between scientific and market concerns was brought back to the forefront of analysis.

What falls over in the notion of AE applied to spin-off policies and strategies is not the capacity of scientists to offer a valuable pool of technological opportunities to market investors, nor really the role of the 'knowledge entrepreneur' in chasing market opportunities. Rather, the focus is shifted towards the alignment of a scientist's objectives to the goals of a nascent firm, where the expected gains of a scientific entrepreneur are not seen only as those of profit in case of firm success, but also come in the form of increased availability of funds for complementary research.

To scientists concerned with their academic careers, research funds made available through the firm's R&D activities may be particularly appealing insofar as they may serve to buy instruments and data, hire additional personnel, pay for travel to conferences, and generally enlarge the professor's budget for research. Hence, the decision to start up a company would depend for a good part on the researcher's expectations of engaging in stimulating, fruitful and possibly generously funded development activities, which comes along with the creation of a new venture, rather than on expectations of profit and growth, especially when she is not required to put in a big share of the equity upfront.

In addition, because the gains to earn from big research budgets vary with the different stages of a career, the propensity of faculty members to engage in interchanges with industry was seen to be also depending on lifecycle effects and on the choices of investigative pathways (Thursby and Thursby 2003a). Whenever the contiguity of scientific and industrial effort fade, monetary incentives should be raised to compensate for the time taken by purely commercial activities with unclear effects on the academic career (Thursby and Thursby 2003b).

The idea that, in many cases, market goals as such simply fail to produce a set of incentives compatible with the day-to-day life of the entrepreneurial scientists has been a finding of many surveys. Jensen *et al.* (2003) report that scientists may voluntary retain disclosures of potentially marketable technologies and suggest that the opportunity cost of development activities was stronger for higher quality scientists, whose inventions arise typically at a very embryonic stage. Franklin *et al.* (2001) report that technology managers indeed regard the academic founders of their spin-off companies as entrepreneurial individuals with good commitment on the research projects, but they signal a stronger mismatch of perceived goals as the most common cause of venture failure.

The researcher's attitude towards pure scientific investigation, the privilege of having her own lab and the ability to enlarge her group of graduate students frequently clashes with reward schemes based upon commercialization. Not surprisingly, many scholars report that the problem arises most often when the development stage was nearly completed and the firm had to promote a general shift of goals towards the industrialization of the product and to cope with marketing and financial pressures (Shane 2004; Vohora *et al.* 2004). It is at that stage that financial constraints challenge the availability of funds for further development and laboratory work and the appeal of having sponsored additional research fades.

In the follow-up of a survey conducted on 62 US universities in the 1990s, Jensen *et al.* (2003) describe the relationship linking university administration, technology managers and individual scientists as an agent–principal game theoretic model. Scientists are seen as positively reacting to both monetary incentives, and to the share of sponsored research they may obtain for their labs, but, because high-quality faculties would disclose inventions at a more embryonic stage, willingness to disclose would depend more substantially on the latter than on the former.

Besides, the opportunity costs faced by scientists would not just depend on exogenous preferences and personal interests, but also on the availability of other funds, on other appointments and on purely lifecycle effects. In this respect, older scientists may be more willing to cash-in the market gains of their knowledge assets than their younger colleagues because they have already achieved the highest academic ranks (Audretsch and Stephan 1996). This could also be the case for professors of continental European countries, where the academic environment is characterized by lower competition and by job security. For instance, Audretsch (2000) found that the probability for an individual scientist to create a private venture is higher for older professors, suggesting the idea that academic entrepreneurship becomes a more viable option when career pressures have cooled down and the scientist has coped with the concern of establishing her scientific position in academia. This can be especially true within the contexts in which social rules discourage for-profit activities, in which case, only older and highly reputed scientists may dare to undergo non-traditional academic pathways (Stuart and Ding 2004). For younger scientists, such as novel PhD students and research assistants, the founding of a venture may rather become appealing as a viable strategy to exit academia (Roberts 1991; Franklin *et al.* 2001).

4.3 *Business creation vs. patent licensing. Do we really need academic spin-offs?*

Although university patents, spin-off company creation, consulting and joint research agreements are often addressed as separate, alternative transfer mechanisms, in practice, commercializing a piece of university research may require a variable mix of all those instruments. For instance, in a recent survey on commercialization of US academic research, it emerged that licensing contracts made by technology transfer offices in the majority of cases involve royalties, annual fees, equity, milestones and consulting agreements (Thursby *et al.* 2005). The question of what instrument is best suited to transfer different pieces of knowledge has been the focus of many recent contributions, whose central argument goes that market inefficiencies in the transfer of knowledge claim for an ownership structure with some risk-taking positions from the party that possesses the most idiosyncratic assets.

Because scientists' knowledge is characterized by natural excludability, it resists codification in a fully transmittable form and tends to stick to individuals, even after a patent has been filed or an article published. At the same time, we have already stressed that many academic inventions are no more than a proof of concept at the frontier of knowledge. It follows that, in order to take up the nutshell technology and undertake the final development stage on their own, firms need to recruit the scientist as a partner or stakeholder: in the absence of her personal involvement, they would not be able to profit from the innovation (Jensen and Thursby 2001). Therefore, it may be that academic scientists face a stronger need to become entrepreneurs, the higher the degree of sophistication of their technology compared to that of the outside business world (Shane 2004).

Besides, the decision of whether or not the exploitation of a technology is best achieved by patent licensing or by a start-up depends on the technological regime and on the appropriability of the innovation. In low-appropriability patent regimes, licensing may be hard and innovations may not be commercialized because of a lack of incentives, but if the knowledge is also characterized by natural excludability, the creation of a company exploiting a scientist's idiosyncratic knowledge may become the only viable transfer option (Shane 2004).

Some empirical evidence in support of this thesis has been provided both in case studies and empirical analyses. Shane (2001b and 2002) found that the probability of an MIT invention to result in of a patent application was higher in strong appropriability regimes. In a related study he also found that the spin-off rate increased with the novelty and importance of the technology behind it (Shane 2001a). In a study of the technology transfer activities at University of California, Lowe (2002) found that patents characterized by a stronger scientific base and a higher degree of tacitness were significantly more likely to be licensed to their original inventors, thus supporting the idea that spin-off creation is necessary when the scientist's knowledge is highly uncodified and idiosyncratic.

Finally, Feldman *et al.* (2002) report that the willingness of US universities to take equity in a new venture was generally higher among longer-experienced technology offices, which suggests that equity positions of university-administrations may offer a second-best solution to the problem of achieving higher transfer of knowledge to the market, one that perhaps involves a lower risk to divert good scientists from their original tasks.

4.4 Consequences (intended and unintended) of academic entrepreneurship

The argument that an academic entrepreneurship may do a non-replaceable job in fostering the emergence of new generations of high-tech firms and the renovation of local economic systems, in recent decades, has been widely popularized by policy-makers in many European countries. In addition, common arguments in favour of academic spin-off creation normally emphasized that the core attitude of spin-off companies for experimentation would resist the start-up phase and result in a superior propensity of the firm to deliver continuous innovation later on.

However, if one considers the widespread consensus of those claims from scholars and policy-makers alike, it comes as a surprise that very few pieces of evidence have been made available so far that assess the actual performances and the contributions of academic venturing to technological change and local development. As we look at the empirical evidence, notwithstanding the problem of the reliability of field analyses in the absence of a clear-cut definition of academic spin-off (Pirnay *et al.* 2002), we have little more than anecdotes on success stories of university-based inventions that were incorporated into a firm, developed a successful application, grew big and eventually clustered with other firms (see Roberts 1991). Research on the biotechnology sector suggests that the presence of a scientist has a positive effect over start-up success. Nevertheless, those results have hardly been extended to different industries (Nerkar and Shane 2003) and to institutional frameworks other than in the United States.

When it comes to appreciating the actual contribution of academic ventures, only some very preliminary evidence is available that proves the supposed higher performances of spin-off companies either in terms of innovativeness, or in terms of employment created and new products developed and sold. Mustar (1997) reports that R&D intensity of French academic spin-offs was higher than that of other new-technology based start-ups. Similar results were found for samples of UK firms.

Perhaps some stronger, though highly industry-specific, evidence has been provided in support of the claim that companies founded by academic personnel were likely to locate around universities (Audretsch and Stephan 1996; Zucker *et al.* 1998b). This can be a somehow desirable feature from the point of view of policy-makers, concerned with fostering economic development locally, and for university administrators alike, to the extent that spin-off companies may serve as good partners for joint research and technology licensing later on. The clustering choices observed in many research spin-offs may reflect the initial need for part-time scientists to locate closer to their academic jobs and to a hard-science environment, in order to comply with their multi-task careers (Audretsch and Stephan 1996). However, it is dangerous to push this observation further and take it as a confirmation of a higher-than-average focus on innovation and high-technology content of spin-off firms (see Shane 2004), as ultimately location entails a strong path dependent component.

Overall, as we look at successful case studies, it is worth asking what was the fundamental contribution offered to firms by the origin in the academic environment: if it was the unique knowledge offered by universities, the support given in terms of credibility and networking in a context of jeopardized information or, finally, if it was simply good training and qualified scientific consulting that proved to be critical.

This is a question worth asking because spin-off activities also bring several downsides and costs even beyond the general costs and risk of the investments.

Major opportunity costs faced by university administrators, irrespective of their civil service mission, are of at least two kinds. First, universities may lose good scientists or may simply divert them from high-quality publications and teaching. Second, at a more fundamental level, they should be afraid of losing their long-lasting reputation of reliable and non-opportunistic agents, which is functional to their capability to act as a broker for the market of technology, as well as for their more traditional goals. This concern seems to have been understated more in the literature than in practice. For instance, some institutions, such as Cambridge University in the UK, although proactive in business creation, refuse to commit their commercialization activities to a purely profit-oriented mission and describe their role as one of facilitators in the diffusion of knowledge for the benefit of society. In practice, concerns have been expressed that professors may use students as low-paid employees and indiscriminately re-sell the effort of collective commitments. Shane (2004) reported that, in order to cope with the problem of moral hazard, many US faculties have also introduced a general prohibition for a scientist to work at the same research project both in their internal unit and in their external private ventures, after a person died at University of Pennsylvania Medical School during the test of a therapy developed by an academic spin-off.

5 Conclusions

Economic incentives moulding academic entrepreneurship are much more affected by the long-standing institutional features of national university systems, than by any ad hoc legislation affecting IPRs in university. These institutional features do not simply influence the intensity of patenting and firm-creation activities. More generally, they explain to what extent commercial activities may or may not help scientific entrepreneurs to progress in their careers. Among those institutional features, university autonomy, personnel mobility, and the principal investigator principle stand out as the most prominent. Patent-based and spin-off based technology transfer is, by and large, the product of a specific institutional history, that of the US research universities, where these features have been prominent. Every introduction of those issues within the various European university systems should require first and foremost strong reflections and adjustments that take into account institutional, organizational and environmental characteristics of academic research at the national level.

Academic entrepreneurs who are active in patenting, firm-founding (and more generally in technology transfer) come disproportionately from the ranks of scientific entrepreneurs with a brilliant scientific record, possibly oriented to fundamental research. These scientists' economic agenda is centred upon entrepreneurial efforts within the university, aimed at gaining reputation through discipline building, creation and management of laboratories and research teams, and an appetite for the economic resources necessary to pursue those goals.

To those scientists, patent licensing and spin-off creation are appealing not just because of the expectation of profits, but also because they offer valuable opportunities to enlarge their sphere of influence, to empower their internal and external consensus, and inflate the budgets available for their research. Hence, any wise policy of technology transfer in academia should move from a broad consideration of the overall personal incentives faced by scientists and framed within the context of academic careers.

The complexity of academic scientists' incentives to commercialize their discoveries suggests an immediate policy conclusion, albeit a speculative one (at this stage of research): the two objectives of promoting academic entrepreneurship and restraining public expenditures for academic science (which are often found to go hand-in-hand in Europe) are largely incompatible. Starving academic science does not push 'unruly' scientists to apply more thoroughly their knowledge to technologically relevant issues; it merely stifles the entrepreneurial spirits of the younger and more dedicated researchers, from whose ranks we expect to emerge one day the most active producers of patents, companies and any other form of technology transfer effort. Additionally, when the goals of science and market diverge, the cost of convincing good scientists to take part in commercial activities grows, and technology managers may end up to with only untalented scientists.

The biggest absence for the literature we reviewed in this chapter is the demand side of the market for academic inventions. Future theoretical efforts to properly conceptualize AE will have to take it into account.

As for empirical research, this will have to be directed towards a better measurement of entrepreneurial activities taking place in universities, without drawing any preconceived distinction between the industrial exploitation of research results, and more traditional efforts to build academic careers within the university via breakthroughs into new research fields and the creation of new research groups, labs and departments.

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Notes

1 DISPEA–Politecnico di Torino.
2 Università di Brescia and KITeS–Cespri–Università Bocconi.
3 We find other striking accounts of this breed of scientists in Latour's (1988) portrait of Louis Pasteur, and in Mowery and Sampat's (2001) and Apple's (1989) biographical notes on Frederick Cottrell and Harry Steenbock.

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Part III

Knowledge-intensive entrepreneurship and innovation systems

The European case

Knowledge-Intensive Entrepreneurship and Innovation Systems

Evidence from Europe

Edited by
Franco Malerba

ROUTLEDGE

Routledge Studies in Global Competition