8. Academic entrepreneurs: critical issues and lessons for Europe

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8.1 INTRODUCTION

This chapter surveys the notion of 'academic entrepreneur', as it emerges from a wide range of contributions to the economics and sociology of science. Insights from those contributions are then used to examine critically the most recent literature on academic spin-offs and university-industry technology transfer.

The chapter proceeds in a cumulative fashion. We start first with the rhetorical device of putting forward a 'straightforward definition' of academic entrepreneurship, one which is most intuitive and at the same time traceable in many recent policy initiatives, both in the US and in Europe (section 8.2).

We then move on to survey the socio-economic literature dealing with the notion of 'entrepreneurship' in academic research. We suggest 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 depend 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 latter taken as the extreme example of the European case (section 8.3).

In section 8.4 we examine the recent literature on spin-off firm creation, and briefly touch upon some related issues on intellectual property rights over academic research results. We suggest that both patenting and spin-off creation result from the broad entrepreneurial agendas described in section 8.3, and not merely from the individual scientists' profit-seeking attitudes.

In section 8.5 we propose several policy implications and directions for future research.

8.2 ACADEMIC ENTREPRENEURS: THE 'STRAIGHTFORWARD' DEFINITION

At first glance, the definition of academic entrepreneur (AE) looks straightforward: the AE is a university scientist, most often a professor, sometimes a PhD student or a post-doc researcher, who sets up a business company in order to commercialize the results of her research. It is the nearest possible definition to the classical one of entrepreneur,[1] enriched of the qualifying adjective 'academic', to stress that the innovations introduced by the entrepreneur originate from the research she conducted as part of her 'other job' as a university scientist.

This straightforward definition cannot but please the policymaker, as it attributes to this special breed of entrepreneur, who already benefits the society through innovation and job creation, an additional social function: the valorization of academic research, often funded by the public purse and targeted to fundamental objectives. And whenever the university administration supports the new company through equity participation, the successful AE will also deserve praise for having contributed to the financial health of her institution.

The straightforward definition is also easy to conceptualize and popularize, as it fits closely a linear model of university-industry and science-technology relationships, with the university being largely in charge of producing science, and the industry being responsible for processing it as an intermediate input to technology.[2]

According to this model, inventions of high commercial value follow inevitably from 'pure' or 'basic' research, the only problem being the uncertain timing. At worst, the flow from science to technology may be subject to interruption if nobody undertakes the applied research and development efforts necessary to turn the inventions into viable innovations.

In this view, any scientist whose shelves are full of prototypes and proofs of concepts awaiting commercial development is then spotted as a potential AE, who simply lacks adequate economic incentives and/or is refrained from venturing into business by the 'Ivory Tower' culture of academia, one which condemns commercialization activities (and therefore makes economic incentives irrelevant). In order to straighten up the incentives, the policymaker is then called to establish a clear IPR regime over the results of publicly funded research (by assigning them either to the scientist or her university, or to any private partner joining the research project) and to promote a cultural change among scientists. A clear definition and attribution of IPRs will in turn create a market for university-based inventions, whose development will be paid for by private investors, in exchange for exclusive licensing rights.

The influence of this perspective on European policymakers, both at the national and at the Union level, is witnessed by the large number of IPR reforms concerning universities that have been introduced all over the Old Continent in the past ten years or so. Such reforms have been most often modelled upon earlier US pieces of legislation, such the Stevenson-Wydler Act and the Bayh-Dole Act of 1980, both of them inspired by the wish to create a market for inventions derived from public science.[3]

As for the creation of an entrepreneurial culture among university scientists, training courses in business and law for scientists and technology transfer officers have proliferated throughout Europe. In a similar vein, it is now common for public research funding agencies to require all applicants to outline a clear 'exploitation plan' for the promised results.[4]

More generally, the repeated statements about the existence of a supposed 'European paradox' (according to which many EU countries would be holding prominent worldwide positions in terms of scientific achievements, but wouldn't be able to 'translate' them into technological advantages) clearly remind us of the 'shelved-inventions' metaphor, and the straightforward definition of AE.[5]

Unfortunately, both the shelved-inventions metaphor and the straightforward definition of AE do not take into full account the complexity of the system of economic incentives that affects academic scientists' behaviour. The linear model of science-technology interaction that inspires both the shelved-inventions metaphor and the straightforward definition of AE has been heavily criticized by economists and sociologists alike. These critics suggest that scientific advancements which are susceptible of practical applications do not merely drop onto technology from above, but are elicited and made possible by the latter, whose autonomous progress poses challenging research questions, produces data, allows for new experimental settings, and creates scientific instruments.[6]

As for the incentives, the straightforward definition of AE represents scientists as individuals free of any contractual engagement (i.e. dedicated to 'pure research' for the sake of advancing knowledge), who must decide point-blank whether or not to activate a contract with a business company (either by licensing their inventions or by taking an equity position in a start-up). Alas, contemporary academic scientists are far from free from contractual obligations: they are employees subject to the control either of the State or of their universities, and linked to other faculty members and students by a number of formal and informal obligations. In addition, they have long-term career plans which have to be taken care of in order to be successful.

In synthesis, the straightforward definition of AE sweeps under the carpet too many details of the contemporary features of the economics of academic science. In order to take in full account the complexity of the phenomenon, academic research should rather be conceived as a 'scientific enterprise', in which career-motivated scientists act as research-oriented entrepreneurs, whose approach to commercial activities depends upon a broader career strategy.

8.3 ENTREPRENEURSHIP IN SCIENCE AND ACADEMIA: A BROADER VIEW

Entrepreneurship is quite a popular word in a number of studies dealing with the philosophy, sociology, economics, and history of science. Far from being occasional and inconsistent, its use points to well-defined and historical features of contemporary science.[7]

8.3.1 Entrepreneurship as an Individual Feature: 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 broker relationship with agents outside the universities (especially policymakers and industrialists) looking for political and material support for that agenda. As for risk-taking, a typical trait of entrepreneurs as defined by many economic theories, innovative scientists venture outside the boundaries of established disciplines or research lines, looking for scientific breakthrough that could earn them fame, but also taking a high risk of not getting any result.

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 knowledge

(Merton, 1973). In Merton's view, such recognition primarily takes the form of acknowledging the scientist's priority claims of having made an important discovery. Philosophers and economists of science have gone a long way in exploring how the quest for priority 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).[8]

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 laboriously 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 policymakers.

Fellow scientists can validate the contents of a scientific paper or programme by citing it as a legitimate source of information, or they can condemn those contents by neglecting the paper 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 co-operation, conference invitations, and joint lobbying for economic resources from state and industry.

In this respect, businessmen and policymakers can be instrumental in providing funds, data, scientific materials and instruments, as well as ethical validation. Participation in 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, consulting, and equity participation to spin-off companies are not simply market and market-like activities which take time away from research, 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, p. 37).

Faced with this rich analysis, the straightforward definition of AE proves to be inadequate. Individual scientists who engage in ambitious research programmes need resources to pursue their objectives, and nurture actively extra-academic contacts to that end. Ease of patenting and access to resources for setting up a company are welcome insofar as 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 compares scientists engaged in academic careers within the boundaries of established disciplines with those whose research agenda foresee the birth of a new discipline, or requires disciplinary boundaries to be redrawn, 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 the scientist-entrepreneur 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.[9]

Summing up, academic entrepreneurship, as part of the more general phenomenon of scientific entrepreneurship, proves to result from a more complex bundle of strategies and incentives than envisaged by the straightforward definition.

8.3.2 Academic Entrepreneurship as an Institutional Feature: US vs. European Universities

One of the best-known papers on entrepreneurship in academia 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 US with the Big Science programmes launched in the aftermath of World War II. 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.

At a closer look, however, the American model of '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 US 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, [1962] 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 happens nowadays 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 strengths of the US universities, and this is also the main background reason for their transformation into entrepreneurial organizations.

Since right after World War II, 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 convincingly making the case for large public funding of research universities, failed to persuade US lawmakers of the need to set up a centralized body for the administration of all funds (Graham and Diamond, 1997).

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 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 (not their departments or their institutions) are made entirely responsible for a project. A strong individual research record is instrumental for the PI 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 criterion for research funding. As a consequence, universities have always engaged 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 leading to winning and then managing the grants. They devote their effort not only to publishing, attending conferences and 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 or 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 expansions depend upon chasing and managing funds, recruiting skilled employees, delivering results, and moving up to higher level funding agencies.[10] PIs provide the necessary entrepreneurial efforts 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 8.3.1. The parallel extends from individual scientists to academic institutions, to the extent that the latter are also engaged in a competitive effort to establish new research lines and disciplines, to solicit funds from both industry and the central governments, and to attract the best scientists for those purposes.

This is a far cry from the way academic research is organized in Europe. The most striking differences in institutional settings between US and European academic systems are well exemplified by French universities, whose history is one of abrupt termination and slow re-creation 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 by the king.[11]

Later on, with the end of the Republic and the creation of the Empire, a brand new institution was set up in between 1806 and 1808, charged with the task of educating a new generation of teachers, lawyers, medical doctors, and the ranks and files of public administration: 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). Still nowadays, the entire process of recruitment occurs at the national level, and the mobility of academic staff across universities is very limited.

For a long time, French universities were devoted only to teaching. Research tasks were 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 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 (Larédo and Mustar, 2001; Neave, 1993).[12]

In recent times, French policymakers have borrowed heavily from the straightforward definition of AE we outlined in section 8.2, but at the same time they have been unwilling to allow for more autonomy of both the universities (which still cannot manage freely their personnel, real estate, and finance) and their researchers (whose contacts with industry are regulated in great detail).[13] While US policies on intellectual property rights and academic spin-offs are often imitated, 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; Romano, 1998; Jong, 2007). Here, as in France, a stark contrast exists between policy measures undertaken to encourage the commercialization of academic research activities, and the widespread reluctance to give more autonomy to universities. In other words, while the straightforward definition of AE seems to be highly popular, no room of action is given to entrepreneurial scientists and universities.

8.4 ACADEMIC ENTREPRENEURSHIP AND FIRM CREATION

In this section we review the specific literature on AEs' contribution to firm creation, through the lenses of our broader definition of entrepreneurship in science. The literature we examine comes by and large from the US, where the debate on university-technology transfer has revolved around the evaluation of the effects of the Bayh-Dole Act and related increase in university patenting; as such, it focuses on the commercialization of patented research results, either through licensing or firm creation or both.

Space constraints force us to avoid discussing the phenomenon of university patenting in depth (for surveys, see Mowery et al., 2001; and OECD, 2003). As an introduction to this section, however, it is worth mentioning that the number of patents taken over academic research results has been growing incessantly over the last 20 years, both in the US and in Europe. Those 'academic patents' account for no less than 4 percent of total domestic patents in the US, and similar figures have been estimated for France, Italy, Sweden, Finland and Norway.[14] In science-based technologies such as Biotech, percentages can easily climb well over 15 percent.

However, the US and Europe differ in the attribution of property over academic patents. While more than 60 percent of such patents in the US are owned by universities, in Europe the same percentage is around 10 percent. Conversely, over 60 percent of European academic patents are owned by business companies, while the same percentage for the US is estimated at no more than 25 percent. For an explanation of these figures, which owe very much to the institutional features of academic systems as described in section 8.3, we turn Lissoni et al. (2007). Here it suffices to say that, at least until recently, the issue of commercializing academic patents was by and large felt only by US university administrators, their European counterparts having solved the problem by leaving all IPRs in their professors' hands, and from those hands into business companies' hands.

US universities' tradition of patent management is not recent, and certainly dates back to before the Bayh-Dole Act. However, until the 1980s, management practices essentially were reduced to patent licensing, either directly or via specialized technology brokers such as the Research Corporation or WARF, the Wisconsin Alumni Research Foundation (Apple, 1989; Mowery and Sampat, 2001).

But with the university patent explosion of the 1980s and 1990s, it soon became clear that in many cases the licensing of potentially valuable patents was not easily achievable for a number of reasons (Jensen et al., 2003; Thursby et al., 2001). First, since 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. Secondly, 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. Thirdly, many of the most promising cutting-edge and disrupting technologies are of no interest to large incumbents and would make a good investment only for venture capital and high-risk equity markets.

At the same time, with the development of biotech companies in the US, several successful examples of superstar scientists that had raised huge amounts of capital in the market by selling the equity of their start-ups were impressing public opinion, and seemed 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 capitalists started to knock on the universities' doors, in search not only of promising business ideas, but also of qualified consultants' and peers' opinions to evaluate and manage the strategic choices of their biotech portfolios.

These new opportunities were received favourably by 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 in finding viable commercialization strategies to growing patent portfolios (Franklin et al., 2001).

8.4.1 Early Studies: Academic Knowledge as a Non-Tradeable Asset

Since the beginning of the 1990s, many scholars, especially in the US, 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 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 on 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 with 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., 1998). 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 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, one wherein scientific results are often immediately suggestive of commercial applications (very much in the spirit of the linear model), make any generalization hard and warn against placing too much emphasis on early results from the literature.

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, but required aligning the professor's 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 around 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, since the diffusion of this knowledge is naturally bounded by face-to-face interactions, the literature foresaw a lesser need to engage in enforcement and protection of IPRs (Audretsch, 1995). Hence, the mantra went that the 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., 1998).

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 prospective value of the venture (Stuart and Ding, 2004; Shane and Khurana, 2003). In the absence of more accurate information, a researcher's eminence could serve to proxy the strength of a start-up company's technological base whereas the star scientist's research specialties would signal the future technology strategies that the company would have 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 associated 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 top universities were more likely to attract venture capitals than those from less prestigious institutions, 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.

8.4.2 Incentive Problems Rediscovered

Following this line of thought, at the beginning of the 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, the emphasis on the knowledge capital and on the alleged superior technological endowments eventually faded at the end of the 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 policymakers, an increasing number of universities had invested in (often unprofitable) technology transfer activities (Thursby and Thursby, 2002). As a consequence, doubts emerged on whether the importance of firm creation from academia had been possibly over-emphasized, 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 the 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 were, in many cases, 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, in the straightforward definition of AE we proposed above, were hard to find. A considerable mismatch of objectives between faculties, technology managers and investors was affecting transactions (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 to 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 down in the straightforward 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, or 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 seen not only as those of profit in the 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 in so far 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 in good part on the researcher's expectations of engaging in stimulating, fruitful and possibly generously funded development activities, which goes with the creation of a new venture, rather than on expectations of profit and growth, especially when she is not required to put a big share of the equity upfront.[15]

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 dependent on lifecycle effects and on the choices of investigative pathways (Thursby and Thursby, 2003a). Whenever the contiguity of scientific and industrial effort faded, monetary incentives should be raised to compensate for the time taken by purely commercial activities with an unclear effect 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 commented on in many surveys. Jensen et al. (2003) report that scientists may voluntarily 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 enlarging her group of graduate students frequently clashes against reward schemes based upon commercialization. Not surprisingly, many scholars report that the problem arises most often when the development stage is nearly completed and the firm has to promote a general shift of goals towards the industrialization of the product and/or 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 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 life-cycle 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, as newly qualified PhD students and research assistants, the founding of a venture may rather become appealing as a viable strategy to exit academia (Franklin et al., 2001; Roberts, 1991).

8.4.3 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. The central argument is that the market inefficiencies in the transfer of knowledge can be corrected by involving in the ownership structure (with some risk-taking positions) the party that possesses the most idiosyncratic assets, as suggested by the 'straightforward' notion of AE.

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, 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, you may find that as academic scientists face a stronger need of becoming entrepreneurs, the higher is 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, 2002) found that the probability of an MIT invention resulting in the establishment of a patent 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 up equity in a new venture was generally higher among longer-experienced technology offices, which suggests that the 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 of diverting good scientists from their original tasks.

8.4.4 (Intended and Unintended) Consequences of Academic Entrepreneurship

The argument that 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 has been widely popularized by policymakers in many European countries. In addition, common arguments in favour of academic spin-off creation normally emphasize that the core attitude of a spin-off company 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 on those claims, it comes as a surprise that little assessment has been undertaken so far on the actual performances and contributions of academic venturing to technological change and local development. As we look at the empirical literature, even 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 other firms (see Roberts, 1991). Research on the biotechnology sector, which we have mentioned in section 8.4.2, 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 the US.

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 product developed and sold. Mustar (1997) reports that the 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.[16]

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., 1998). This can somehow be a desirable feature from the point of view of policymakers, 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 close 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 how these really benefited from their origin in an academic environment: Did they enjoy access to the unique knowledge offered by universities? Or did they merely benefit from the support given in terms of credibility and networking in a context of jeopardized information? Or, finally, did they simply gain from being close to good training sites and qualified scientific consulting markets?

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 at least of two kinds. Firstly, universities may lose good scientists or may simply divert them from high quality publications and teaching. Secondly, at a more fundamental level, they may be afraid of losing their long-lasting reputation of reliable and non-opportunistic agents, which is fundamental to their ability 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 the University of Cambridge (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 scientists to work at the same research project both in their internal unit and in their external private ventures, after a person died at the University of Pennsylvania Medical School during the test of a therapy developed by an academic spin-off.

8.5 CONCLUSIONS

Academic entrepreneurs who are active in patenting, firm-founding, and more generally in technology transfer, come disproportionably 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 their knowledge more thoroughly to technologically relevant issues; it merely stifles the entrepreneurial spirits of the younger and more dedicated researchers, from whose ranks we expect the most active producers of patents, companies, and any other form of technology transfer effort to emerge. Additionally, when the goals of science and market diverge, the cost of convincing good scientists to take part in commercial activities increases and technology managers may end up with only untalented scientists.

In this view, the much larger success of the US academic system in fostering academic entrepreneurship, compared to Europe, can be explained as a mere reflection of the US’s large success in fostering scientific entrepreneurship as such. In turn, this success depends on the long-standing institutional features of the various national university systems. These institutional features do not simply affect 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.

The main limitation of the analysis we conducted in this chapter is the absence of considerations on the demand side of the market for academic inventions. By and large, however, this is not our choice, but a reflection of the strong supply-side orientation of the literature we chose to review. Future theoretical efforts to conceptualize AE properly will have to take demand into proper 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.

NOTES

1. 'The entrepreneur is the head of the firm and coordinates the factors of production; introduces new methods, products, and processes and creates opportunities for growth; bears the risks connected with his or her activities; and enjoys power and high status in capitalist market societies' (Martinelli, 2001; p. 4545).
2. For a critical synthesis of the linear model of science-technology interaction, see Kline and Rosenberg (1986). On the influence retained by the linear view among policymakers, scientists, and the popular press see David (1997, especially pp. 8-9) and Martin (2003, p. 9).
3. The Bayh-Dole Act, originally intended to promote the exploitation of publicly-funded research by small companies, assigns to academia all the intellectual property rights on the results of federally funded research (in doing so, it imitated similar provisions taken by the National Science Foundation in the 1970s). The Stevenson-Wydler Act lays out similar provisions for federal laboratories. On the relationship between the linear view of science-technology interaction and the Bayh-Dole Act, see Colyvas et al. (2002) and Mowery (2001, p. 28). On the wave of Bayh-Dole-like pieces of European legislation see OECD (2003) and, for a critique, Mowery (2001; pp. 31-40) and Mowery and Sampat (2005). Pavitt (2001) offers a more general critique of the European policymakers' tendency to learn the wrong lesson for the US science policy experience.
4. See the example we put forward in section 8.4.3.
5. On the European paradox see Caracostas and Muldur (2001). For a recent critique of the argument, see Dosi, Llerena and Sylos-Labini (2005). It is worth pointing out that the paradox argument has been applied to other countries and regions before Europe, and surfaces cyclically in the history of science and technology policies. For example, the Bayh-Dole Act and the Stevenson-Wydler Act we mentioned above followed an intense debate on the apparent failure of the US national innovation system to translate its undisputed scientific leadership into an equivalent technological dominance, at a time when the latter was disputed by Japan and, to a lesser extent, Germany. The European Commission itself, forged the European paradox argument very much upon pre-existing literature on the 'Swedish paradox', whose proponents also lamented the Scandinavian country's inability to get enough technological advancements from a world class scientific research system (Edquist and McKelvey, 1998; Jacobbson and Rickne, 2004).
6. For a classic treatment, besides Kline and Rosenberg (1986), see Rosenberg and Nelson (1994).
7. For a survey on the use of the entrepreneurship concept in universities, see also Keast (1995).
8. A major point of contention between the new economics of science and the science studies approach relates the public good nature of scientific knowledge (Callon, 1994; Cowan, David and Foray, 2000). This dissent leads the two schools to judge differently the systemic outcome of strengthening the IPR

regime over academic research results. This point is not of pre-eminent interest here.

9. 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 (see section 4.1).
10. According to Crow and Bozeman (1998) laboratories represent the core 'production unit' of science; similar findings are reported, for a few case studies, by Slaughter and Leslie (1997, chapter 5). About Europe, see Carayol and Matt (2004).
11. The most prominent Ecoles are still nowadays the Ecole Polytechnique (1793), the Ecole des Mines (1793), and the Ecole Pratique des Hautes Etudes (1868).
12. Similar arrangements exist also for other public research centres, such as INSERM, the national institute for health research.
13. Llerena et al. (2003) describe how a new innovation law was introduced in 1999, in order to provide new incentives for researchers to engage in collaboration with industry, by taking leave up to six years to set up a new company, or by holding equity positions in hi-tech start-ups. Applications, however, ended up not being examined by individual universities, but by an overly cautious national commission. A similar fate occurred, in 2001, to a set of recommendations concerning IPRs in PROs, issued by the Ministry of Research (Gallochat, 2003).
14. On France, Italy and Sweden, see Lissoni et al. (2007), who also provide a comparison with the US. On Finland, see Meyer et al. (2003). On Norway, see Iversen et al. (2007).
15. This point is well illustrated, for a small sample of French academic start-ups, by Shinn and Lamy (2006).
16. On this issue, see Shane (2004, chapter 2).

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