

INTELLECTUAL PROPERTY RIGHTS AND KNOWLEDGE TRANSFER FROM PUBLIC RESEARCH TO INDUSTRY IN THE US AND EUROPE: WHICH LESSONS FOR INNOVATION SYSTEMS IN DEVELOPING COUNTRIES?

FABIO MONTOBBIO*

1. INTRODUCTION

The issue of intellectual property and knowledge transfer from universities and public research organizations (PROs) stirs heated debate and is the object of strong policy interest in developed and developing countries alike. The question that many authors and policy makers try to tackle is how knowledge produced in universities and PROs can be transferred and used in industry, in order to contribute to economic growth, development and improvement in standards of living. The issue is complex because universities and PROs have a broad and changing role in national innovation systems that ranges from general education to basic research (Lissoni and Foray, (2008); Mowery and Sampat, (2004), Rosenberg and Nelson, (1994)). Moreover, intellectual property is only one of many channels through which knowledge flows between universities, PROs and industry and IP regulations cover many delicate issues (e.g. subject matter, type of licenses, research exemptions) which may affect scientists' choices about the number and type of research projects to undertake and, therefore, the trajectory of research and type of knowledge created. Moreover, the knowledge bases of different scientific disciplines differ substantially and this creates different research and disclosure methods on the university side, different appropriability strategies on the firm side, and different levels of efficiency of intellectual property for technology transfer.

Patenting and licensing from universities and public research centers are particularly important phenomena in biotechnology, drugs and medical science. In the US, licensing revenues reached 1.6 billion US dollars in 2005 and some recent success stories have attracted a lot of attention, e.g. the patent covering Emtrivia – an anti-retroviral drug that generated a revenue of 540 million US dollars for Emory University and 40 per cent of that amount for the three Emory inventors. Beyond these (very much hyped) success stories, the issue still causes heated controversies among scientists, managers and technology transfer practitioners. The conventional wisdom about patenting university research, and in particular, about the introduction of the Bayh Dole Act in the US, can be epitomized with the following words: "Overnight, universities across America became hotbeds of innovation, as entrepreneurial professors took their inventions (and graduate students) off campus to set up companies of their own (...). A goose that lays such golden eggs needs nurturing, protecting and even cloning, not plucking for the pot." (Innovation's golden goose – *The Economist*, December 14, 2002). At the same time, concerns are expressed by many authors, in particular in the field of biomedicine, that claim that the rules of open science are being jeopardized and the access to public knowledge could be restricted. This is expected to be particularly harmful for cumulative innovations and for developing countries. The statement in *The Economist* finds, therefore, its detractors: "Universities have evolved from public trusts into something closer to venture capital firms. What used to be a scientific community of free and open debate now often seems like a litigious scrum of data hoarding

* Associate Professor of Economics at, Insubria University, Varese and Senior Researcher at CESPRI, Bocconi University, Italy. The views expressed in this paper are those of the author and do not necessarily represent those of WIPO.

and suspicion. And what's more, Americans are paying for it through the nose." (The Law of Unintended Consequences – Clifton Leaf – *Fortune Magazine*, September 19, 2005). Many voices also in business and management point to possible problems in technology transfer arising from an aggressive approach of universities to intellectual property and some authors interpret the recent decline in university funding from industry as proof of the increased difficulties in the negotiations of sponsored research agreements, generated in particular by disagreements over the treatment of intellectual property¹ (Rapoport, (2006)).

This paper is aimed at providing a survey on the main empirical results in economics regarding the use of intellectual property in universities and PROs. In particular, it explores the effects of intellectual property on technology transfer and on the processes of knowledge creation and scientific development. In this paper, I focus on the relationship between intellectual property and technology transfer from an empirical perspective. Therefore, I do not discuss (with some necessary exceptions) the empirical evidence on channels of technology transfer not related to intellectual property (and the broader role of universities for local and regional economic development) and I do not discuss the theoretical models that address the issue of intellectual property and technology transfer from university and public research.²

Other surveys are available that cover many aspects of this literature that has been growing remarkably in recent years. In particular, Geuna and Nesta (2006) and Verspagen (2006) dealt with the economic literature on university patents and took a European perspective. Thursby and Thursby (2007) surveyed both models and empirical evidence on university patenting and licensing. Almost all the evidence they discussed comes from the US. Roathermel *et al* (2007) provided an extensive review on intellectual property and entrepreneurship. Foray and Lissoni (2008) and Mowery and Sampat (2004) discussed the broader role of universities in the national innovation system. Campos *et al* (2007) extended the analysis to developing countries.

This paper is organized as follows. In section 2, I discuss the main economic justifications for intellectual property in public research. In section 3, I summarize the debate on university patenting in the US and the EU, and discuss the different institutional environments and specific policy issues. In section 4, the concerns related to patenting science are taken into consideration. In section 5, the role of technology transfer offices (TTOs) and the determinants of their productivity is discussed. Section 6 concludes and discusses some lessons that can be learned for innovation systems in developing countries. In particular, I discuss some dilemmas that developing countries may have to face when designing their IP policies for universities and public research organizations. Finally, I discuss potential areas of additional research in developing countries.

2. THE ECONOMIC JUSTIFICATION FOR IP ON PUBLIC RESEARCH

The basic economic justification for university patenting is based on the idea that it facilitates the commercialization of the discoveries produced by scientific research (Arora *et al*, (2001), Kitch, (1977)). Thanks to well defined IPRs, firms or individuals have the incentives to invest additional R&D in product development because imitation is deterred and they can appropriate the related monopoly rents. Without a patent, the non rival and non excludable nature of knowledge would dissipate the expected profits and, therefore, the incentives to have extra R&D to bring such a product into the market.

This justification differs from the traditional economic justification for having a patent system. Typically, a patent is considered an incentive to innovate and a mechanism of knowledge diffusion through the disclosure of the technical details of the innovation. However, this is not the

case for scientific research performed in universities for at least two reasons. First, the mission of research universities and PROs is to solve the public good type of market failure through patronage, i.e. a publicly financed system of research (Arrow, (1962), Nelson (1959). David, (1993), (1998)). If only market based incentives are present, companies are expected to under invest in basic science and this requires public intervention to support basic scientific research and its diffusion. Second, incentives to disclose and to publish scientific discoveries are generated by the priority reward system in science. As a result, the main economic argument for patenting by universities and PROs is not the incentive to invent or disclose, but the incentive to transfer to private firms and to commercialize the generated knowledge. Patents are then considered the effective instrument to create markets for technologies.

This argument requires that licensing is exclusive, that there are substantial additional costs necessary to develop the invention and, finally, that there is no possibility to register patents on the results of the additional R&D effort. If there is no exclusivity, many companies can access the patented technology and this reduces the incentive to sustain the development costs. If the development can be done at no cost, companies will do that to improve the product and the issue of incentive is simply solved by competition forces and, finally, patenting downstream research could provide companies with the incentives for additional R&D (instead of intellectual property on upstream discoveries) (Mowery et al, (2001), Mazzoleni and Nelson, (1998), Verspagen, (2006)).

While this is the major logic behind policy recommendations and interventions in favor of university patenting in advanced countries, it is not the only one. In many developing countries,³ the emphasis is not only on using intellectual property to promote cooperation and technology transfer between universities and industry, but also on preserving the public control on inventions generated by universities and PROs. These inventions should be patented to defend the public nature of all possible applications that may derive from them.⁴ In many developing countries, IP policies may be designed together with specific health and food policies. In fact, the issue is perceived as particularly important in crucial sectors like agriculture, biomedicine and energy. Two issues are important in this respect: the alleged decrease in the quality of patents in the US and the increased number of patents in research tools. The first issue is linked to the non obviousness standard which is aimed at protecting the public pool of knowledge and, according to some authors (e.g. Merrill *et al* (2004)), has declined in the US in particular in relation to software and DNA sequences. The second issue is addressed at some length in section 4 and raises concerns related to the generated barriers to entry in some research fields.

The use of intellectual property to protect public interest may result in an enhancement of the public good nature of the knowledge produced by preventing companies or individuals to patent innovations from university-generated inventions. At the same time, for example in military technologies, patenting (coupled with a secrecy clause) may help in keeping key technologies under control and to avoid knowledge spillovers. In this case, universities and public research organizations have to control that scientists and public servants do not appropriate and do not disclose independently the relevant knowledge.⁵

To sum up, the starting point of this survey is that the economic justification for intellectual property in universities and PROs has two facets: commercialization and public interest. The former keeps on being underlined in the political discourse in developed countries, while the latter may be particularly important for developing countries in key sectors like pharmaceuticals and agriculture. However, the specific design of IP policies may vary considerably according to the weight that policy makers want to assign to these two normative facets of intellectual property. Two dimensions may be particularly relevant in this respect: (1) the degree of exclusivity of licensing schemes; (2) the specific regulations on who is the owner of the university-generated

inventions. First, exclusive licenses are clearly needed for commercialization, but may conflict with the second justification as long as they limit the use and diffusion of the discovery. Second, in some European countries, universities are not entitled to retain IPRs over university based inventions. Intellectual property is assigned by law to professors who, therefore, differ from a normal employee. As I shall discuss in section 3.2, this could facilitate the transfer of technology from individual inventors to companies. In any case, if the public institution does not have the property right, this clashes with the idea of intellectual property being necessary to maintain control over the technology.

This survey explores the empirical work in economics in which the two broad issues of knowledge transfer and public interest have been articulated in a set of empirical questions. In particular, the questions that the recent literature has tried to address are: is university intellectual property bringing into the market important inventions? Is intellectual property hindering the scientific development or shifting research toward a more applied nature? Is it efficient as a means for technology transfer? Are there institutional differences in the use of intellectual property for public research? What are the effects on technology transfer? What is the role of TTOs? What makes TTOs efficient? Which are the best licensing schemes?

3. AN OVERVIEW OF THE DEBATE ABOUT UNIVERSITY PATENTS IN THE US AND EU

The first way to look at the role of intellectual property in technology transfer is, on the one hand, to understand the historical evolution of the relation between IP institutions and public research and, on the other, the changing attitude towards intellectual property of universities and scientists over the past few decades. In fact, a great body of recent literature has tried to address the issue looking at the historical evolution of the practice of university patents in the US, where universities started to use patents in the 1920s. In Europe, only recently has empirical research tried to understand the attitude of universities and PROs towards intellectual property and to compare the institutional differences among European countries and between Europe and the US.

3.1 University Patenting in the US

In the last 25 years, there has been a remarkable increase of university patents and licensing activity in the US. Reliable data is provided by the National Science Foundation (e.g. NSB (2004)) and the Association of University Technology Managers (AUTM) which produces a detailed annual survey on university licensing and new products from university research.⁶ Patenting by academic institutions at the USPTO has increased over time, rising from 436 issued patents in 1981 to more than 3,500 patents in 2001. New patent applications by the 191 respondents to the 2005 AUTM survey numbered 10,270. In parallel, the ratio of academic patents – relative to the US private and non-profit sectors – has also risen significantly from 1.48 per cent in 1981 to a peak of 4.81 per cent in 1999. During the same period, there has been a rapid increase in the number of academic institutions receiving patents, although the distribution of patenting activity remains highly concentrated among a few major research universities. Moreover, in the period 1990–2000, there has been a remarkable increase in the licensing of university patents and revenues from licensing and fees (NSB (2004)).

Conventional wisdom links the increase of university patents to the Bayh Dole Act (BDA). However, US universities (in particular land grant ones) started patenting back in the 1920s (Mowery, Sampat (2001a)). It is worthwhile noting how the issue of university patenting was addressed at the early stages of the US innovation system. In fact, the motivations for universi-

ty patenting reflect the two facets we have underlined in the previous section: commercialization and public interest. Mowery and Sampat (2001a) cite, among other documents, a paper from the American Association for the Advancement of Science (AAAS) published on Science in 1934, where it is clearly shown that university patents are needed in order to provide incentives for the development and commercialization of new products (AAAS (1934)). The AAAS expressed the concern that university patents should prevent unqualified companies or individuals from charging monopoly rents or withholding the scientists' invention from use. In other words, scientific advances patented by universities should warrant that the research results are widely used and correctly exploited by competent firms.

The AAAS report stresses that the public interest issue is particularly important in two circumstances: when innovation is cumulative (with broad and basic inventions) and in the field of public health. Importantly, the report shows some reluctance to support the direct involvement of universities in patent management and points to the necessity to find competences for technology management outside the university. In fact, many US universities in the following years used the Research Corporation, founded in 1912, to manage their patents (Mowery, Sampat, (2001b)). During the 1920s and the 1930s two issues were considered relevant by university administrators, particularly in public universities. The first issue, as a result of the need to justify taxpayers' money, was to consider patenting as a sign of the link between the research effort and knowledge that becomes economically valuable at the local level. Secondly, with the Great Depression, patenting and licensing were needed to generate extra funds for the university (Mowery and Sampat, (2001a)).

In the US, after World War II, there was a big shift in the attitude of universities toward intellectual property that was the result of three interconnected issues. The first was the increased amount of federal funds, in particular in biomedicine. More money for research resulted in increases also in the scale of research activity and its output in US universities. The second issue was the related expansion of molecular biology in which intellectual property is particularly effective. Actually, most of the growth in university patenting activity in the last decades comes from this scientific field. Finally, during the 1970s, the perception in the US of the risk of losing technological leadership was particularly strong and, accordingly, the necessity to protect domestic technology guided some policy intervention⁷ (Mowery, Sampat, (2001b)). In this context, the Bayh Dole Patent and Trademark Amendment Act (BDA) was approved in 1980. This gives uniform treatment to university and PRO patents derived from research funded with federal funds (Mowery *et al* (2001), Eisenberg, (1996)). The BDA is part of a general reinforcement of IPRs (which include the Stevenson-Wydler Act and the creation of the Court of Appeals for the Federal Circuit (CAFC) and the inclusion of IP issues in international trade negotiations) and tried to solve some uncertainty about licensing of academic inventions in previous IP arrangements with federal funding agencies. The BDA had its economic justification in the attempt to create an institutional setting conducive to the commercialization of the discoveries made within university laboratories and, to this end, it intended to facilitate exclusive licensing to support the development phase of the innovation process.

It is important to note that the BDA affected the attitude of US universities towards intellectual property and licensing. However, the positive trend in university patenting after 1980 would have probably occurred even without the BDA. In parallel to the general expansion of the patentable subject matter (that includes software, financial services, life forms and biotechnology), there was a change in attitude toward university patenting by some large academic institutions, even before the BDA (e.g. Columbia University in biomedicine) (Mowery *et al* (2001), (2004), Mowery and Ziedonis (2002), Sampat (2006)).

The salient characteristics of the BDA are that it leaves universities free to use exclusive licensing, and royalties have to be shared with the inventors (40 per cent in the Emory case, even if uni-

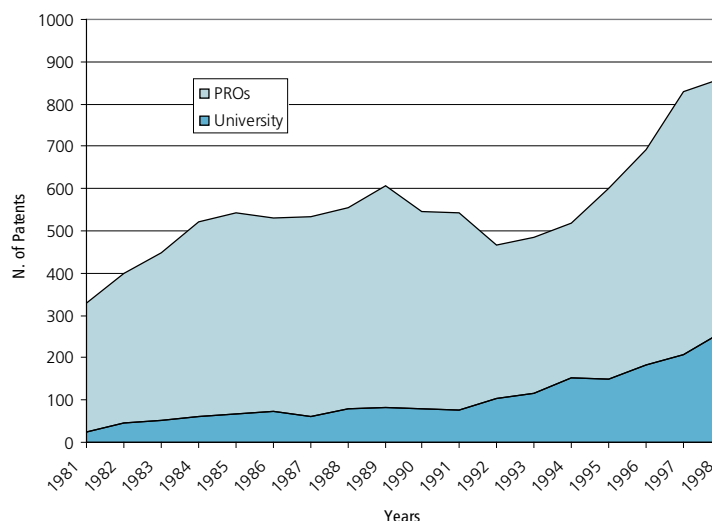
versities differ substantially in the way they share patent revenues and fees). The BDA includes a royalty-free government use and a “march-in” right, which, however, has never been used. Moreover, it is interesting to observe that the universities and TTOs have “right of first refusal” which means that the university has exclusive control rights over the scientists’ inventions.

3.2 Europe

In Europe, there has also been an increase in university patenting even if its magnitude is inferior relative to the US. In addition, there are strong institutional and national specificities and the available evidence is still weak. First of all, issues related to federal sponsoring of research do not arise as often as in the US. There are different relationships between funding or “federal” funding agencies (e.g. *Centre National de la Recherche Scientifique* (CNRS) or the *Commissariat à l’Energie Atomique* in France (CEA), *Comitato Nazionale per la Ricerca e lo Sviluppo dell’Energia Nucleare* or *Consiglio Nazionale delle Ricerche* (CNR) in Italy, or, finally, *Max-Planck-Gesellschaft* or *Helmholtz Gemeinschaft – Forschungszentrum Julich* in Germany) and universities. As we have seen, the BDA in the US allows universities to retain the IPRs over research results funded from federal agencies. In contrast, in many European countries, national agencies administer and spend a large share of R&D funds directly within their own laboratories. For example, in Italy and France, the CNR and the CNRS (or the INSERM and the CEA) are very active patenters and keep control on IPRs. Figure 1 shows the number of patents at the EPO owned by universities and PROs in France, Germany, Italy and the UK and what is noticeable is the growing, but extremely limited, absolute number of university-owned patents and the relatively higher number of patents owned by PROs.

Accordingly, given the low number of patents owned by universities, Europe has its own policy issues. In some countries, the existence of the professor’s privilege has played an important role. In Germany (as in Austria, Denmark and Sweden) the so-called professor’s privilege allowed university professors to retain property rights over their research findings. It is worthwhile noting that in 2000 German law abolished the professor’s privilege (the same occurred in Austria and Denmark) (see OECD (2003), Lissoni *et al* (2007)). For universities and research centers in France, Italy and the UK, the standard rule applied, according to which the employers retained the property rights (e.g. see Sections 39-43 of the UK Patent Act). In Italy, in 2001, the professor’s privilege was introduced for the first time and amended in subsequent legislative interventions.

Figure 1. Number of Patents by PROs and Universities in France, Germany, Italy and the UK (1981-1998)

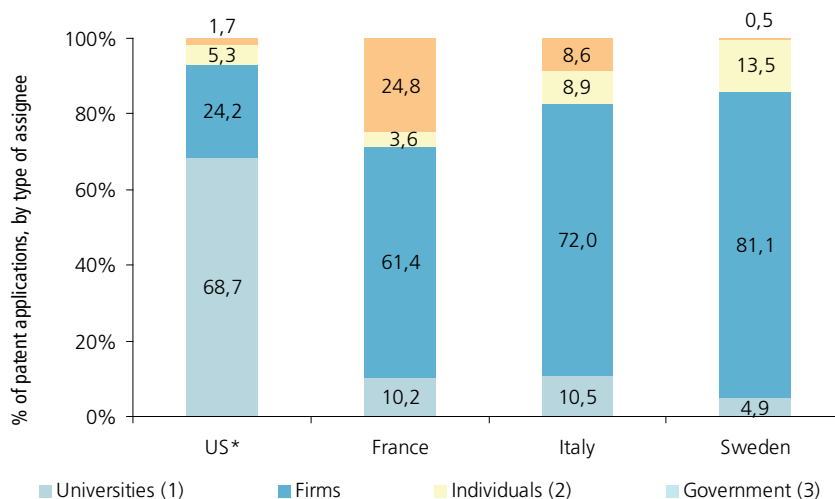


Source: EP-CESPRI Database (see also Bacchiocchi and Montobbio (2007))

Importantly, recent research shows that in many European countries IPRs on the output of university research activity are often owned by private companies (Lissoni *et al* (2007); Giuri *et al* (2007)). Consequently, the count of university patents (patents owned by universities) underestimates the technological activities of the European universities and the amount of technology transfer between universities and industry. Meyer *et al* (2003) and Balconi *et al* (2004) showed that 3 per cent of the patents in Italy (at the EPO) and 8 per cent of the patents in Finland (at the EPO) have at least one academic inventor. Moreover, in Italy, approximately 70 per cent of the patents with an academic inventor belong to private firms (Balconi *et al* (2004), Breschi *et al* (2007)). Similar evidence seems to emerge for Germany, France and Sweden (Schmiemann and Durvy (2003); Gering and Schmoch (2003); Lissoni *et al* (2006) and (2007)).

Lissoni *et al* (2007) undertook a considerable effort in matching the inventors' names from the EP-CESPRI database and the names of university professors from different sources in France, Italy and Sweden. They showed that the share of university-invented patents over the total number of patents in these countries was between 3 per cent and 6 per cent and this figure was comparable with that observed in the US. Moreover, Figure 2 displays the ownership of academic patents by assignees for France, Italy and Sweden and compares it with the US, as discussed in Thursby *et al* (2007). The difference between the various European countries and the US is striking. In the US, commercial companies own only 24 per cent of US academic patents. At the same time, in Europe these shares are respectively 60 per cent in France, 72 per cent in Italy and 81 per cent in Sweden. Universities, as already emphasized, own a very small share of university generated patents, around 10 per cent in France and Italy and 5 per cent in Sweden.

Figure 2. Ownership of academic patents by domestic inventors in France, Italy, Sweden, and the US*, 1994-2001



* US patent/inventor pair data from Thursby *et al.* (2006)

(1) US data include no-profit organizations (4,2% of tot obs); all data include co-assigned patents

(2) US data include "unassigned"

(3) European data include public laboratories

Source: Lissoni *et al* (2007) and Thursby *et al* (2007)

This is the result of the specific institutional characteristics of the various national research and innovation systems, in particular, the different role of the PROs on the one hand and, on the other, the lack of control over IP issues of many European universities. In Sweden, it may be because of the professor's privilege, whereas in France and Italy universities are not particularly autonomous from central government in fund raising and professors perceive themselves as civil

servants employed by the government rather than by the university. This created an incentive system such that universities did not create internal structures able to manage IPRs and professors felt free to dispose of the IPRs over their research results even in the absence of the professor's privilege (Lissoni *et al* (2007)). For example, Baldini *et al* (2006) showed that Italian universities created IPR regulations only in the second half of the 1990s. The important question that arises from this evidence is whether the fact that so many university-invented patents are owned by companies can be interpreted as a sign of an effective technology transfer.

A possible answer comes from the case of Denmark. Valentin and Jensen (2007) analyzed the impact of the Law on University Patenting (LUP) in 2000 that abolished the professor's privilege making a comparison with Sweden in the field of biotechnology. They observe a decline in collaboration between Danish firms and Danish scientists after the LUP approval and an increase in collaboration with non-Danish researchers. Moreover, they note that, when research is exploratory, the presence of a third actor (TTOs) brings delays in decisions over intellectual property and uncertainty.

It is remarkable that the institutional characteristics of the processes of interaction between universities, PROs and industry seem, to some extent, independent from the specific design of IP legislation. We observe similar patterns in the ownership structure of university-generated inventions in France, Germany, Italy and Sweden, countries that differ in terms of legislation. So it is possible to argue that technology transfer and cooperation between university and industry develops and adapts over the years according to established practices embedded in the variety of institutional actors. Changes in IP regulation may, therefore, be disruptive of the established practices.

3.3 The Importance of University and PROs Patents

Another (indirect) way to start answering the question about the impact of university and PRO patents on technology transfer is to take the approach of Henderson *et al* (1998) (HJT): "the extent to which this explosion [of university patents] should be taken as evidence of a large increase in the contribution of universities to commercial technology development depends on the extent to which it represents more commercially useful inventions vs. the extent to which it represents simply increased filing of patent applications on marginal inventions." (p.119)

Accordingly, they ask whether the relative growth in university patents changes the characteristics of these patents, in particular their importance and the way in which knowledge is transferred from universities. HJT compared the universe of university patents between 1965 and 1992 and a random control sample (equal to 1 per cent of USPTO patents). They measured the importance and "generality" of university patents using patent citations⁸ and showed that over the whole period university patents were more general and important than their controls. Generality was measured using the number of technological classes the citing patents belong to and importance was measured counting the citations received by each patent. A high generality index indicates that the patent possibly had a widespread impact and affected subsequent innovations in different fields of technology. University patents are expected to be more general than corporate patents because universities should undertake research that is more basic and, therefore, the ensuing results should have a wider use across different disciplinary fields. HJT found that, after the introduction of the BDA, the relative importance and generality of these patents decreased. Two factors may explain this decline: (1) fewer original patents from smaller universities without a strong experience in patenting; (2) a general decline in the average quality of the patents with many patents receiving zero citations.

To sum up, HJT claimed that after the BDA, there was an increase in the propensity to patent, but fewer general and important inventions were produced. The increased technology transfer effort thus brings less significant technologies into the market. However, Sampat *et al* (2003), using a longer time series of citations, showed that university patents take longer to be granted; on average they receive citations more slowly and the quality decline observed by HJT could depend upon the truncation of the citations data and this different intertemporal distribution of citations to university patents. Moreover, Mowery and Ziedonis (2002) found that the generality and importance of the patents of two large US universities (University of California and Stanford University) did not decline after the BDA. At the same time, more experienced universities have more general patents than their less experienced counterparts that entered into patenting after the BDA. However, Mowery *et al* (2002), (2004)) suggested that the importance of patents of entrant institutions increased in the 1980s and 1990s and, therefore, a learning process took place over time.

There are wide differences across technological disciplines in the relevance of university patenting. Patent growth is concentrated mainly in biotechnology and pharmaceuticals (Mowery and Ziedonis (2002), Mowery and Sampat (2005)). As already mentioned in the previous section, this expansion depends upon federal support to medical research in the US and the expansion of molecular biology at the end of the 1970s. Moreover, it is only in pharmaceuticals, communications, and electronics that the results of university research are conducive to R&D projects which require clearly identified intellectual property. The question, therefore, is also whether the importance and value of university patents vary across different technological fields. It may be that reinforcing patenting is beneficial only for some fields and crowds out other technology transfer systems such as publications, conferences, workshops and consulting. In this respect, Bacchiocchi and Montobbio (2007) estimate the process of diffusion and decay of university and corporate patents in six countries and, using EPO data, show that US university owned patents are more cited relative to company patents, in particular in the drug and medical sector.

Fabrizio (2007) suggested that increasing university patents were associated with slowing commercial exploitation. She used USPTO patents and patent citation data from NBER and citations to non patent literature from the MicroPatent Database and showed that the slowdown in the pace of knowledge exploitation (e.g. the mean value of the citation-lag distribution) depends upon the increase in university patents, in particular in those technological areas that rely more heavily on public science (i.e. a higher-than-average citation rate to non-patented prior art).

Sampat (2006) compared a sample of university patents and a random control sample from the USPTO and showed a remarkable increase in the citation to non-patent literature of university patents (relative to their control) between 1976 and 1996. This evidence might suggest that universities are increasingly patenting science.

In Europe, as policy-makers move steadily in the direction of stimulating patenting activity of universities and PROs, no evidence is yet available on the relative characteristics of university and PRO patents and on their relative value. One problem that arises is that the EPO does not register the institutional nature of the applicant in a separate field. Actually, there is no comprehensive evidence available yet, apart from specific case studies at the departmental or university level (OECD (2003), Geuna and Nesta (2006), Sapsalis *et al* (2006), Sargossi and Van Pottelsberghe (2003)). Bacchiocchi and Montobbio (2007) provided an attempt at filling this gap using an original database on patents from universities and PROs. Their paper estimated the process of diffusion and decay of university and corporate patents in six countries and tested the differences across countries and across technological fields using data from the EPO: in Europe they did not find evidence suggesting that university and PRO patents are of a higher quality. Their results showed that knowledge produced in universities and PROs appears to dif-

fuse more rapidly, in particular in Germany, the US and, to a lesser extent, France and Japan. However, strong national specificities emerge in this respect.

Finally, Crespi *et al* (2006) compared university-owned and university-invented patents resulting from university–firm research joint ventures. They used the Patval database and asked whether university-owned patents are more often applied, or are more valuable, than privately owned patents. They concluded that university owned patents do not differ significantly from privately owned patents. Crespi *et al* (2006) interpreted this result using the model by Aghion and Tirole (1994) that shows that a potential market failure (sub optimal social value of the innovation) exists when companies own the patent from a public private research joint venture if the university has low bargaining power and is cash constrained. The evidence of no statistical effect of ownership on the rate of commercial application of university patents may suggest that there is no evidence of potential market failure in the allocation of IP ownership from European research joint ventures (Verspagen (2006) discusses this point thoroughly).

3.4 Summing Up

This section has analyzed the historical evolution of university patenting in the US and the institutional differences between the US and Europe. The evidence shows that in the US importance and generality have not displayed a significant decline in recent years. Also universities are undergoing a learning process that increases the value of their patents. Moreover, there is no evidence of a shift in university research toward more applied science or of a clear decline in the basic nature or importance of university inventions. At the same time, in Europe, there is evidence of increased use of university patents, but there are strong specificities in the form of a relatively more important role of PROs and different ownership structure of university patents. While it is now clear that the contribution in terms of patents of European universities is not unlike the contribution of US universities, the impact of these institutional specificities on the process of knowledge transfer is still largely unexplored.

Overall this evidence does not rule out the possibility that restrictions on science may emerge, together with costs of access to science and negative effects on other forms of disclosures of scientific results. The next section is devoted to the analysis of these issues.

4. PATENTING SCIENCE

In recent years, empirical economists have shown that industrial activity relies substantially on basic research. In many cases, public research performed by universities and PROs provides companies not only with knowledge and understanding of basic phenomena, but also with tools and methodologies. However, the idea that publicly funded new ideas spill over without cost to the private sector is naïve. Many empirical works show that the relationship between university and industry is based upon many forms of reciprocal interaction, and the process is far from being without cost. Moreover, many authors have noted that publicly funded research also has an important role in training researchers and facilitating information flows across a scientific and technical community that transcends organizational boundaries (Cockburn and Henderson, (1998)). I mention here a few empirical papers among the multitude of contributions in the field. Cohen *et al* (2002) used data from the Carnegie Mellon Survey to show that public research both suggests R&D projects and contributes to the completion of existing R&D projects. University research affects industrial R&D through many channels other than patents: published papers and reports, public conferences and meetings, informal information exchanges and consulting. This influence is greater for larger companies.

Mansfield (1995) showed that a large number of industrial innovations in many high-tech industries are based directly on academic research. He also found that the quality of the university's faculty in the relevant department, the size of its R&D expenditures and industry geographic proximity are important factors that affect the university's impact on industrial innovations. Mansfield (1991) and (1998) confirmed that a substantial share of industrial innovations (over 10 per cent) would not have been possible without academic research. Industrial innovation benefits greatly from open science also in pharmaceuticals. In this sector, where intellectual property is typically considered the major instrument of appropriability, Cockburn and Henderson (1998) showed that companies, on the one hand, have to invest in substantial R&D to complement externally generated knowledge and, on the other, they have to be connected with public-sector institutions. They comment on their results as follows: "(...) the ability to 'do good science' in the private sector may not be supportable in the long run without a close partnership with the institutions of open science. Policies which weaken these institutions, make public sector researchers more market oriented, or redistribute rents through efforts to increase the appropriability of public research through restrictions in the ways in which public and private sectors work with each other may be, therefore, counterproductive in the long run". (p.180)

Many authors share this concern and suggest that university patents may restrict access to public knowledge and, in the long run, change the rules of open science. This may occur along the following lines: decreased informal interaction, incentives to increase secrecy in research and teaching, delayed publications, restricted access to patented research tools, costly negotiations and opposition procedures. First of all, concerns have been expressed in relation to patents for foundational upstream discoveries that could be used for downstream scientific research (Nelson and Merges (1990), Mazzoleni and Nelson, (1998), Cohen (2005)). This problem is particularly severe when universities are left free to license their discoveries exclusively.⁹ Colyvas *et al* (2002) surveyed 11 case studies (inventions) from Stanford and Columbia universities in biomedicine, electronics, software and medical devices. They underlined that patents are particularly important for embryonic inventions. In these cases, the ability to issue exclusive licenses is particularly important, but at the same time, the danger of exclusivity is particularly severe. This is because there is great uncertainty around the possible technological trajectories that may depart from the invention and this makes it difficult to choose the right licensee *ex ante*.

Second, there may be a problem with secrecy and data withholding. In particular, it is worthwhile mentioning two articles – among others – in the *New England Journal of Medicine* and the *Journal of the American Medical Association* (Blumenthal *et al* (1996) and Campbell *et al* (2002)) that point to the negative effects of patenting in life sciences on scientific publications. Campbell *et al* (2002) reported on a survey of 1,897 geneticists showing that almost half of them had been denied requests or additional information, data or materials regarding published research. Moreover, 10 per cent of all post-publication requests for additional information were denied. In many cases, therefore, published research could not be confirmed.

Blumenthal *et al* (1996) surveyed 210 life-science companies and underlined that over 60 per cent of companies providing support for life-science research in universities (this support is small comparable to federal funding) had received patents as a result of the relation with public research. Moreover, the companies reported that researchers are often required to keep the results of research secret beyond the time needed to file a patent. Given this preliminary empirical evidence, I will focus on two aspects that have been the object of particular attention in the last few years. The first is the well-known anti-commons problem and the second asks whether patenting activity has an impact on other forms of scientific disclosures, such as publications.

4.1 The Problem of the Anti-Commons

The “anti-commons” problem, in its more general formulation, refers to the idea that the privatization of the scientific commons reduces the benefits from scientific progress. More specifically, the anti-commons problem was suggested for biomedical innovation in light of the proliferation of patents on genes and gene fragments. Given the increase in the number of patents and the number of patent holders over a given product innovation or research tool, the cost of acquiring and negotiating the rights may become prohibitive and the likelihood of breakdown in negotiations over IPRs is higher. In this case, a loss of collective surplus is expected and, in the biomedical field in particular, the fragmentation of property rights may impede the development and commercialization of promising therapeutics and diagnostics (Heller and Eisenberg (1998), Murray and Stern (2007a) and (2007b)).¹⁰

Walsh *et al* (2003) conducted 70 interviews with IP lawyers, managers and scientists from biotech and pharmaceutical firms and universities (10 interviews of university scientists) examining the impact of patenting and licensing of research tools on biomedical innovation. They showed that the “patent landscape” is becoming more complex, exclusive licensing is pervasive and the pre-conditions for anti-commons effects exist. At the same time, they found little evidence of breakdowns in negotiations, or on projects that are not undertaken. In any case, they found that licensing fees for research tools have risen and this may be a problem, in particular for smaller firms and universities. They emphasized that some working solutions have emerged to deal with patents on research tools such as licensing, inventing-around or off-shore R&D to avoid infringement liability. However, what seems to be particularly important for universities is a sort of “informal research exemption”. Even if this possibility is now undercut by CAFC’s 2002 *Madey v. Duke* decision abrogating the (narrow) research exemption, faculty members seem to feel free to use research tools for research. Companies in most cases do not bring universities to court because they fear a loss in reputation, because they perceive that university research adds value and possibly because of the high cost of enforcing rights through litigation. Some exceptions are however observed in the field of clinical diagnostic. Overall, the situation is perceived as manageable, and results are confirmed by a subsequent larger survey (Walsh *et al* (2005)). Walsh *et al* (2005) analyzed the results from 655 researchers (398 from academia) in the fields of biomedicine (in particular proteomics and three specific signaling proteins). They did not observe that patent thickets significantly limit research activity in the field. However, few respondents seem to be aware of the necessity to regularly conduct patent searches and of risks related to infringements. For this reason, we cannot exclude that litigation may more significantly affect the researchers’ activities in the future.

Walsh *et al* (2005) showed that access to tangible research inputs (materials) is more problematic and this should be, in their opinion, the main object of policy interest. However, it is worthwhile noting that the reasons the researchers gave for not sharing are more connected to scientific competition and costs related to material transfers, than commercial factors.

Murray and Stern (2007a) used a different perspective and methodology to examine the anti commons problem. They focused on the research in Pasteur’s Quadrant: that is research activity that focuses both on fundamental scientific understanding and on usefulness and applications (Stokes (1997)). In this case, researchers can disclose their inventions using both patents and publications. Accordingly, Murray and Stern (2007a) constructed a sample of 169 patents associated with papers published in *Nature Biotechnology* over the period 1977-99. They considered that the initial knowledge disclosed through the scientific publication and patents were granted with a time lag. Therefore, they could study citation patterns before and after a patent is granted. They found that the citation rate declines by between 10 and 20 per cent after a patent grant, and the decline is more pronounced for researchers with public-sector affiliations.

Therefore, they reject the null hypothesis that intellectual property does not affect the diffusion of scientific research, and the existence of IP-related restrictions on subsequent research cannot be excluded. Huang and Murray (2007) confirmed these results for 1,279 patents on human genes, particularly in the presence of patent thickets and ownership fragmentation.

Rosell and Agrawal (2006) asked whether knowledge from university research was disseminated to a narrower variety of users. They used the National Bureau of Economic Research patent database as described by Hall *et al* (2001) and a report of university patents (USPTO (2002)). They calculated a Herfindahl type measure of the concentration of patents across applicants and estimated whether patented university inventions were more widely disseminated than those of firms. They found that the 'university diffusion premium' – i.e. the degree to which knowledge flows from patented university inventions are more widely distributed than those of firms – declined by over half between the early and late 1980s.

4.2 Patents and Publications

This section explores the empirical work that analyzes the issue of university patenting and its impact on the scientific activity of academic researchers. Many authors have underlined that the relationship between patenting and publishing may be negative at the individual level mainly for two reasons: there may be a "publication delay" effect and/or a "basic-applied trade-off" (Breschi *et al* (2006)). First, publication delays may be necessary to meet the novelty step requirement in all patent legislations throughout the world: only new ideas can be patented, and ideas that entered the common pool of knowledge (no matter how recently and no matter by which means) through a published output are not new. Academic researchers who aim to take a patent, either in their own name, or in the name of their universities or business partners, should keep their inventions secret until the patent application has been filed. Second, the diversion of a researcher's attention from basic research to more applied targets may result in lower rates of publications in refereed journals, or in less ambitious publications with a lower impact on the scientific community. This can be expected to exert non-negligible effects only if patenting is non-occasional, especially if resulting from business-oriented research. Thus, we expect academic inventors with prolonged contacts with industry and more than one patent to be the most affected by the tradeoff (for a discussion, see Breschi *et al* (2007)).

There are at least three counter-arguments against the existence of a patenting-publishing tradeoff at the individual level. First, there may be a "resource effect". This argument suggests that the individual researcher who chooses to address her/his research to IPR relevant objectives does so in order to access additional resources. Scientists can access not just financial resources and expensive scientific instruments, but also "focused" research questions (cognitive resources). Answers to research questions raised by technological puzzles may at the same time be economically valuable and scientifically relevant, up to the point of opening up new research avenues and disciplines (Mansfield (1995) and (1998)). Possibly, the resource effect would show up much more clearly for patents applied for by business companies, with the scientists appearing just as designated inventors, rather than by the scientists themselves or their universities (or public funding agencies).

The other two counter-arguments against the publishing-patenting tradeoff derive from long-debated questions in the sociology of science. We may label them the "productivity fixed effect" and the "augmented Matthew effect". Both of them suggest that academic inventors may be among the most productive scientists, namely those with the highest publication rates. The "productivity fixed effect" argument simply suggests that both patents and publications are proxies of a scientist's productivity. The "augmented Matthew effect" builds upon the classic

remarks by Merton on the tendency of the priority reward system to benefit highly productive scientists, especially precocious ones, with a number of cumulative advantages, ranging from higher visibility and reputation to ever-increasing ease of access to research opportunities and resources (Merton, (1968)).

Due to increased data availability, in particular the use of EPO and USPTO patent databases and the Web of Science, there is an increasing number of papers that have studied the relationship between patents and publications.

Agrawal and Henderson (2002) analyzed the patenting and publication behavior at the Mechanical and Electrical Engineering Department of the MIT (68 interviews) and showed that patenting is not a major activity in these fields and there is no evidence of a tradeoff at the individual level between patents and publications. Azoulay *et al* (2006) used a panel of 3,862 scientists in life sciences and did not find evidence of a negative effect of patents on the quantity and quality of publications. They controlled for the inherent “patentability” of the scientists’ research and did not exclude the possibility that patenting also changes the content of these publications by binding them more tightly to commercialization. Markiewicz and DiMinin (2005) again found complementarity between patenting and publishing using a panel of 150 randomly chosen academic inventors at the USPTO and a control of 150 scientists who were not inventors. Breschi *et al* (2006) and (2007)) investigated the scientific productivity of Italian academic inventors on patent applications to the EPO. They used a longitudinal data set comprising 299 academic inventors and matched them with an equal number of non patenting researchers. They inquired whether a tradeoff between publishing and patenting, or between basic and applied research exists on the basis of the number and quality of publications, but found no trace of such a tradeoff, finding instead a strong and positive relationship between patenting and publishing, even in basic science. Moreover, Breschi *et al* (2006) found this result particularly relevant in pharmaceuticals and electronics and telecommunications.¹¹

Stephan *et al* (2007) used approximately 10,000 scientists from the Survey of Doctorate Recipients in various disciplines. They found that work context and field were important predictors of the number of patent applications. They also found patents to be positively and significantly related to the number of publications even if the cross-sectional nature of their data precluded an examination of whether a tradeoff exists between publishing and patenting.

Other papers have also explored what are the determinants of patenting activity for the scientists at the individual level. Azoulay *et al* (2007), Breschi *et al* (2006) and Calderini *et al* (2007) found that individual scientific productivity is a major factor that exposes scientists to the risk of patenting. In particular, Azoulay *et al* (2007) used their panel of 3,862 academic life scientists and implemented discrete time hazard rate models and fixed effect logistic models to find that patenting events are preceded by a flurry of publications, controlling for individual heterogeneity and latent patentability of a scientist’s research. They, therefore, emphasized not only that academic inventors are among the most active scientists, but also that patenting behavior is also a function of scientific opportunity. Breschi *et al* (2005) showed for the sample of Italian academic inventors, that more productive scientists are more likely to become academic inventors, not to the detriment of their orientation towards basic research. Research cooperation with industry is a useful predictor of patenting, when IPRs are owned by commercial companies. Finally, Calderini *et al* (2007), using a sample of 1,276 Italian scientists and 131 inventors in material sciences, found that the probability to patent depends upon the basic nature of the invention, the impact factor of the journal in which it was published and on individual productivity of the inventors. However, they suggested that the relationship is not linear and that for individuals who publish very basic or very high-impact research, every increase in productivity results in a reduced probability to patent, although this effect is very small.

4.3 Summary and Discussion

The studies surveyed did not find strong evidence of anti-commons effects or significant foreclosure of public science in the research fields where university patenting is a particularly significant activity. Taken together, these papers also convey the idea that academic inventors are among the most prolific scientists in term of scientific publications and there is no evidence of a strong tradeoff between patenting and publishing at the individual level. However, some words of caution are needed. First of all, there is much sectoral heterogeneity. On the one hand, it is reassuring that most of the 'complementarity' results between patents and publications are related to pharmaceutical or life sciences where the issue of university patenting is particularly important and the anti-commons problem felt to be more severe. On the other hand, the scant evidence that we have for other fields suggests that there is no (or a very weak) relationship between publishing and patenting. More importantly, this literature still struggles with counterfactuals and endogeneity issues. We are not really sure what would have happened had the academic inventors not patented their research results.

Second, we do not know which institutional processes may be conducive to both patenting and publishing and, indeed, if there are several. As suggested by Stephan *et al* (2007), context variables are important and the underlying model probably depends on whether the inventor is involved in consultancy with a private company or the research is purely publicly funded; whether the scientists are employed in a small or large university; in universities with competent staff skilled on IPR issues, or whether scientists are occasional or persistent innovators.

We have evidence that high-quality research and high-quality researchers tend to go together with patenting. Murray and Stern (2007a) showed that patented research is on average more often cited and continues to be cited even if at a lower rate. However, we still cannot exclude, for the afore-mentioned reasons, that patents may have a wider negative impact on scientific behavior. In particular, we do not know whether scientists are shifting their resources toward other unpatented research activities and we do not know whether the very productive scientists who patent and publish are, because of the patents, publishing at a sub-optimal rate. Finally, case study evidence suggests that patenting is becoming important for its bargaining power to exchange and share protected tools and materials. This may considerably change the rules of the game and penalize institutions and individuals with weak bargaining power. Since this is a relevant argument for developing countries, I will come back to the issue in the final section.

5. TECHNOLOGY TRANSFER OFFICES AND LICENSING

In the previous section, I noted that there was substantial empirical evidence on the benefits deriving from knowledge flows between academia and the rest of the economy. In this section I focus on the licensing of university owned inventions to private firms and the role of technology transfer offices (TTOs). Such technology licensing activity has grown dramatically in the past two decades. In particular, I explore the institutional context in which TTOs operate and its effect on the propensity to commercialize research and, especially, the relevance of the presence of prominent faculty members who themselves are engaged in this activity.

5.1 University Licensing and TTOs Profits

In the US, there has been a substantial increase in patenting and licensing and in the number of TTOs. The sheer numbers tell a story of continuous growth of university patenting, licensing and invention disclosures. According to the 2005 AUTM survey, there were 28,349 currently

active licenses in the US between companies and universities and 4,932 new licenses were signed in 2005. The total university licensing income reached 1.6 billion US dollars in 2005 (1.4 billion US dollars in 2004) (Thursby and Thursby (2007), AUTM (2005) and (2004)). At the same time, it is important to note the highly skewed distribution of licensing revenues across universities. In 2005, Emory accounted for approximately 585.5 million US dollars and New York University for 133.8 million US dollars. It is difficult to say whether many TTOs cover their costs and generate profits for their universities (Thursby and Thursby (2007), NSB (2004)).

Thursby and Thursby (2007) wondered why so many universities set up a TTO if for many TTOs the licensing income is low. They gave three possible explanations. The first could be that universities hope to “hit the jackpot” as in the Emory case. The second explanation is that TTOs may serve other university goals different from licensing, such as sponsored research. Finally, they suggested that there could be emulative behavior. They noted that there are a number of TTOs in universities with a very low research budget. For these institutions it is probably not necessary to have a TTO.

Moreover, Thursby *et al* (2001) and Thursby and Thursby (2002) analyzed the nature and determinants of this increased licensing activity. Thursby and Thursby (2002) developed a model to examine the extent to which the growth in licensing is due to the observable inputs (patenting, licensing and disclosures) or driven by a change in the propensity of faculty and administrators to engage in commercializing university research. They used survey data from 65 universities and observed that patent applications grow much faster than innovation disclosures which depend more closely on faculty choices. As a result, they suggested that increased licensing is due primarily to an increased willingness of faculty and administrators to license, rather than a shift in faculty research. In this connection, Thursby *et al* (2001), in a survey of 62 US universities, underlined the fact that additional disclosures generate smaller percentage increases in licenses, and those increases in licenses generate smaller percentage increases in royalties. Overall, these results confirm the findings of Henderson *et al* (1998) that universities are trying to extract as much as they can from a given set of discoveries and this decreases the value and the generality of the marginal patents.

One final possible concern is related to the cost of oppositions and lawsuits for universities. What is the effect of increased patenting by universities on enforcement costs? Shane and Somaya (2007) studied the effects of patent litigation on university efforts to license technology. They used secondary data on licensing and interviews with TTO directors for research universities and discovered that patent litigation impacts negatively on university licensing activity. They emphasized that litigation changes the nature of TTOs’ activities and shifts resources from marketing and licensing toward lawsuits and opposition activities.

5.2 Putting TTOs in Context: The Performance of Different TTOs and the Role of Faculty

A second group of papers refers not only to the type, growth and profitability of TTO activity, but also to the determinants of TTO efficiency. Thursby and Kemp (2002) considered that the TTO inputs are: number of staff, federal funds for research, faculty size and research quality. Output is measured in terms of patents, disclosures, licenses executed, royalties and research funds from industry. They showed that universities are more commercially productive than they were in the recent past and at the same time there is a wide heterogeneity of efficiency across the 111 universities they studied. They found that the increase in overall university resources is not a determinant of the increased licensing activity and higher levels of commercialization.

Lach and Shankerman (2004) and (2008)) developed a model and performed an econometric exercise on the role of economic incentives in university research and licensing outcomes. In particular, they examined how the share of license royalties received by academic inventors affects the number and licensing value of inventions in universities. They used data from the Association of University Technology Managers and collected information on the distribution of royalty shares from university websites for 102 US universities between 1991 and 1999. In the US, the inventors share with the university a portion of the fees and royalties from licensing IPRs and universities differ substantially in these royalty sharing arrangements. There are two type of agreements: linear and non-linear royalty schedules. In the case of the former, inventors receive a constant share of the license income generated by an invention. The average figure in this case is 41 per cent (maximum 65 per cent, minimum 25 per cent). In the latter case, inventors' royalty shares vary (in the majority of cases regressively) with the level of licensing income. In this case, variation across universities is even wider because the inventor's share ranges between 20 per cent and 97 per cent with an average value of 51 per cent. Lach and Shankerman showed that both academic research and inventive activity in universities respond to variations in inventors' royalty shares. In particular, they found that universities, particularly private universities with higher royalty shares for inventors, generate higher levels of licensing income. The papers of Lach and Shankerman are particularly important because they show that the specific design of intellectual property and the incentives in the form of royalty shares can have real effects on the direction of research. Royalty incentives work through two mechanisms: raising faculty effort and sorting scientists across universities. These incentives mainly increase the quality rather than the quantity of inventions.¹²

Di Gregorio and Shane (2003) studied TTOs from the point of view of IP-related start up formation and inquired why some universities generate more new companies to exploit their intellectual property than others. They analyzed a panel of 102 universities over the 1994–98 period for which they collected data on start-ups, patents, intellectual eminence, venture capital and policy-related information with a survey of TTO directors. Therefore, they asked which factors affect the creation of new companies: the availability of venture capital in the university area; the commercial orientation of university research and development; intellectual eminence; university policies.

Their results showed that only the last two factors affected the creation of start-up firms. In particular the relevant policies are: (1) making equity investments in TTO start-ups; (2) maintaining a low inventor's share of royalties. This result can be compared with Lach and Schankerman (2004). Many universities leave a high proportion of royalties to inventors in order to encourage the reporting and exploitation of inventions. Di Gregorio and Shane (2003) suggested, however, that significant royalty sharing may create disincentives to the creation of start-up companies. They also showed that more eminent universities have greater TTO start-up activity. Their results confirm previous evidence that star scientists found companies to earn rents on their intellectual capital and that the growth of biotech companies in the US regions is strictly linked to the high scientific standard of the researchers (Zucker *et al* (1998)).

Stuart and Ding (2006) underlined, for a sample of approximately 6,000 life scientists and 600 start ups (or participation in the scientific advisory board of a new biotechnology firm), that the institutional context is crucial to explain the heterogeneity of behaviors of transition to commercial activities. In particular Stuart and Ding found that the orientation of colleagues and co-authors towards commercial science, as well as a number of other workplace attributes, significantly influenced scientists' hazards of transitioning to for-profit science. The quality of faculty members affects not only start-up formation, but also licensing activity. Elfenbein (2007) used approximately 1,700 inventions considered patentable from the Harvard University's Office of Technology and Trademark Licensing and the Office of Technology Licensing and Industry

Sponsored Research at Harvard Medical School. He showed that inventors' prior academic output is positively correlated with the likelihood that their new technologies will be licensed.

Faculty behavior, however, is also important because faculty-specialized knowledge is needed to develop licensed technologies (Agrawal and Henderson (2002), Colyvas *et al* (2002), Jensen and Thursby (2001), Thursby *et al* (2001), Thursby and Thursby (2002) and (2007)). Jensen and Thursby (2001) and Thursby *et al* (2001) found that 71 per cent of licensed inventions used faculty in further development after the license was signed. Thursby and Thursby (2004) showed that faculty used 55 per cent of the time for the development of licensed technologies that were only a proof of concept (54 per cent for prototypes). Therefore, when the technology is at an early stage of development, the involvement of the scientists is crucial, even if companies typically do not perceive this involvement to be cheaper than in house development. Finally, Agrawal (2006) showed that the likelihood and degree of commercial success are related positively to the extent in which the firm engages the inventor and his graduate students in technology development after a license is signed. He claimed that the inventor's tacit knowledge is a crucial asset in the process of commercialization.

5.3 Preliminary Evidence from Europe

In Europe, the role of TTOs has been much less studied. First, because there is a very high diversity across countries and because there is no coherent data and systematic data collection as in the US with the AUTM surveys. An exception is provided by Arundel and Bordoy (2006) who conducted a survey for the Association of Science and Technology Professionals (ASTP) on the technology transfer activities of ASTP members (universities and other PROs). The ASTP has 209 members, and represents 20 per cent of the approximately 1,000 TTOs in Europe. The survey collected data for 2004 and 2005 and analyzed 74 responses from universities and 27 responses from other public institutes in 22 European countries. Arundel and Bordoy (2006) showed that the average TTO has 8.7 staff members. University TTOs have lower staffing levels (5.43) than PROs (12.3). However, there is wide variation across institutions and the staff distribution is extremely skewed (Conti *et al* (2007)). University TTOs are relatively recent, with an average age of eight years since establishment. These results were confirmed by the 2005 annual survey of the other important network of TTOs, companies affiliated to universities and PROs, known as ProTon Europe.¹³

In fact, in many European countries, universities and PROs have created TTOs in the last decade (OECD (2003)). Germany has established patent exploitation agencies at a regional level. In Italy, Baldini *et al* (2006) showed that universities started to adopt patent policies and regulation over the last ten years. Also, in Belgium, Denmark and France, TTOs are small with a very limited number of staff members (Bach *et al* (2007), Conti *et al* (2007)). It is not surprising, therefore, that licensing activity is not as developed as in the US. ProTon (2007) showed that the number of licenses grew between 2004 and 2005. However, the absolute number is still very low (731 licenses for 392 respondents in 2005) and the license revenues are only equal to 0.17 per cent of the R&D investment. Conti *et al* (2007) showed that the distribution of licenses is skewed with many institutions having very few licenses (the median number of licenses across TTOs is only 4.5). This confirms the evidence provided by the OECD (2003) that the majority of PROs negotiate a very small number of licenses each year. The OECD (2003) also underlined that a major share of license agreements in Italy, the Netherlands and Switzerland were concluded for patent pending inventions or non patented inventions (e.g. biological materials or know-how), as well as for copyrighted materials.

Only in the UK are TTOs more developed. Chappel *et al* (2005) found that there TTOs have low levels of absolute efficiency. Universities located in regions with higher levels of R&D and GDP appear to be more efficient in technology transfer. The authors underlined the necessity to enhance the skills and capabilities of TTO managers and licensing professionals in the UK. Similarly, Conti *et al* (2007) estimated the determinants of the number of licenses for the respondents to the ASTP and found that the skill composition of a TTO plays an important role in determining its productivity. In particular, they claimed that employing PhDs appears to reduce the coordination costs arising from interactions between the TTO and academic researchers.

5.4 Summary and Discussion

This section has shown that significant differences exist across universities and TTOs in their generation of new firms, patenting and licensing activities. University policies that provide economic incentives for TTO staff and faculty, and the scientific status of researchers and departments, greatly affect this variation. Faculty involvement in the development phase also clearly emerges as an important determinant of success. This produces a better understanding of the context in which technology transfer is particularly successful and has some important implications for specific institutional schemes in terms, for example, of royalty sharing and equity participation.

It is important, however, to emphasize that most of the evidence we have surveyed comes from top universities in the most advanced country. The ability to generalize for other countries with different levels of development is limited. For example, we do not know the factors affecting the efficiency of TTOs in universities that are not research-oriented and do not systematically exploit their intellectual property. For example, in Europe, it seems particularly important that TTOs develop the hiring of technically competent staff. Moreover, in the evidence I have surveyed, some factors such as commercial orientation, the availability of venture capital funds or the presence of an incubator, do not seem to be major determinants of commercialization in terms of start up and licensing activities. The fact, however, that these practices may be important in different countries and fields cannot be ruled out.

6. INTELLECTUAL PROPERTY ON PUBLIC RESEARCH: CONCLUSIONS AND OPEN ISSUES FOR DEVELOPING COUNTRY INNOVATION SYSTEMS

This paper summarizes the recent empirical literature in economics that has analyzed the role of patents in universities and PROs in facilitating knowledge transfer. Assessing empirically whether intellectual property facilitates knowledge transfer from public research to industry is an extremely difficult task because there are many different and interdependent channels of interaction and spillovers between universities, PROs and companies and it is difficult to build counterfactuals. A large number of empirical papers on this topic have focused mainly on the US experience where patenting public research has increasingly been a vehicle for effective transfer of technology from universities and public research to industry.

The empirical work in economics has shown that knowledge transfer between university and industry is based on many different forms of interaction. Most of the research has focused on life sciences and biotechnology where basic research is very close to commercial applications. In these fields, there has been an impressive growth of university patents. However, technology transfer mechanisms vary considerably according to the particular scientific field, the stage of development of the invention and across regions because they are adapted to different institutional settings and research systems.

I think, however, that some lessons can be drawn from the literature surveyed and from the US experience. First of all, companies' absorptive capacity is extremely important. Companies have to be "connected" with public research in order to be able to absorb new ideas and discoveries. Substantial R&D is often necessary within companies to develop complementary knowledge that can be used to develop and commercialize innovation from public science. Geographic proximity and co-location between an "anchor tenant" firm and the research institutions seem to be particularly conducive to vertical knowledge flows between downstream industrial R&D and upstream university research (Agrawal and Cockburn (2003), Cockburn and Henderson (1998)).

At the same time, much of the "transferred" knowledge is tacit (or the costs of transferring are high) and faculty members are considered to play an important role, in particular for early stage embryonic inventions. In fact, top researchers in science and engineering are particularly active in technology transfer through start up, licensing and publications.

In the innovation systems of developing countries we can expect to see companies specialized in more traditional, less science-intensive sectors and a research system less mature with fewer resources dedicated to research activity. Considering that evidence suggests that patenting and licensing (even in the US) are of secondary importance in most fields, and taking into account that in emerging innovation systems markets for technologies are less developed, intellectual property in public research probably plays a less relevant role. It is worthwhile reiterating the point made by Mowery and Sampat (2005) that the explosion in university patenting in the US is to a great extent related to the biotechnology revolution that in turn has its roots in the considerable amount of federal funds dedicated to medical research in the US after WWII in a country with a long-standing, close relationship between PROs, universities and industry.

A first issue is, therefore, the improvement of the scientific quality and productivity in universities and PROs and the absorptive capacity of companies. It is important that in the innovation systems of developing countries, universities reach high standards in education and training of personnel and expand the networks of scientific and technological capabilities (Campos *et al* (2007)). In this context, IP regulations should be designed to improve collaboration between industry and public institutions and – since intellectual property is becoming a central aspect of cooperation with industry – avoiding unintended consequences, in particular when collaboration is exploratory. In this vein, Sampat (2003) and Mowery and Sampat (2005) criticized the movement to mimic the BDA to improve the "entrepreneurial" nature of the university system in developing countries. They suggested that broadly disseminating new knowledge is to the comparative advantage of universities and PROs in these countries and "policies like the Morrill Act of 1890 –which created incentives for US universities to create and diffuse knowledge targeted at local agricultural and industrial needs – would yield far greater social returns than Bayh-Dole type legislation" (Sampat (2003), p.64).

Secondly, evidence suggests that university income from royalties and fees is extremely skewed. Many TTOs in Europe (but also in the US) have a negligible number of executed licenses (Geuna and Nesta, (2006), OECD (2003), ProTon (2007)). To "win the jackpot" is an extremely rare event, particularly for small universities with limited economies of scale and few research projects. Also, in the US, it is difficult to say whether many TTOs generate profit for their universities since licensing revenues often do not outweigh the operating costs of the TTOs. Moreover, the TTOs appear to be particularly efficient when they are staffed with competent and well-paid people and in specific contexts where commercialization of public research is a common and pervasive activity. Considering, finally, that TTOs may help technology transfer in particular in science and engineering universities, administrators and policy makers facing tight budget constraints should always evaluate carefully the opportunity costs of creating new and expensive institutional entities.

In particular, this discussion suggests that the fixed cost of TTOs could be conveniently spread by building “central brokers” (e.g. at the regional level). Transfer activities and learning could take place over a relatively large number of inventions and exploit the benefits of portfolio diversification. A potential drawback of regional approaches could be that stimulating invention disclosures, writing patent applications and finding licensees may require geographic proximity to facilitate informal interaction and close working between faculty members and employees of individual PROs and universities.

Third, faculty involvement is extremely important for fruitful cooperation with industry, in particular when technology transfer offices lack the resources and expertise necessary to search for potentially valuable innovations. Our evidence suggests that researchers may perceive transfer activities as a dangerous diversion from their publication activity because there can be high costs in interacting with licensing professionals and technology transfer offices (Owen-Smith Powell (2001)) and because licensing may include some non-disclosure or publication delay agreements (Thursby *et al* (2001)). However, scientists respond to perceived economic incentives and substantial royalty sharing seems to be a convincing argument (Owen-Smith Powell (2001), Lach and Shankerman (2004)).

An extreme form of incentive for faculty members to participate in the commercialization process is the so-called professor's privilege that assigns to individual scientists the property right over an invention arising out of university research. In this respect, the European experience is that industry-university cooperation involves adapting to specific institutional settings and research systems. Changing the design of intellectual property may disrupt the established practices of cooperation. In Denmark, the abolition of professor's privilege in 2001 and the new attitude of universities towards intellectual property may have caused biotechnology companies to change research partners and move some research projects to Sweden (where the privilege is maintained). Conversely, in Italy the introduction of the professor's privilege in 2001 caused concern among universities and companies because of the difference in treatment of researchers from private and public sectors, in a context where the majority of university-invented patents are owned by commercial companies. This reinforces the feeling that a specific IP design must be aligned with the other components of the research and innovation systems. In this respect, the professor's privilege might not be appropriate when, in developing countries, public institutions want to keep control of intellectual property over strategic technologies (in agriculture or health) for public interest or policy reasons.

This survey also discusses the potentially harmful effects of patenting scientific commons. This problem may be particularly acute in developing countries in key sectors like agriculture, biotechnology and health. The costs of access to databases, materials and research tools may become prohibitive. Moreover, developing countries may suffer potential negative effects of university patenting on other technology transfer mechanisms: publications, conferences, informal interaction with researchers and consulting.

In this case, the survey and quantitative evidence provided in this paper suggest that academic patenting is not fatally undermining the scientific system (Murray and Stern (2007a) and (2007b), Cohen *et al* (2005)). US based evidence shows that patents impose some extra costs on scientific research and in some cases delay publications, but overall there is no strong evidence of systematic privatization of intellectual commons. At the same time, as strongly emphasized by Murray and Stern (2007b), the rules of the game are changing rapidly and the rise of academic patenting has increasingly stratified the power structure of academic science since patents are not only used to commercialize but also to provide bargaining power with other scientists. University patents may, therefore, become an important currency in the global scientific college. This currency may be particularly expensive for individuals and institutions that are traditionally in a weak bargaining position.

While many universities and research centers in developing countries may be interested (or may be forced) to play this game – exchanges of cell samples are crucial in certifying and replicating results, in particular in the case of viruses that may lead to vaccines and diagnostic tests, like the controversy about AIDS blood test patents (Murray and Stern, (2007b) – close attention must be paid in order to safeguard knowledge access and limit restrictions on the use of research tools and materials. This is particularly important because there are many (possibly biotech) products in agriculture and health that have only a developing country market and, therefore, the private sector in developed countries may have no incentive to undertake the necessary R&D investment. National legislation should, therefore, ensure adequate disclosure in the research system and protect scientists from the most aggressive types of IP licensing. In this respect, inventions from public science should probably be licensed non-exclusively in developing countries. Moreover, research exemptions should be adopted for public and “non commercial” research and a “grace period” should be introduced for university researchers according to which it is possible to have a one-year lag between the patent application and the publication of the research. Finally, ensuring that low-quality patents are not granted (e.g. raising the “non-obviousness bar”) could help to alleviate the possible negative impact of patenting public research.

6.1. Potential Areas of Additional Research in Developing Countries

A lot of quantitative and qualitative evidence is needed to understand precisely how IP regulations affect technology transfer from universities and PROs in developing countries. The amount of knowledge and technology that is transferred from university to industry (and/or is the result of cooperation between these two types of institutions) depends on: (1) the amount of knowledge generated within universities and PROs (i.e. the scientific productivity of individual scientists and researchers); (2) the type of knowledge disclosure; (3) the nature and type of their research; (4) the absorptive capacity and demand for new knowledge by companies. All these aspects are affected by the specific IP design in different disciplinary fields.

The first question is, therefore, to measure the scientific and patenting activity in universities and PROs and subsequently to assess how the scientific productivity of individual researchers is affected by patents. Much work here has to be done to build reliable databases on patents invented by university professors. As is happening in Europe, I expect many university patents in developing countries to be owned by private companies or by individual inventors. This creates difficulties in quantifying the number of university-invented patents because the university name does not appear in the patent document. A possible solution is to apply the methodology explained in Lissoni *et al* (2007) and to match a database with the names of individual professors with a database showing the names of the domestic inventors of the patents. Moreover, individual scientists’ publication profiles can be tracked thanks to the increased availability of bibliometric databases. It is important to underline once again that intellectual property is expected to play some role only in specific disciplinary fields. It could also be interesting to evaluate the effects of recruitment policies in universities and PROs that introduce intellectual property or other forms of technology transfer to evaluate researchers’ activity (as happened, for example, in the Mexican *Sistema Nacional de Investigadores*)¹⁴ and to inquire as to the effects of these policies on scientists’ activity, their promotion and career paths.

In this vein, another interesting topic largely under-researched is the relationship between intellectual property and labor mobility. Mobility of scientists is extremely relevant for developing countries because, on the one hand, the brain drain affects the scientific productivity of local universities and, on the other, many highly prolific scientists in developing countries have taken their postgraduate degrees in top US and European universities. In this respect, case studies

could trace the movement of people from US and European universities to domestic universities, and study – together with the different scientific productivity of this sub-sample of researchers – whether they face restrictions on the use and diffusion of their discoveries (often from laboratories situated in foreign countries), and how, if at all, IP protection affects this process. Here again, important differences may emerge across different disciplinary fields. For instance, what is the effect of patents on research tools to the incentive to move from a foreign university to a domestic one, where the cost of access to patented research tools may be perceived as prohibitive? Is this stronger in a country with stronger IP protection? Is it more likely to share materials and data with the original university in such cases? Are more mobile scientists more productive and more likely to take patents on their research or to create start ups? If this is the case, do they play a special role in connecting universities and companies?

Secondly, since intellectual property and licensing are not independent from other means of technology transfer (such as scientific publications, consulting, workshops and collaborative agreements), there is room for a set of quantitative studies in different countries and disciplinary fields on how the increased involvement of individual researchers and universities in intellectual property and licensing is hindering or enhancing other forms of knowledge disclosure like scientific publications.

In particular, it would be interesting to study the effects of changes in legislation on scientists' choices. Scientists choose their research projects, the way they disclose their findings and, possibly, the way they transfer the knowledge produced; all these choices are increasingly affected by the specific IP setting. Institutional changes that can be taken into account may be related to the owner of the property right (the inventor – as in the professor's privilege case – or the institutions), to changes in regulations within universities or to the creation of TTOs.

At the institutional level, it is always difficult (even in Europe and the US) to have a quantitative account of the costs and benefits of the use of intellectual property in universities and PROs. Collecting data on TTO costs, application fees and opposition costs and on revenues from licensing or other forms of transfer, would greatly help to assess the impact of intellectual property on the knowledge transfer activity of these institutions.

Third, patenting in universities and PROs may affect the nature and the direction of scientific research. Again, individual scientists' publications can be used and the journal fields may inform about the nature of scientific research that is performed. It would also be interesting to observe the scientific activity at the laboratory level and the dynamic interaction between specific IP policies, fund raising and recruitment policies. An exogenous source of variation could be found in changes in legislation like, for example, the Law N. 10.973, December 2, 2004, in Brazil, or the restructuring of governmental research institutes in China.

Moreover, one could take the Henderson *et al* (1998) perspective and ask whether the contribution of universities to commercial technology development is the result of the creation of more useful inventions in developing countries or, alternatively, simply an increased propensity to patent in universities. Also, in this case, some characteristics of the university patents – like their technological value, their generality or basic nature – may be measured using patent citations.

It would also be interesting to have a detailed understanding, again through case studies in specific fields or surveys, on how patenting in research tools creates barriers to entry for research in developing countries or, at the opposite end, whether the absence of patent protection has attracted funds for research on something that is protected elsewhere. In addition, cross-country comparisons could help to disentangle the effects of different norms regarding research

exemptions, grace periods and non obviousness standards. The underlying research question is always to disentangle how different forms of knowledge spillovers are conditioned by the IP regime in the country, in specific industries.

Moreover, intellectual property on research results in many developing countries may be motivated by public interest. It is important for many governments in developing countries for research results to be widely used and correctly exploited, in particular in crucial sectors like food and health. In this respect, how intellectual property should be used for public interest in universities and PROs – in connection with health systems and food programs – is a very interesting field of research.

Finally, in developing countries, detailed case studies could be done to discover which arrangements are particularly effective in regions and industries where the number of high tech companies is small and innovation is incremental. Another stream of research could ask which type of company is more likely to engage in cooperative agreements with universities and how these relationships are affected by different IP regimes. Over the past 20 years, some countries have undertaken profound processes of liberalization and privatization. Does the changing competitive environment require different IP arrangements to promote technology transfer and cooperation? Do privatized companies invest less in university-based research? Is this related to IP issues?

Notes

- 1 The proceedings and the presentations at the Re-Engineering the Partnership: Summit of the University-Industry Congress at the National Academies in Washington D.C. (April 25, 2006) – available at <http://www7.nationalacademies.org/guirr/Meetings.html> – offer a clear picture of the concerns related to the role of intellectual property in the current university-industry relations in the US. Moreover, Stanley Williams, HP Corporation, testimony to Senate, September 17, 2002 complained: “US-based corporations have become so disheartened and disgusted with the situation – i.e., negotiating IPRs with US universities – they are now working with foreign universities, especially the elite institutions in France, Russia and China, which are more than willing to offer extremely favourable intellectual property terms.”
- 2 Providing an extremely detailed description of the different rules and norms that regulate technology transfer in different countries is also beyond the reach of this paper.
- 3 As in Brazil, in the debate related to the new IP Law N. 10.973, December 2, 2004.
- 4 Interestingly, this is the same logic that pushed US universities to have their first patents in the 1920s and 1930s: to obtain control of the technology from “patent pirates” and to preserve the reputation of universities and PROs from its use against the public interest (Mowery and Sampat (2001a)).
- 5 The extreme example is provided by the IP strategy of the Manhattan project that ultimately produced a large and aggressive patenting program on the processes to build the atomic bomb (Wellerstein (2008)).
- 6 <http://www.autm.net/surveys>.
- 7 For example it is important to mention the expansion of programs to support Public-Private Partnerships (e.g. RandE Tax Credit, NSF-ERC, IUCRC, Advanced Technology Program-ATP) and the relaxation of antitrust enforcement to promote collaborative research (e.g. National Cooperative Research Act (NCRA) of 1984 followed by the National Cooperative Research and Production Act (NCRPA) of 1993).
- 8 Patent citations delimit the scope of the property right and, at the EPO, are included in the patent document by the patent examiners who draft their reports, trying to include all the technically relevant information within a minimum number of citations (EPO, 2005). Recent evidence strongly supports their use to measure the value of innovations and to track knowledge flows from the cited to the citing inventors or applicants (Trajtenberg (1990), Trajtenberg *et al* (1997), Jaffe and Trajtenberg (1996), Jaffe *et al* (2000), Jaffe *et al* (1993), Harhoff *et al* (1999), Hall *et al* (2005)).
- 9 Nelson and Merges (1990) and Murray and Stern (2007b) provide an interesting set of examples.
- 10 Shapiro’s (2000) analysis of the patent thickets raises a similar issue.
- 11 There are many papers that explore the relationship between patenting and publishing in different sectors and countries. Czarnitzki *et al* (2006) discovered a positive relationship between publishing output and patenting for more than 3,000 German professors active in a range of science fields. Goldfarb *et al* (2006) studied the behavior of 57 scientists in electrical engineering and 15 in biochemistry at Stanford and found complementarity. The effects of the inventive activity on publications is stronger in biochemistry. Van Looy *et al* (2006) found that 32 inventors of EPO patents at Louvain University were more productive than a sample of non-inventors in the same field and they did not observe substitution between patenting and publishing over time.

- 12 Belenzon and Shankerman (2007) and Siegel *et al* (2003) also suggested that the most critical organizational factors for success in licensing are the reward systems and compensation practices for faculty and TTO staff.
- 13 ProTon Europe has been supported as a thematic network under the 5th Framework Program of the European Commission. At the end of July 2006, ProTon Europe had more than 230 direct members employing about 2,000 knowledge-transfer professionals. ProTon Europe and its partner national associations cover more than 500 transfer offices in Europe.
- 14 http://www.conacyt.mx/SNI/Index_SNI.html

References

- Agrawal, A., 'Engaging the Inventor: Exploring Licensing Strategies for University Inventions and the Role of Latent Knowledge', *Strategic Management Journal*, 27: 1, 63-79, 2006.
- Agrawal, A. and I. Cockburn, 'The Anchor Tenant Hypothesis: Exploring the Role of Large, Local, R&D-Intensive Firms in Regional Innovation Systems', *International Journal of Industrial Organization*, 21 (9), 1227-1253, 2003.
- Agrawal, A. and R. Henderson, 'Putting Patents in Context: Exploring Knowledge Transfer from MIT', *Management Science*, 48: 1, 44-60, 2002.
- American Association for the Advancement of Science (AAAS), 'The Protection by Patents of Scientific Discoveries: Report of the Committee on Patents, Copyrights, and Trademarks', *Science Press*, New York, 1934.
- Arora, A., A. Fosfuri and A. Gambardella, *Markets for Technology: The Economics of Innovation and Corporate Strategy*, The MIT Press, Cambridge, US, 2001.
- Arrow, K., 'Economic Welfare and the Allocation of Resources for Invention', in *The Rate and Direction of Inventive Activity*, R. Nelson (ed.), Princeton University Press, 609-625, 1962.
- Arundel, A. and C. Bordoy, 'The 2006 ASTP Survey', Association of European Science and Technology Transfer Professionals (ASTP), The Hague, Netherlands, June 14, 2006.
- Association of University Technology Managers (AUTM), 'Annual Survey', 2004 and 2005.
- Azoulay, P., W.W. Ding and T.E. Stuart, 'The Impact of Academic Patenting on (Public) Research Output', *NBER Working Paper N. 11917*, National Bureau of Economic Research, 2006.
- Azoulay, P., W.W. Ding and T.E. Stuart, 'The Determinants of Faculty Patenting Behavior: Demographics or Opportunities?' *Journal of Economic Behavior and Organization*, Vol. 63, issue 4, pages 599-623, 2007.
- Bacchiocchi, E. and F. Montobbio, 'Knowledge Diffusion from University and Public Research. A Comparison between US, Japan and Europe using Patent Citations', *Journal of Technology Transfer*, forthcoming 2007.
- Bach, L., N. Carayol and P. Llerena, 'Assessing the Performance of French University Transfer Offices: Preliminary Results', mimeo, 2007.
- Balconi, M., S. Breschi and F. Lissoni, 'Networks of Inventors and the Role of Academia: an Exploration of Italian Patent Data', *Research Policy*, 33, pp. 127-145, 2004.
- Baldini, N., R. Grimaldi and M. Sobrero, 'Institutional Changes and the Commercialization of Academic Knowledge: A Study of Italian Universities' Patenting Activities between 1965 and 2002', *Research Policy*, 35 (4), pp. 518-532, 2006.
- Belenzon, S. and M. Shankerman, 'Harnessing Success: Determinants of University Technology Licensing Performance', *Discussion Paper N. 6120*, CEPR, 2007.
- Blumenthal, D., N. Causino, E. Campbell and K. Louis, 'Relationships between Academic Institutions and Industry in the Life Sciences: An Industry Survey', *New England Journal of Medicine*, 334, 368-374, 1996.
- Breschi, S., F. Lissoni and F. Montobbio, 'From Publishing to Patenting: Do Productive Scientists turn into Academic Inventors?' *Revue d'Economie Industrielle*, n° 110, 2ème trimestre, 2005.

- Breschi, S., F. Lissoni and F. Montobbio, 'University Patenting and Scientific Productivity. A Quantitative Study of Italian Academic Inventors', *Working Paper N. 189*, CESPRI, available at http://www.cespri.unibocconi.it/folder.php?id_folder=1917andtdbn=albero, 2006.
- Breschi, S., F. Lissoni and F. Montobbio, 'The Scientific Productivity of Academic Inventors: New Evidence from Italian Data', *Economics of Innovation and New Technology*, Vol. 16, Issue 2, 2007.
- Calderini, M., C. Franzoni and A. Vezzulli, 'If Star Scientists do not Patent: The Effect of Productivity, Basicness and Impact on the Decision to Patent in the Academic World', *Research Policy*, forthcoming 2007.
- Campbell, E., B. Clarridge, M. Gokhale, L. Birenbaum, S. Hilgartner, N. Holtzman and D. Blumenthal, 'Data Withholding in Academic Genetics: Evidence from a National Survey', *Journal of the American Medical Association*, 287: 4, 473-479, 2002.
- Campos, A., P. D'Este and A. Geuna, 'Critical Appraisal of the Current Understanding of the Linkages between University and Industry', mimeo, SPRU, University of Sussex, 2007.
- Chapple, W., A. Lockett, D.S. Siegel and M. Wright, 'Assessing the Relative Performance of University TTOs in the UK', *Research Policy*, 34: 369-384, 2005.
- Cockburn, I. and R. Henderson, 'Publicly Funded Science and the Productivity of the Pharmaceutical Industry', in *Innovation Policy and the Economy*, A. Jaffe, J. Lerner and S. Stern (eds.), Volume 1, pp. 1-34, MIT Press for the National Bureau of Economic Research, Cambridge, US, 2001.
- Cockburn, I. and R. Henderson, 'Absorptive Capacity, Coauthoring Behavior, and the Organization of Research in Drug Discovery', *Journal of Industrial Economics*, 46 (2), pp. 157-182, 1998.
- Cohen, W.M., R.R. Nelson and J.P. Walsh, 'Protecting their Intellectual Assets: Appropriability Conditions and why US Manufacturing Firms Patent (or Not)', *NBER Working Paper N. 7552*, National Bureau of Economic Research, 2000.
- Cohen, W.M., R.R. Nelson and J.P. Walsh, 'Links and Impacts: The Influence of Public Research on Industrial R&D', *Management Science*, Vol. 48, N. 1, pp. 1-23, January 2002.
- Cohen, W., 'Patents and Appropriation: Concerns and Evidence', *Journal of Technology Transfer*, 30: 1-2, 57-71, 2005.
- Colyvas, J., M. Crow, A. Gelijns, R. Mazzoleni, R. Nelson, N. Rosenberg and B. Sampat, 'How do University Inventions get into Practice?' *Management Science*, 48: 1, 61-72, 2002.
- Conti, A., P. Gaule and D. Foray, 'Academic Licensing: a European Study', *Working Paper 2007-001*, CEMI, 2007.
- Crespi, G., A. Geuna and B. Verspagen, 'University IPRs and Knowledge Transfer. Is the IPR Ownership Model More Efficient?' mimeo, SPRU, University of Sussex, 2006.
- Czarnitzki, D., W. Glänzel and K. Hussinger, 'An Empirical Assessment of Co-Activity Among German Professors', *Discussion Paper N. 06-080*, ZEW, 2006.
- David, P., 'Intellectual Property Institutions and the Panda's Thumb: Patents, Copyright, and Trade Secrets in Economic Theory and History', in *Global Dimensions of Intellectual Property Rights in Science and Technology*, M.B. Wallerstein, M.E. Mogege and R.A. Schoen (eds.), National Academy Press Ch. 2, National Research Council, 1993.
- David, P.A., 'Common Agency Contracting and the Emergence of "Open Science" Institutions', Papers and Proceedings of the Hundred and Tenth Annual Meeting of the American Economic Association, *The American Economic Review*, Vol. 88, N. 2, pp. 15-21, May 1998.
- Di Gregorio, D. and S. Shane, 'Why Do Some Universities Generate More Start-Ups than Others?', *Research Policy*, 32: 2, 209-227, 2003.
- Eisenberg, R., 'Public Research and Private Development: Patents and Technology Transfer in Government Sponsored Research', *Virginia Law Review*, 1663-1727, 1996.
- Elfenbein, D., 'Publications, Patents, and the Market for University Inventions', *Journal of Economic Behavior and Organization*, forthcoming 2007.

- Fabrizio, K.R., 'University Patenting and the Pace of Industrial Innovation', *Industrial and Corporate Change*, 16/4, forthcoming 2007.
- Gering, T. and U. Schmoch, 'Management of Intellectual Assets by German Public Research Organizations', in *Turning Science into Business: Patenting and Licensing at Public Research Organizations*, OECD, Ch. 3. 169-188, Paris, 2003.
- Geuna, A. and L. Nesta, 'University Patenting and its Effects on Academic Research. The Emerging European Evidence', *Research Policy*, 35(6), 790-807, 2006.
- Giuri, P., M. Mariani, S. Brusoni, G. Crespi, D. Francoz, A. Gambardella, W. Garcia-Fontes, A. Geuna, R. Gonzales, D. Harhoff, K. Hoisl, C. Le Bas, A. Luzzi, L. Magazzini, L. Nesta, O. Nomaler, N. Palomas, P. Patel, M. Romanelli and B. Verspagen, 'Inventors and Invention Processes in Europe: Results from the PatVal-EU Survey', *Research Policy*, V. 36 (8), 2007.
- Goldfarb, B., G. Marshke and A. Smith, 'Scholarship and Inventive Activity in the University: Complements or Substitutes?' mimeo, 2006.
- Hall, B.H., A.B. Jaffe and M. Trajtenberg, 'Market Value and Patent Citations', *The RAND Journal of Economics*, 36, 1, pp. 16-38, 2005.
- Hall, B., A. Jaffe and M. Trajtenberg, 'The NBER Patent Citation Data File: Lessons, Insights, and Methodological Tools', *Working Paper 8498*, National Bureau of Economic Research, Cambridge, US, 2001.
- Harhoff, D., F. Narin, F.M. Scherer and K. Vopel, 'Citation Frequency and the Value of Patented Inventions', *The Review of Economics and Statistics*, 81 (3), pp. 511-515, 1999.
- Heller, M. and R. Eisenberg, 'Can Patents Deter Innovation? The Anti-Commons in Biomedical Research', *Science*, 280: 5364, 698-701, 1998.
- Henderson, R., A.B. Jaffe and M. Trajtenberg, 'Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965-1988', *Review of Economics and Statistics*, 80 (1): 119-127, 1998.
- Huang, M.F., 'Golden Helix or Tangled Web: Assessing the Effect of Gene Patents on the Use of Genetic Knowledge', mimeo, 2007.
- Jaffe, A.B. and M. Trajtenberg, 'Flow of Knowledge from Universities and Federal Laboratories: Modelling the Flow of Patent Citations Over Time and Across Institutional and Geographic Boundaries', *Proceedings of the National Academy of Sciences* 93: 12671-12677, 1996.
- Jaffe, A.B., M. Trajtenberg and M.S. Fogarty, 'Knowledge Spillovers and Patent Citations: Evidence from a Survey of Inventors', *The American Economic Review*, Vol. 90, N. 2, Papers and Proceedings, pp. 215-218, 2000.
- Jaffe, A.B., M. Trajtenberg and R. Henderson, 'Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations', *The Quarterly Journal of Economics*, 108, 577-598, 1993.
- Jensen, R. and M. Thursby, 'Proofs and Prototypes for Sale: The Licensing of University Inventions', *American Economic Review*, 91: 1, 240-259, 2001.
- Kitch, E., 'The Nature and Function of the Patent System', *Journal of Law and Economics*, 20: 2, 265-290, 1977.
- Lach, S. and M. Schankerman, 'Royalty Sharing and Technology Licensing in Universities', *Journal of the European Economic Association*, MIT Press, vol. 2 (2-3), pages 252-264, 04/05, 2004.
- Lach, S. and M. Schankerman, 'Incentives and Innovation in Universities', *Rand Journal of Economics*, forthcoming 2008.
- Lissoni, F., B. Sanditov and G. Tarasconi, 'The Keins Database on Academic Inventors: Methodology and Contents', *Working Paper N. 181*, CESPRI, available at http://www.cespri.unibocconi.it/folder.php?vedi=3507&dtbn=alberoandid_folder=1917, 2006.
- Lissoni, F. and D. Foray, 'University Research and Public-Private Interaction', in *Handbook of Economics of Technical Change*, B.H. Hall and N. Rosenberg (eds.), forthcoming 2008.
- Lissoni, F., P. Llerena, M. McKelvey and B. Sanditov, 'Academic Patenting in Europe: New Evidence from the KEINS Database', *Working Paper N. 202*, CESPRI, available at http://www.cespri.unibocconi.it/folder.php?vedi=3903&dtbn=alberoandid_folder=1917, 2007.

- Mansfield, E. and J.Y. Lee, 'The Modern University: Contributor to Industrial Innovation and Recipient of Industrial R&D Support', *Research Policy*, 25 (7), pp. 1047–1058, 1996.
- Mansfield, E., 'Academic Research and Industrial Innovation', *Research Policy*, 20 (1), pp. 1–12, 1991.
- Mansfield, E., 'Academic Research underlying Industrial innovations: Sources, Characteristics, and Financing', *Review of Economics and Statistics*, 77 (1), pp. 55–65, 1995.
- Mansfield, E., 'Academic Research and Industrial Innovation: An Update of Empirical Findings', *Research Policy*, 26, pp. 773–776, 1998.
- Markiewicz, K.R. and A. Di Minin, 'Commercializing the Laboratory: The Relationship Between Faculty Patenting and Publishing', mimeo, 2005.
- Mazzoleni, R. and R. Nelson, 'The Benefit and Costs of Strong Patent Protection: A Contribution to the Current Debate', *Research Policy*, 27: 273-284, 1998.
- Merges, R. and R.R. Nelson, 'On the Complex Economics of Patent Scope', *Columbia Law Review*, 90: 4, 839-916, 1990.
- Merrill, S.A., R.C. Levin and M.B. Myers (eds.), *A Patent System For The 21st Century*, Committee on Intellectual Property Rights in the Knowledge-Based Economy, National Research Council of the National Academies, The National Academies Press, 2004.
- Merton, R.K., 'The Matthew Effect in Science. The Reward and Communication Systems of Science Reconsidered', *Science*, 159 (3810), pp. 56-63, 1968.
- Meyer, M., T. Sinilainen and J.T. Utecht, 'Toward Hybrid Triple Helix Indicators: A Study of University-Related Patents and a Survey of Academic Inventors', *Scientometrics*, 58, pp. 321-350, 2003.
- Mowery, D., R.R. Nelson, B.N. Sampat and A.A. Ziedonis, 'The Growth of Patenting and Licensing by US Universities: An Assessment of the Effects of the Bayh-Dole Act of 1980', *Research Policy*, 30 (2), pp. 99-119, 2001.
- Mowery, D., R.R. Nelson, B.N. Sampat and A.A. Ziedonis, *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer Before and After the Bayh-Dole Act in the United States*, Stanford University Press, 2004.
- Mowery, D. and B.N. Sampat, 'The Bayh-Dole Act of 1980 and University-Industry Technology Transfer: A Model for Other OECD Governments?' *Journal of Technology Transfer*, 30, pp. 115–127, 2005.
- Mowery, D. and A. Ziedonis, 'Academic Patent Quality and Quantity before and after the Bayh Dole Act in the United States', *Research Policy*, 31, 399-418, 2002.
- Mowery, D.C. and B.N. Sampat, 'Universities and Innovation', in *The Oxford Handbook of Innovation*, J. Fagerberg et al (eds.), Oxford University Press, 2004.
- Mowery, D., B. Sampat and A. Ziedonis, 'Learning to Patent: Institutional Experience, Learning, and the Characteristics of US University Patents after the Bayh-Dole Act, 1981-1992', *Management Science*, 48: 1, 73-89, 2002.
- Mowery, D.C. and B.N. Sampat, 'University Patents, Patent Policies, and Patent Policy Debates, 1925-1980', *Industrial and Corporate Change*, 10: 781-814, 2001a.
- Mowery, D. and B. Sampat, 'Patenting and Licensing University Inventions: Lessons from the History of the Research Corporation', *Industrial and Corporate Change*, 10: 317-355, 2001b.
- Murray, F. and S. Stern, 'Do Formal Intellectual Property Rights Hinder the Free Flow of Scientific Knowledge? An Empirical Test of the Anti-Commons Hypothesis', *Journal of Economic Behavior and Organization*, forthcoming 2007a.
- Murray, F. and S. Stern, 'When Ideas are not Free. The Impacts of Patents on Scientific Research', in *Innovation Policy and the Economy*, A. Jaffe, J. Lerner and S. Stern (eds.), V. 7, 2007b.
- National Science Board (NSB), 'Science and Engineering Indicators – 2004', National Science Foundation, Arlington, 2004.

- Nelson, R.R., 'The Simple Economics of Basic Scientific Research', *Journal of Political Economy*, 67: 297–306, 1959.
- Nelson, R.R., 'The Role of Knowledge in R&D Efficiency', *Quarterly Journal of Economics* 97(3): 453–70, 1982.
- Nelson, R.R., 'Observations on the Post-Bayh-Dole rise in Patenting at American Universities', *Journal of Technology Transfer*, 26(1–2): 13–19, 2001.
- OECD, *Turning Science into Business: Patenting and Licensing at Public Research Organizations*, OECD, Paris, 2003.
- Owen-Smith, J. and W. Powell, 'To Patent or Not: Faculty Decisions and Institutional Success at Technology Transfer', *Journal of Technology Transfer*, 26, 99–114, 2001.
- ProTon, 'The ProTon Europe 2005. Annual Survey Report', available at <http://www.protoneurope.org>, 2007.
- Rapoport, A., 'Where has the Money Gone? Declining Industrial Support of Academic R&D', National Science Foundation, available at <http://www.nsf.gov/statistics/infbrief/nsf06328/nsf06328.pdf>, 2006.
- Rosell, C. and A. Agrawal, 'University Patenting: Estimating the Diminishing Breadth of Knowledge Diffusion and Consumption', mimeo, 2006.
- Rosenberg, N. and R.R. Nelson, 'American Universities and Technical Advance in Industry', *Research Policy*, Vol. 23, N. 3, pp. 323, 1994.
- Rothaermel, F.T., S. Agung and L. Jiang, 'University Entrepreneurship: A Taxonomy of the Literature', *Industrial and Corporate Change*, 16, forthcoming 2007.
- Sampat, B.N., 'Patenting and US Academic Research in the 20th Century: The World Before and After Bayh-Dole', *Research Policy*, 35(6), pp. 772–789, 2006.
- Sampat, B., 'Recent Changes in Patent Policy and the "Privatization" of Knowledge', in *Knowledge Flows and Knowledge Collectives: Understanding the Role of Science and Technology Policies in Development*, CSPO (ed.), available at <http://www.csपो.οrg/home/csपोideas/00001.htm>, 2003.
- Sampat, B., D. Mowery and A. Ziedonis, 'Changes in University Patent Quality After the Bayh-Dole Act: a Re-Examination', *International Journal of Industrial Organization*, 21, 1371–1390, 2003.
- Sapsalis, E., B. Van Pottelsberghe de la Potterie and R. Navon, 'Academic vs. Industry Patenting: an In-depth Analysis of What Determines Patent Value', *Research Policy*, 35 (10), 1631–1645, 2006.
- Sargossi, S. and B. Van Pottelsberghe de la Potterie, 'What Patent Data Reveals about Universities – The Case of Belgium', *Journal of Technology Transfer*, 28(1), 47–51, 2003.
- Schmiemann, M. and J.-N. Durvy, 'New Approaches to Technology Transfer from Publicly Funded Research', *Journal of Technology Transfer*, 28, 9–15, 2003.
- Shane, S. and D. Somaya, 'The Effect of Patent Litigation on University Licensing Efforts', *Journal of Economic Behavior and Organization*, forthcoming 2007.
- Siegel, D.S., D. Waldman and A. Link, 'Assessing the Impact of Organizational Practices on the Relative Productivity of University Technology Transfer Offices: An Exploratory Study', *Research Policy*, Vol. 32 (1), pages 27–48, 2003.
- Stephan, P.E., S. Gurmu, A.J. Sumell and G. Black, 'Who's Patenting in the University? Evidence from a Survey of Doctorate Recipients', *Economics of Innovation and New Technology*, 16/2, pp. 71–99, 2007.
- Stuart, T.E. and W.W. Ding, 'When Do Scientists Become Entrepreneurs? The Social Structural Antecedents of Commercial Activity in the Academic Life Sciences', *American Journal of Sociology*, 112, pp. 97–144, 2006.
- Thursby, J.G., R.A. Jensen and M.C. Thursby, 'Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major US Universities', *Journal of Technology Transfer*, 26 (1–2): 59–70, 2001.
- Thursby, J.G. and S. Kemp, 'Growth and Productive Efficiency of University Intellectual Property Licensing', *Research Policy*, 31 (1): 109–124, 2002.

- Thursby, J.G. and M.C. Thursby, 'Who is Selling the Ivory Tower? Sources of Growth in University Licensing', *Management Science*, 48 (1): 90–104, 2002.
- Thursby, J.G. and M.C. Thursby, 'Are Faculties Critical? Their Role in University-Industry Licensing', *Contemporary Economic Policy*, 22: 162–178, 2004.
- Thursby J., A. Fuller and M. Thursby, 'US Faculty Patenting: Inside and Outside the University', *NBER Working Paper N. 13256*, National Business Economic Research, 2007.
- Thursby, J. and M. Thursby, 'Knowledge Creation and Diffusion of Public Science with Intellectual Property Rights', forthcoming in *Intellectual Property Rights and Technical Changes*, K. Maskus (ed.), Frontiers in Economics Series, Vol. 2, Elsevier Ltd., March 2007.
- Trajtenberg, M., 'A Penny for Your Quotes: Patent Citations and the Value of Innovations', *The RAND Journal of Economics*, Vol. 21, N. 1., pp. 172-187, 1990.
- Trajtenberg, M., R. Henderson and A. Jaffe, 'University vs. Corporate Patents: A Window on the Basicness of Invention', *Economics of Innovation and New Technology*, 5, 19-50, 1997.
- US Patent and Trademark Office, 'US Colleges and Universities-Utility Patent Grants, Calendar Years 1969-2000', 2002.
- Valentin, F. and R.L. Jensen, 'Effects on Academia-Industry Collaboration of Extending University Property Rights', *Journal of Technology Transfer*, 32, 251-276, 2007.
- Van Looy, B., J. Callaert and K. Debackere, 'Publication and Patent Behaviour of Academic Researchers: Conflicting, Reinforcing or Merely Co-Existing?' *Research Policy*, 35, 596-609, 2006.
- Verspagen B., 'University Research, Intellectual Property Rights and European Innovation Systems', *Journal of Economic Surveys*, 20/4, pp. 607-632, 2006.
- Walsh J.P., A. Arora and W.M. Cohen, 'Effects of Research Tool Patents and Licensing on Biomedical Innovation', in *Patents in the Knowledge-Based Economy*, W.M. Cohen and S.A. Merrill (eds.), The National Academies Press, Washington, D.C., 2003.
- Walsh, J., C. Cho and W. Cohen, 'Patents, Material Transfers and Access to Research Inputs in Biomedical Research', Report to the National Academy of Sciences' Committee on Intellectual Property Rights in Genomic and Protein-Related Inventions, 2005.
- Wellerstein, A., 'Patenting the Bomb: Nuclear Weapons, Intellectual Property, and Technological Control', *ISIS*, forthcoming 2008.
- Zucker, L., M. Darby and M. Brewer, 'Intellectual Human Capital and the Birth of US Biotechnology Enterprises', *American Economic Review*, 88 (1), 290–305, 1998.

COMMENTS ON INTELLECTUAL PROPERTY RIGHTS AND KNOWLEDGE TRANSFER FROM PUBLIC RESEARCH TO INDUSTRY IN THE US AND EUROPE: WHICH LESSONS FOR INNOVATION SYSTEMS IN DEVELOPING COUNTRIES?

ALBERT G. HU

Professor Montobbio has produced a very exhaustive survey of the literature on the role that IPRs play in the process of knowledge transfer from public research institutions to industry in the US and Europe. Public research institutions, private industry, and the institutions that connect the two to channel knowledge transfer from the former to the latter, are critical components of the national innovation systems in developed countries. The dynamic interaction between these institutions has been instrumental in the success of industries such as biotechnology.

To help focus my comments, I will first summarize what we have learnt from Professor Montobbio's comprehensive survey. First, the fundamental incentive structure of university researchers in the OECD countries does not seem to have changed. The best minds of science and technology are still primarily occupied with conducting research, the results of which end up in the public domain. This is perhaps heartening to those of us who may worry that the heightened economic incentives promised by IPR may lure researchers away from the cutting edge of science. Second, universities in the US are clearly trying to appropriate a larger share of the social returns to their research discoveries: the propensity to patent has gone up in US universities. Lastly, despite the wealth of data and information available and processed, we know very little about the impact of this higher appropriability on basic and applied research.

Cumulative Research: an Organizing a Conceptual Framework

The literature is quite diverse and somewhat fragmented. As an organizational and presentational suggestion, it is useful to have a conceptual framework to tie together the discussion of the economic issues involved in various parts of this literature. The model of cumulative research (Green and Scotchmer (1995), Scotchmer (1996)) is useful in analyzing the implications of the design of IPR regimes when research takes place sequentially and inter-temporal knowledge spillovers complicate the division of profits between the innovators. For example, it would seem to be most productive to situate the issue of whether and how IPRs should be granted to university and public research discoveries within the cumulative research framework. Having such a framework – I am not suggesting the inclusion of a theoretical model but just couching the discussion of the economic issues in such terms – would help to clarify what the underlying fundamental tradeoffs are.

Public Interest Justification of IPRs in Public Research

The survey highlighted a public interest justification of IPRs in public research. The basic argument is that granting IPRs to public research discoveries is necessary as a way to prevent them from being appropriated and monopolized by private agents. I find this argument rather tenuous. It is basically suggesting that the way to overcome the evil of a monopoly is to create

* Associate Professor, Department of Economics, National University of Singapore, Singapore. The views expressed in these comments are those of the author and do not necessarily represent those of WIPO.

another, albeit perhaps a benign one. But if society's concern is the misappropriation of research discoveries in the public domain by private parties, a more cost-effective solution may be to shore up the patent office, since such a patent should not have been granted in the first place.

Robustness of the Findings of this Literature

The survey could benefit from a more critical assessment of the robustness of the findings reported in the literature. For example, in assessing the impact of IPRs on university research, most of the studies have focused on biotechnology and other life sciences. To what extent can the results be generalized to other sectors? Concurrent to the passing of Bayh-Dole Act, there have been changes in patent laws that expanded the scope of patent protection, e.g. genes; new technology opportunities have also emerged in life sciences; government support of scientific research has also demonstrated a bias in favor of life sciences. Have these confounding factors been properly accounted for?

Professor Montobbio has given some very interesting comparisons of the mode of commercialization of university research between the US and Europe. For example, many university patents in Europe are owned by private companies rather than the universities themselves. To what extent should we expect this different IPR arrangement to affect commercialization of university research and the incentive structure of university researchers? Are there other institutions involved in the process of commercializing university research in Europe?

Implications for Developing Countries

Developed countries' experience in using IPRs to promote commercialization of public research generates useful lessons for developing countries. The increasing propensity to grant IPRs to public research in developed countries is likely to lead to a higher cost of conducting research for public and university researchers in developing countries. There could be a higher cost of research materials or limited access to information and data. Another implication is that, given the nature of technological change in developing countries, the social cost of a close relationship between public research institutions and the private sector could be lower than that in developed countries. The primary function of universities in developing countries is education and training, whereas the dominant mode of technological change for most developing country firms is learning and adopting existing technology. As a result, policy-makers in developing countries would face a somewhat different tradeoff in welfare calculations in designing policies to encourage collaboration between public research institutions and private enterprises. Lastly, the experience of the newly industrialized Asian economies shows that public-private collaboration does not necessarily involve IPR as an incentivizing mechanism. For example, in one country, the Industrial Technology Research Institute, a public research institution, has largely played the role of identifying technology that is appropriate for adoption by domestic firms and providing the technical support to ensure its successful adoption. Many of the domestic technology giants today have been spin-offs from the Industrial Technology Research Institutes. Future research that examines how such institutional arrangement has promoted public-private collaboration without IPRs would be useful.

Restructuring China's Government Research Institutions

To provide a developing country perspective on this issue, I offer a brief account of the Chinese government's effort to restructure its large number of public research institutions (Hu and Jefferson (2008)). China's public research institutions were largely built in the central plan era

following the public research model of the former Soviet Union. Most of these institutes had over time become insulated from the increasingly market-driven economy. In the mid-1990s, the Chinese government started a gradual process of restructuring these research institutes with the aim of achieving an allocation of science and technology resources that could better serve the goal of economic development.

By 1999, there were 5,500 government research institutes. Between then and 2004, over 1,400 of them had been restructured with the objective of reorienting their research towards applied and commercializable research. Some of these were turned into for-profit consultancies and some acquired by or merged into enterprises. For most of the remaining institutes, the government started substantially reducing direct funding. It became necessary for the institutes to find their own resources to maintain their research programs and for expansion. High-powered incentive schemes have been implemented in these institutes. For example, based on information collected from an interview with a research institute under the Chinese Academy of Agricultural Sciences, as much as one-third of licensing revenues of an innovation can go to the individual inventors. However, to maintain and enhance the rigor of basic research, the central government has increased funding to the 98 research institutes under the Chinese Academy of Sciences, which are China's elite research institutions. The incentive structure in these research institutes has remained largely publication-driven.

References

- Green, J.R. and Scotchmer, S., 'On the Division of Profit in Sequential Innovation', *Rand Journal of Economics*, 26: 20-33, 1995.
- Hu, A.G.Z. and G.H. Jefferson, 'Science and Technology in China', in *China's Great Economic Transformation*, T. Rawski and L. Brandt (eds.), Cambridge University Press, January 2008.
- Scotchmer, S., 'Protecting Early Innovators: Should Second-Generation Products be Patentable?' *Rand Journal of Economics*. 27 (2): 322-33, Summer 1996.

COMMENTS ON INTELLECTUAL PROPERTY RIGHTS AND KNOWLEDGE TRANSFER FROM PUBLIC RESEARCH TO INDUSTRY IN THE US AND EUROPE: WHICH LESSONS FOR INNOVATION SYSTEMS IN DEVELOPING COUNTRIES?

DOMINIQUE FORAY*

How best can public research contribute to industry's performance in innovation? An important point of departure is that research and invention are not innovation (David and Metcalfe (2008)). There is much more to the process of innovation than R&D. Achievement of innovation requires accessing and combining many more kinds of knowledge and capabilities than that summed up by the phrase "science and technology"; knowledge of markets and organizations and of the availability of factor inputs are key aspects of innovation, and this type of knowledge is not where a public research organization specializes. In the innovation business, a public research organization will never be better than a second-rank institution at best. This observation underscores the significance of the division of labor between public research and private firms that specialize in different tasks.

However, specialization, which is a good thing, is likely to create boundary problems that can impede interactions and connections between public research and the industry and service sectors. It is to these barriers, and the incentives to build connections that the paper by Professor Montobbio is devoted.

Better Connections and Interactions: a European Quest?

As stated by David and Metcalfe (2008), it is hard to find an innovation policy document from government, business or university sources that does not call for greater, wider or deeper interaction between private firms and universities. However, what is meant by interaction? The modes of connection are many and are used in different ways at different times. It seems that two very different and sometimes conflicting notions of connection or interaction are at stake:

- One – somewhat traditional – involves networks of people, collaborative funding of research programs and informal contacts. The recruitment of graduates in the business sector is part of this concept.
- The other sense of connection is about having universities better exploit the ideas developed there – through professional management of intellectual property, opening technology transfer offices and launching their own spin-offs and start ups.

While the first of these concepts of connection respects the division of labor between public research and business, the second seeks to transform it by bringing public research more fully into the market.

The movement to promote technology transfer from public research to industry via patent licensing in Europe was fueled by a widespread supposition that public research was dangerously disconnected from the processes of private sector innovation. The obvious contrast for

* Chair of Economics and Management of Innovation, Ecole Polytechnique Fédérale de Lausanne, Switzerland. The views expressed in these comments are those of the author and do not necessarily represent those of WIPO.

Europe was with the US research universities patenting and licensing frenetically. Professor Montobbio is right to claim that evidence of this kind has to be carefully scrutinized: the appearance of a lack of university patents in Europe must be understood to be a lack of university-owned patents – not indicative of any dearth of university invention and connection. This means that in Europe private firms, rather than universities, apply for patents at the end of collaborative projects. At the system level, it does not matter whether the patent applicant is the private firm or the university.

Overcoming Dilemmas

As summed up in Professor Montobbio's paper, a recurrent result from various surveys shows the critical role of faculty in successful technology transfer. This role is unquestionably important at the invention disclosure stage but obviously extends beyond it.

Successful relations with industry therefore require faculty efforts in the management of those relations (invention disclosure, identification of partners, contribution to the development of the technology) but that effort potentially diverts faculty from its role in academic research. However, Professor Montobbio rightly recalls that according to several case studies and surveys, the potential risk entailed by this dilemma seems to be smaller than expected: many studies have shown that a combination of scientific and commercialization activities appears at least feasible. A large base of evidence shows that entrepreneurial scientists are highly productive and that technology transfer activity does not divert from basic research.

The next logical question then is how they can manage to be both strong academic publishers and active entrepreneurs. Recent case studies (Callaert *et al* (2006)) highlight the importance of two mechanisms for multi-tasking in an efficient way:

- a high degree of topic overlap will make application and commercial development a joint product of basic research and create a potential for economies of scope;
- the size and composition of the team need to be aligned with the multi-task agenda.

However, it is always useful to point out that one cannot, from the evidence that is reviewed by Professor Montobbio, assume an answer to the fundamental question of system-level effects. The question is whether the split between those researchers who seek active involvement in commercial exploitation of their research findings and those who do not, is stable or unstable. This is a "system balance" problem, both for the institution, and for the collectivity of institutions. It is here that the central administration's attitude can be critical. Does it encourage the movement towards technological commercialization as a legitimate, indeed, institutionally rewarded activity for researchers? Is the administration simply permitting a drift in that direction, accommodating the requirements of industry in the licensing agreement that permit suppression of research findings from research publications? Or does it seek to create a reward structure that is "neutral" insofar as it does not allow the relative earnings from research of those who are equally productive but choose not to involve themselves directly with commercialization to increasingly lag behind those of their entrepreneurial colleagues?

Manipulating Incentives: from a "By-Product Economy" to a "Joint Product Economy"

As in any other economic activities, people respond to incentives. The decision by a faculty member regarding a potential involvement in activities dealing with knowledge transfer and development in industries is obviously based on considering the various costs and benefits of this activity as compared with the costs and benefits of other more traditional academic tasks.

A decade ago the dominant incentive structures for faculty created a strong imbalance in favor of traditional academic missions, fundamental research and education. This was satisfactory as these two missions are those that potentially generate the two fundamental kinds of spillovers that benefit industry. On the other hand, all activities related to development, industrial problem-solving and commercialization had the status of some sort of by-product. In such a context, the sense of priorities and hierarchies between different objectives (for faculty) was not lost: it was crucial to allocate the greater part of resources to basic research, thus producing new ideas to fuel technology transfer and to be published in important journals to attract good students who would then help the faculty to manage their multitask agenda. If this is not done, not only is basic research at risk but also, in the long term, faculty and their research teams will be unable to deliver anything useful to industry. In this by-product regime, compromises and tradeoffs are easier to achieve since there is a clear mission priority and academic missions are maintained.

In such a by-product economy, however, one can expect a lot of lost opportunities, some of the best inventions may not be disclosed; the most productive researchers are less likely to want to take the time to disclose inventions, and there is much less work on further development.

Another argument against keeping this by-product economy is that open science is inefficient in product development (muted response to signals of market demand, excessive resources devoted to communication, sub-optimal scale, weak incentives to work on “boring” projects) and a re-organized science could do a better job. Along these lines, inducing faculty to disclose inventions and get involved in further development is therefore a critical issue that must be addressed.

In a sense, the challenge should be to shift university research from a situation in which technology transfer and commercialization are seen as by-products to a situation in which these functions acquire a new higher status, that of a joint product. We refer to the definition of these concepts in accounting: joint products are two products that are simultaneously yielded from one shared cost and they have comparably high (sales) value. By-products for their part are produced along with a main product. The latter constitutes the major portion of the total (sales) value. By-products have a considerably lower (sales) value than these main products. We can apply these terms to apply to basic research and technological applications, substituting “perceived value to the academic professor” for sales value.

Such a shift, therefore, involves increasing the “perceived value to the academic professor” of development and commercialization, and this requires creating a new balance in the incentive structure. Lach and Schankerman (2004) showed that the design of incentives can have a real effect on disclosure and commercialization in universities. They exploited cross-university variations in the share of licensing royalties received by academic scientists to estimate the role of monetary incentives. They showed that academic research and inventive activity in universities do respond to variations in inventors’ royalty shares: the incentive effect induces greater effort by scientists toward invention disclosure, or it works through sorting of scientists across universities. Incentives do matter.

Increasing monetary incentives to encourage faculty toward more disclosure (and more involvement in further development) may have an effect on faculty’s motivations to be involved in technology transfer. However, this strategy also entails risk. As already mentioned, we know from multi-task problems in principal-agent theory that when output is generated by workers exerting effort on two or more different tasks, there is a need to optimally balance incentives across these tasks. Otherwise, people will devote too much effort to those tasks that provide them with the highest marginal return.

Since the long-term level of research productivity depends on the level of effort devoted to basic research, it is important to avoid any incentive bias. An important issue is, for example, that any change in incentive structures (to increase effort toward disclosure and commercialization) has to be designed in an integrative and concerted way with the bodies in charge of academic incentives.

References

- Callaert, J., B. Van Loy, D. Foray and K. Debackere, 'Combining the Production and the Valorization of Academic Research: A Qualitative Investigation of Enacted Mechanisms', KU Leuven and EPFL, 2006.
- David, P. and S. Metcalfe, 'Universities and Public Research Organizations in the ERA', Report for the "Knowledge for Growth" Expert Group, EC (DG-Research), 2008.
- Lach, S. and M. Schankerman, 'Royalty Sharing and Technology Licensing in Universities', *Journal of the European Economic Association*, MIT Press, 2004.
- Montobbio, F., 'Intellectual Property Rights and Knowledge Transfer from Public Research to Industry in US and Europe: which Lessons for Innovation Systems in Developing Countries?' this publication.