Intellectual Property Rights and Knowledge Transfer from Public Research to Industry in US and Europe: which Lessons for Innovation Systems in Developing Countries?

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1. Introduction.

The issue of intellectual property (IP) and knowledge transfer from universities and public research organizations (PROs) stirs heated debate and is object of strong policy interest in developed and developing countries. 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 the standards of living. The issue is complex because universities and PROs have a broad and changing role in national innovation systems that expands from general education to basic research (Lissoni and Foray, 2008; Mowery and Sampat, 2004; Rosenberg and Nelson, 1994). Moreover IP is only one of many channels through which knowledge flows between universities, PROs and industry, IP regulations cover many delicate issues (e.g. subject matter, type of licenses, research exemptions) which may affect the 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 base 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 IP for technology transfer.

Patenting and licensing from universities and public research centres are a particularly important phenomena in biotechnology, drugs and medical science, licensing revenues reach in the US 1.6$ billions 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 for Emory University and the 40% of it for the three Emory inventors). Beyond these (very much hyped) success stories the issue still rages 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, 12/14/2002). At the same time concerns are expressed by many authors, in particular in the field of biomedicine, that claim that the rule of open science are 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 Economist statement 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 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 IP and some authors interpret the recent decline in university funding from industry as a proof of the increased difficulties in the negotiations of sponsored research agreements, generated in particular by disagreements over the treatment of IP[1] (Rapoport, 2006).

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

Also, other surveys are available that cover many aspects of this literature that is growing remarkably in recent years. In particular Geuna and Nesta (2006) and Verspagen (2006) deal with the economic literature on university patents and take an European perspective, Thursby and Thursby (2007) survey both models and empirical evidence on university patenting and licensing. Almost all the evidence they discuss come from the US. Roathermel et al. (2007) provide and extensive review on IP and entrepreneurship. Foray and Lissoni (2008) and Mowery and Sampat (2004) discuss the broader role of universities in the national innovation system. Campos et al. (2007) extends the analysis to developing countries.

This paper is organized as follows. In Section 2 I discuss the main economic justifications for IP in public research. In Section 3 I summarize the debate on university patenting in US and 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 the technological transfer offices and the determinants of their productivity is discussed. Section 6 wraps up and discuss 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

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[1] The Proceedings and the presentations at the Re-Engineering the Partnership: Summit of the University-Industry Congress at the National academies in Washington DC (25 April 2006 - available at http://www7.nationalacademies.org/guirr/Meetings.html) offer a clear picture of the concerns related to the role of IP in the current university-industry relations in the US. Moreover Stanley Williams, HP Corporation, testimony to Senate, Sept 17, 2002 complained: "US-based corporations have become so disheartened and disgusted with the situation [i.e., negotiating IP rights 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] Also providing an extremely detailed description of the different rules and norms that regulate technology transfer in different countries is beyond the reach of this paper.

universities and public research organizations. Finally I discuss potential areas of additional research in developing countries.

2. The economic justification of IP from public research

The basic economic justification for university patenting is based on the idea that it facilitates the commercialization of the discoveries produced by the scientific research (Arora et al. 2001; Kitch, 1977). Thanks to well defined intellectual property rights, firms or individuals have the incentives to invest *additional* R&D in the 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 university 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. Secondly 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 university and PROs patents is not the incentive to invent or disclose, but is 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 that are necessary to develop the invention and, finally, that there is no possibility to have 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 IP 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 favour of university patenting in advanced countries, it is not the only one. In many developing countries[3] the emphasis is not only on using IP to promote cooperation and technology transfer between university and industry but also on preserving the public control on university and PROs generated inventions. 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 have to 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 increased low quality of patents in the United States 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. Merril 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 causes concerns related to the generated barriers to entry in some research fields.

The use of IP 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 keeping key technologies under control an to avoid knowledge spillovers. In this case universities and public research organisations have to control that scientists and public servants do not appropriate and do not disclose independently the relevant knowledge[5].

In sum the starting point of this survey is that the economic justification of IP in university and PROs has two faces: commercialization and public interest. The former keeps on being underlined in the political discourse in developed countries, 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 faces of IP. Two dimensions may be particularly relevant in this respect: (1) the degree of exclusivity of licensing schemes and (2) the specific regulations on who is the owner of the university generated inventions. Firstly exclusive licenses are clearly needed for commercialization but may conflict with the second justification as long as it limits the use and diffusion of the discovery. Secondly in some European countries universities are not entitled to retain the intellectual property rights over university-based inventions. The IP is assigned by law to professors that therefore differ from a normal employee. As I shall discuss in Section 3.2, this could facilitate the transfer of technology from

[3] Like in Brazil in the debate related to the new IP law N. Law No 10.973, December 2nd, 2004.
[4] Interestingly this is the same logic that pushed US universities to have their first patents in the 1920s and 1930s: to have the control of the technology from 'patent pirates' and to preserve the reputation of universities and PROs from its use against the public interest (Mowery, 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).

individual inventors to companies. In any case if the public institution does not have the property right, this clashes with the idea of the IP are necessary to maintain the control over the technology.

This survey explores the empirical work in economics in which the two broad issues on 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 IP bringing into the market important and general inventions ? Is IP hindering the scientific development or shifting research towards a more applied nature ? Is IP efficient as a mean of technology transfer ? Are there institutional differences in the us of IP for public research? Which are the effects on technology transfer ? What is the role of TTOs ? What makes the TTOs efficient ? Which are the best licensing schemes ?

3. An overview of the debate about university patents in US and EU

The first way to look at the role of IP in technology transfer is, on the one side, to understand the historical evolution of the relation between IP institutions and public research and, on the other side, the changing attitude towards IP of universities and scientists over the past decades. In fact, a great amount 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 empirical research has tried to understand the university and PROs attitude towards IP 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 are 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 patents applications by the 191 respondents at the 2005 AUTM survey are 10,270. In parallel the ratio of academic patents - relative to the U.S. private and non-profit sectors - has also risen significantly from 1.48 percent in 1981 to a peak of 4.81 percent in 1999. During the same period there has been a rapid increase in the number of academic institutions receiving patents, although the

[6] http://www.autm.net/surveys/

distribution of patenting activity remains highly concentrated among few major research universities. Moreover in the period 1990 - 2000 there has been a remarkable increase of 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) start patenting back in the 1920s (Mowery, Sampat, 2001a). It's worthwhile noting how the issue of university patenting is addressed at the early stages of the US innovation system. In fact the motivations for university patenting reflect the two faces 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 published on Science in 1934 where it is clearly pointed out that university patents are needed in order to provide incentives for the development and commercialization of new products (AAAS, 1934). The AAAS expresses 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 university 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 university 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 20s and the 30s two issues are considered relevant by university administrators in particular in the public universities. The first issue is to justify the tax-payer money and patenting is considered a sign of a link between the research effort and knowledge that becomes economically valuable at the *local* level. Secondly, with the great depression, patenting and licensing may generate extra funds for the university (Mowery and Sampat, 2001a).

In the US after WWII there is a big shift in the attitude of universities toward IP that is the result of three interconnected issues. The first one is the increased amount of federal funds, in particular in biomedicine. More money to research increases also the scale of research activity and its output in US university. The second one is the related expansion of molecular biology in which IP is particular effective. Actually most of the growth in university patenting activity in the last decades comes from this scientific field. Finally during the 70s the perception by US of the risk of loosing the technological leadership is particularly strong and, accordingly, the necessity to protect domestic technology guides some policy intervention[7] (Mowery, Sampat, 2001b). In this context the Bay Dole Patent and Trademark Amendment Act (BDA) was approved in 1980. The BDA gives uniform treatment university and PRO patents derived from research funded with federal funds (Mowery et al. 2001; Eisenberg, 1996). The BDA belongs to a general reinforcement of the intellectual property rights (which includes the Stevenson-Wydler Act and the creation of the Court of Appeals for the Federal Circuit and the inclusion of IP issues in international trade negotiation) and tries to solve some uncertainty about licensing of the academic inventions in previous IP arrangements with the funding federal agencies. The BDA has 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 aim, it intends to facilitate exclusive licensing to support the development phase of the innovation process.

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

The salient characteristics of the BDA are that it leaves universities freedom in using exclusive licensing, royalties have to be shared with the inventors (40% in the Emory case, even if universities 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 have 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 is also 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, in Europe issues related to federal sponsoring of research do not arise as strongly as in the USA. In Europe there are different relationships between funding or 'federal' funding agencies (e.g. Centre National de la Recherche Scientifique or the Commissariat a l'Energie Atomique in France, Comitato Nazionale per la Ricerca e lo Sviluppo dell'Energia Nucleare or

[7] For example it is important to mention the expansion of programs to support Public-Private Partnerships (e. g. R&E 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)

Consiglio Nazionale delle Ricerche 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 the 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 their control on IPRs. Figure 1 show the number of patents at the EPO owned by universities and PROs in Germany, France, Italy and UK and it is noticeable the growing but extremely limited absolute number of university-owned patent and the relatively higher number of patents owned by PROs.

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

Importantly, recent research shows that in many European countries intellectual property rights on the output of university research activity is often owned by private companies (Lissoni et al. 2007; Giuri et al. 2007). Consequently the count of university patents (patents owned by universities) underestimate the technological activities of the European universities and the amount of technological transfer between university and industry. Meyer et al. (2003) and Balconi et al. (2004) show that 3% of the patents in Italy (at the EPO) and 8% of the patents in Finland (at the EPO) have at least one academic inventor. Moreover in Italy approx. 70% 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, 2007).

Lissoni et al. (2007) have undertaken a considerable effort in matching the inventors' names from the EP-CESPRI database and the name of university professors from different sources in France, Sweden and Italy. They show that the share of university-invented patents over total number of patents in these countries is between 3% and 6% and this figure is comparable with the one observed in the US. Moreover Figure 2 displays the ownership of academic patents by assignees for France, Sweden and Italy and compare it with the US as discussed in Thursby et al. (2007). The difference between the different European countries and the US is striking. In the US business companies own only 24% of

US academic patents. At the same time in Europe these shares are respectively 60% in France, 72% in Italy and, finally, 81% in Sweden. Universities, as already emphasised, owns a very small share of university-generated patents between 10% in France and Italy and 5% in Sweden.

This is the result of the specific institutional characteristics of the various national research and innovation systems. In particular the different role (relatively to the US) of the PROs on the one side and, on the other side, the lack of control over IP issues of many European universities. In Sweden it may be because of the professor privilege, in France and Italy universities are not particular autonomous from central government in fund raising and professors perceive themselves as civil servants employed by the government, rather than univesities. This created an incentive system such that universities did not created 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 privilege (Lissoni et al. 2007). For example Baldini et al. 2006 show that Italian universities created IPR regulations only recently in the second half of the 1990s. The important questions that arise from this evidence is whether the fact that so many university-invented patent are owned by companies can be interpreted as a sign of an effective technology transfer.

A possible answer come from the case of Denmark. Valentin and Jensen (2007) analyse 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 after the LUP approval a decline in collaboration between Danish firms and Danish scientists 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 delay in decisions over IP and uncertainty.

Moreover it is remarkable that the institutional characteristics of the processes of interaction between universities PROs and industry seem to some extent independent form the specific design of IP legislation. We observe similar patterns in the ownership structure of university generated inventions in Italy, France, Germany and Sweden, all 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 PROs 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 invention versus 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 compare the universe of university patents between 1965 and 1992 and a random control sample (equal to 1% of USPTO patents). They measure the importance and generality of university patents using patent citations[8] and show that over the whole period university patents are more general and important than their controls. Generality is measured using the number of technological classes the citing patents belong to and importance is measured counting the citations received by each patent. HJT find that after the introduction of the BDA the relative importance and generality of these patents decrease. Two factors may explain this decline: (i) less original patents from smaller universities without a strong experience in patenting and (ii) a general decline of the average quality of the patents with many patents receiving zero citations.

In sum HJT claim that after the BDA there was an increase in the propensity to patent but less general and important inventions were produced. The increased technological transfer effort thus brings into the market less significant technologies. However Sampat et al. (2003) using a longer time series of citations show that university patents take longer to be granted, on average they receive citations more slowly and, finally, 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) find 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) suggest that the importance of patents of entrant institutions increased in the 80s and 90s and therefore a learning process takes place overtime.

There are wide differences across technological disciplines in the relevance of university patenting. The patent growth is concentrated mainly in biotechnology and pharmaceuticals (Mowery and Ziedonis, 2002; Mowery and Sampat, 2005). As we have already mentioned in the previous section, this expansion depends upon the federal support to medical research in the US and the expansion of molecular biology at the end of the 70s. 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

[8] Patent citations delimit the scope of the property right and, at the EPO, are included in the patent document by the patent examiners that 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; Haroff et al. 1999; Hall et al. 2005).

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 like 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 show using EPO data that US university-owned patents are more cited relative to company patents in particular in the Drug and Medical sector.

Fabrizio (2007) suggests that increasing university patents is associated with slowing commercial exploitation. She uses USPTO patents and patent citations data from NBER and citations to non-patent literature from the MicroPatent Database and shows 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 patent prior art).

Sampat (2006) compares a sample of university patents and a random control sample from the USPTO and show a remarkable increase in the citation to non patent literature of university patents (relatively to their control) between 1976 and 1996. This evidence might suggest that universities are increasing 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 arises because the EPO does not register in a separate field the institutional nature of the applicant. Actually there is no comprehensive evidence available yet, apart from specific case studies at the department or university level (OECD, 2003; Geuna and Nesta, 2006; Sapsalis et al., 2006; Sargossi and Van Pottelsberghe, 2003). Bacchiocchi and Montobbio (2007) provide an attempt at filling this gap using an original database on patents from universities and PROs. Their paper estimates the process of diffusion and decay of university and corporate patents in six countries and tests the differences across countries and across technological fields using data from the EPO and in Europe they do not find evidence that suggests that university and PRO patents have a higher quality. Thier results show that knowledge produced in universities and PROs appears to diffuse more rapidly, in particular in the US, Germany and, to a minor extent, France and Japan. However strong national specificities emerge in this respect.

Finally Crespi et al. (2006) compare university-owned and university-invented patents resulting from university–firm research joint ventures. They use the Patval database and ask whether university-owned patents are more often applied, or are more valuable, than privately owned patents. They always conclude that university-owned patents do not differ significantly from privately owned patents. Crespi et al. (2006) interpret this result using the model by Aghion Tirole (1994) that show 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 university has a 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 thoroughly this point).

3.4 Summing up

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

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 the analysis of this issue.

4. Patenting Science

Empirical economists in recent years 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 spillover costlessly 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 costless. Moreover many authors have noted that publicly funded research also has an important role in training researchers and facilitating information flow across a scientific and technical community that transcends organizational boundaries (Cockburn and Henderson, 1998). I just mention here few empirical papers among the multitude of contributions in the field. Cohen et al. (2002) uses the 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 different from patents: published papers and reports, public conferences and meetings, informal information exchanges and consulting. This influence is greater for larger companies.

Mansfield (1995) shows that a large amount of industrial innovations in many high tech industries are based directly on academic research. He finds also that the quality of the university's faculty in the relevant department, the size of its R&D expenditures and industry geographical proximity are important factors that affect the university impact on industrial innovations. Mansfield (1991) and (1998) confirm that a substantial share of industrial innovations (over 10%) would have not been possible without academic research. Industrial innovation benefits greatly from open science also in pharmaceutical. In this sector, where IP is typically considered the major instrument of appropriability, Cockburn and Henderson (1998) show that companies, on the one side, have to invest in substantial R&D to complement externally generated knowledge, on the other side they have to be connected with public sector institutions. They comment 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 the 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 by for downstream scientific research (Nelson, Merges 1990, Mazzoleni, Nelson, 1998; Cohen 2005). This problem is particularly severe when universities are left free to license exclusively their discoveries[9]. Colyvas et al. (2002) survey 11 case studies (inventions) from Stanford and Columbia university in Biomedicine, Electronics, Software and Medical Devices. They underline 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 are particularly severe. This is because there is a very high uncertainty around the possible technological trajectories that may depart from the invention and this makes it difficult to choose the right licensee ex-ante.

Secondly there may be a problem with secrecy and data withholding. In particular it's worthwhile mentioning two articles - among others - in the New England Journal of Medicine and

[9] Nelson and Merges 1990 and Murray and Stern 2007b provide an interesting set of examples.

Journal of American Medical Association (Blumenthal et al. 1996 and Campbell et al. 2002) that point at the negative effects of patenting in life-science on scientific publications. Campbell et al. (2002) reports on a survey of 1897 geneticist showing that almost half of them have been denied requests or additional information, data, or materials regarding published research. Moreover ten percent of all post-publication requests for additional information were denied. In many cases therefore published research could not be confirmed.

Blumenthal et al. (1996) survey 210 life-science companies and underline that over 60 percent 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 in what follows I will focus on two aspects that have been object of particular attention in the last few years. The former is the well-known *anti-common problem* and the latter asks whether patenting activity has an impact on other forms of scientific disclosures like publications.

4.1 The problem of the anti-commons

The anti-common 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 with the proliferation of patents on genes and gene fragments. In front of the increase in the number of patents and number of claimants over a product innovation or a research tools, the cost of acquiring and negotiating the rights may become prohibitive and the likelihood of breakdown in negotiations over IP rights is higher. In this case a loss of collective surplus is expected and, in particular in the biomedical field, the fragmentation of property rights may impede the development and commercialization of promising therapeutics and diagnostics (Heller and Eisenberg, 1998; Murray and Stern, 2007a, 2007b)[10].

Walsh et al. (2003) conducted 70 interviews with IP lawyer, managers and scientists from biotech and pharmaceutical firms and universities (10 interviews to university scientists) examining impact of patenting and licensing of research tools on biomedical innovation. They show that the "patent landscape" is becoming more complex, exclusive licensing is pervasive and the preconditions for anti-commons effects exist. At the same time, they find little evidence of breakdowns in negotiations, or about projects that are not undertaken. In any case they find that licensing fees for research tools have risen and this may be a problem in particular for smaller firms and universities. They emphasise that some working solutions have emerged to deal with patents on research tools like

[10] Shapiro's (2000) analysis of the *patent thickets* raises a similar issue

licensing, inventing around or off-shore R&D to avoid infringement liability. However for universities it seems to be particularly important 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 and companies in most cases (with the exception of clinical diagnostic) do not suit universities because they fear a loss in reputation and because they perceive that university research adds value. Overall the situation is perceived as manageable, and results are confirmed by a subsequent larger survey (Walsh et al. 2005). Walsh et al. (2005) analyse the results from 655 researchers (398 from academia) in the fields of biomedicine (in particular proteomics and three specific signalling proteins). They do not observe that patent thickets limit significantly the 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. If this the reason we cannot exclude that the possibility of litigation may affect more significantly the researcher's activities in the future.

Walsh et al (2005) show 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 give for not sharing are more related to scientific competition and costs related to material transfers rather than commercial ones.

Murray and Stern (2007a) use a different perspective and methodology to examine the anti-commons problem. They focus on the research that lies 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) construct a sample of 169 patents associated with papers published in Nature Biotechnology over the period 1977 to 1999. They considers that the initial knowledge disclosed is through the scientific publication and patents are granted with a lag. Therefore they can study citation patterns before and after a patent is granted. They find that the citation rate declines by between 10 and 20 percent after a patent grant, particularly the decline is more pronounced for researchers with public-sector affiliations. They accordingly reject the null hypothesis that IP 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) confirm these results for 1279 patents on human genes in particular in presence of patents thickets and ownership fragmentation.

Rosell and Agrawal (2006) ask whether knowledge from university research is disseminated to a narrower variety of users. They use the National Bureau of Economic Research patent database, as described by Hall et al. (2001) and a report of university patents (USPTO, 2002). They calculate a Herfindahl-type measure of the concentration of patents across applicants and estimate whether patented university inventions are more widely disseminated than those of firms. They find that the 'university diffusion premium' – i.e. is 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 analyses 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). Firstly, 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 that aim at taking a patent, either in their own name, or in the name of their universities or a business partner, should keep their inventions secret as long as the patent application has not been filed. Secondly, 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 it 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 trade-off (for a discussion, see Breschi et al., 2007).

There are at least three counter-arguments against the existence of a patenting-publishing trade-off 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 'focussed' research questions (cognitive resources). Answers to research questions raised by technological puzzles may be at the same time economically valuable and scientifically relevant, up to the point of opening up new research avenues and disciplines (Mansfield 1995, 1998). Possibly the resource effect to 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 two other counter-arguments against the publishing-patenting trade-off 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 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 increased number of papers that have studied the relationship between patents and publications

Agrawal and Henderson (2002) analyse the patenting and publication behaviour at the Mechanical and Electrical Engineering department at the MIT (68 interviews) and show that patenting is not a major activity in these fields and there is no evidence of a trade off at the individual level between patents and publications. Azoulay et al. (2006) use a panel of 3862 scientists in life science and do not find evidence of a negative effect of patents on the quantity and quality publication. They control the inherent "patentability" of the scientists' research and do not exclude the possibility that , patenting also changes the content of these publications by connecting them more tightly to commercialization. Markiewicz and DiMinin (2005) find again complementarity between patenting and publishing using a panel of 150 random academic inventors at the USPTO and a control of 150 scientists that are not inventors. Breschi et al. (2006, 2007) investigate the scientific productivity of Italian academic inventors, on patent applications to the European Patent Office. They use longitudinal data set comprising 299 academic inventors, and we match them with an equal number of non-patenting researchers. They enquire whether a trade-off between publishing and patenting, or a trade-off between basic and applied research exists, on the basis of the number and quality of publications and find no trace of such a trade-off, and find instead a strong and positive relationship between patenting and publishing, even in basic science. Moreover Breschi et al. (2006) find that this result is particularly strong in pharmaceuticals and Electronics and Telecom[11].

Stephan et al. (2007) use approx. 10,000 scientists from the Survey of Doctorate Recipients in various disciplinary fields. They find that work context and field are be important predictors of the number of patent applications. They also find patents to be positively and significantly related to the number of publications even if the cross-sectional nature of their data preclude an examination of whether a trade-off exists between publishing and patenting.

[11] There are many papers that explore the relationship between patenting and publishing in different sectors and countries. Czarnitzki et al. (2006) discover a positive relationship between publishing output and patenting for more than 3000 thousands German professors active in a range of science fields. Goldfarb et al (2006) study the behaviour of 57 scientists in electrical engineering and 15 in biochemistry at Stanford and find complementarity. The effects of the inventive activity on publications is stronger in biochemistry. Van Looy et al (2006) find that 32 inventors of EPO patents at the Louvain University are more productive than a sample of non inventors in the same field and they do not observe substitution between patenting and publishing over time.

Other papers have also explored which 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) find that individual scientific productivity is a major factor that exposes scientists at the risk of patenting. In particular Azoulay et al. (2007) use their panel of 3862 academic life scientists and implement discrete time hazard rate models and fixed effects 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 emphasize not only that academic inventors are among the most active scientists but also that patenting behaviour is also a function of scientific opportunities. Breschi et al. (2005) show for the sample of Italian academic inventors that more productive scientists are more likely to become academic inventors, to no detriment of their orientation towards basic research. Research co-operation with industry is a useful predictor of patenting, when IPRs are owned by business companies. Finally Calderini et al. (2007) for a sample of 1276 Italian scientists and 131 inventors in Material Science they find that the probability to patent depends upon the basicness and the impact of the journal and on the individual productivity. However they suggest that the relationship is not linear and that for individuals that 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

These studies do 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 all these papers convey also the idea that the academic inventors are among the most prolific scientists in term of scientific publications and there is no evidence of a strong trade off between patenting and publishing at the individual level. However some words of caution have to be shed. First of all there is a lot of sectoral heterogeneity. On the one side 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 particular important and the anti-common problem felt more severely. On the other side the scant evidence that we have for other fields suggest that there is no (or very weak) relationship between patenting and patenting. More importantly this literature still struggles with counterfactuals and endogeneity issues. We are not really sure on what would have happened, had the academic inventors not patented their research results.

Secondly we do not know which are exactly the institutional processes that may be conducive to both patenting and publishing and, indeed, there are more than one. As suggested by Stephan et al. (2007) context variables are important and the underlining model probably depends on whether there is consultancy with a private company or pure public funded research, scientists are employed in small or large university, or in universities where staff is competent and skilled on IPR issues or, finally whether scientists are occasional or persistent innovators.

So we have evidence that high quality research and high quality researchers tend to go together with patenting. Murray and Stern (2007a) show that patented research is on average more cited and keeps on being cited even if at a lower rate. However we cannot still 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 towards other un-patented research activities and we do not know whether the very productive scientists that 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 having bargaining power to exchange and share protected tools and materials. This may change considerably 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 this issue in the last section.

5. Technology Transfer Offices and Licensing

In the previous section I noted that there is substantial empirical evidence about 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 is a substantial increase in the number of TTOs, patenting and licensing. The sheer numbers tell us a story of continuous growth of university patenting, licensing and invention disclosures. According to the 2005 AUTM survey, there are 28,349 current, active licenses in the US between companies and universities and 4,932 new licenses signed in 2005. The total university licensing income reaches 1.6$ billion in 2005 (1.4 in 2004) (Thursby and Thursby 2007; AUTM, 2005, 2004). At the same time it is important to note that the highly skewed distribution of licensing revenues across universities. In 2005 Emory account for approx 585.5$millions and New York University for

133.8$ million. Actually 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) wonder why so many universities set up a TTO if for many TTOs the licensing income is low. They give three possible explanations. The first one could be that universities hope to "hit the Jackpot" as in the Emory case. The second explanation is that TTOs may serve other universities goals different from licensing like, for example, sponsored research. Finally they suggest that there could be an emulative behaviour. They note that there are a number of TTOs in universities with a very low budget for research. For these institutions probably it's not necessary to have a TTO.

Moreover Thursby et al (2001) and Thursby and Thursby (2002) have analysed the nature and determinants of this increased licensing activity. Thursby and Thursby (2002) develop 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 use survey data from 65 universities and observe that patent applications grow much faster than innovation disclosures that depend more closely on faculty choices. As a result they suggest that increased licensing is due primarily to an increased willingness of faculty and administrators to license rather than a shift in faculty research. Relatedly Thursby et al. (2001) in a survey of 62 US universities and underline 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 idea of Henderson et al. (1998) that universities are trying to extract as much as they can form 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. Which is the effect of increased patenting by universities on enforcement costs ? Shane and Somaya (2007) study the effect of patent litigation on university efforts to license technology. They use secondary data on licensing and interviews with TTOs directors for research universities and discover that patent litigation impacts negatively on university licensing activity. They emphasise that litigation changes the nature of TTOs activities and shift resources from marketing and licensing towards lawsuits and opposition activities.

5.2 Putting TTOS in Context: different TTOs Performances and the Role of Faculty

A second group of papers refers not only on the type, growth and profitability of TTOs activity but also on the determinats of TTOs efficiency. Thursby and Kemp (2002) consider that the TTO inputs are number of staff, federal funds for research, faculty size and research quality. The output is measured in terms of patents, disclosures, licenses executed, royalties and research funds from industry. They show 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 consider. They find 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, 2008) develop a model and perform an econometric exercise on the role of economic incentives in university research and licensing outcomes. In particular they examine how the share of license royalties received by academic inventors affects the number and licensing value of inventions in universities. They use data from the Association of University Technology Managers, and collect information on the distribution of royalty shares from university websites for 102 U.S. universities between 1991 and 1999. In the US the inventors share with the university a portion of the fees and royalties from licensing IP rights and universities differ substantially in these royalty sharing arrangements. There are two type of agreements. Linear and non linear royalty schedules. In the former case inventors' get a constant share of the level of license income generated by an invention. The average figure in this case is 41% (max 65%, min 25%). In the latter case inventors' royalty shares vary (in the majority of cases regressively) with the level of license income. In this case variation across universities is even larger because the inventor's share ranges between 20% and 97% with an average value of 51%. Lach and Shankerman show that both academic research and inventive activity in universities respond to variations in inventors' royalty shares. In particular they find that universities with higher royalty shares generate higher levels of license income, in particular for private universities. The papers of Lach and Shankerman are particularly important because show that the specific design of IP 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 and the incentives mainly increase the quality rather than the quantity of inventions[12].

Di Gregorio and Shane (2003) study TTOs from the point of view of IP related start up formation and enquire why some universities generate more new companies to exploit their IP than do others. They analyse a short panel of 102 universities over the 1994–1998 period for which they collect data on start-ups, patents, intellectual eminence, venture capital and policy related information with a survey of TTOs directors. Therefore they can ask 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; and, finally, university policies.

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[12] Belenzon and Shankerman (2007) and Siegel et al. (2003) also suggest that the most critical organizational factors for success in licensing are the reward systems and compensation practices for faculty and TTO staff.

Their results show that only the last two factors affect the creation of start-up firms. In particular the relevant policies are (1) making equity investments in TTOs start-ups and (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, at the same time Di Gregorio and Shane (2003) suggest that significant royalty-sharing may create disincentive to the creation of start-up companies. Di Gregorio and Shane show also that more eminent universities have greater TTO start-up activity than other universities. Their result confirm previous evidence that star scientists found companies to earn rents on their intellectual capital and 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) underline for a sample of approx. 6000 life scientists and 600 start ups (or participation to scientific advisory board of a new biotechnology firm) that the institutional context is crucial to explain the heterogeneity of behaviours of transition to commercial activities. In particular Stuart and Ding find that the orientation toward commercial science of individuals' colleagues and co-authors, as well as a number of other workplace attributes, significantly influenced scientists' hazards of transitioning to for-profit science. The quality of the faculty members affects not only start-ups but also the licensing activity. Elfenbein (2007) uses approx. 1700 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 shows that inventors' prior academic output is positively correlated with the likelihood that their new technologies will be licensed.

Faculty behaviour however is important also because faculty specialized knowledge is needed to develop the licensed technologies (Agrawal and Henderson 2002; Colyvas et al. 2002; Jensen and Thursby 2001; Thursby et al. 2001; Thursby and Thursby 2002; Thursby and Thursby 2007). Jensen and Thursby (2001) and Thursby et al. (2001) find that 71 percent of licensed inventions use faculty in further development after the license is signed. Thursby and Thursby (2004) show that faculty uses 55 percent of the time for the development of licensed technologies that were only a proof of concept (54 percent for prototypes). Therefore when the technology is at a early stage of development the involvement of the scientists is crucial and even if companies typically do not perceive this involvement cheaper than in-house development. Finally Agrawal (2006) shows that the likelihood and degree of commercial success are related positively to the extent to which the firm engages the inventor and his graduate students in the technology development after a license is signed. He claims 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 enquired. First because there is a very high diversity across countries and because there is no coherent data and systematic data collection as it happens in the US with the AUTM surveys. An exception is provided by Arundel and Bordoy (2006) that in MERIT 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, represents 20% of approximately 1000 TTOs in Europe. The survey collected data for 2004 and 2005 and analyses 74 responses from universities and 27 responses from other public institutes in 22 European countries. Arundel and Bordoy (2006) show that the average TTO has 8.7 staff members. Universities TTOs have lower staffing levels (5.43) than PROs (12.3). However there is a lot of variation across institutions and the staff distribution is extremely skewed (Conti et al. 2007). University TTOs are relatively young, with an average age of 8 years since establishment. These results are confirmed by the 2005 annual survey of the other important network of TTOs, companies affiliated to universities and PROs that is called ProTon Europe[13].

In fact in many countries universities and PROs have created TTOs in Europe in the last decade (OECD 2003). Germany has established patent exploitation agencies at a regional level. In Italy Baldini et al. (2006) show that universities started to adopt patent policies and regulation in the last ten years. Also in Belgium and Denmark, and France TTOs have small size 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 developed as in the US. ProTon (2007) shows that the number of licenses is growing between 2004 and 2005. However the absolute number is still very low (731 licences for 392 respondents in 2005) and the licence revenues are only equal to the 0.17% of the R&D investment. Conti et al. (2007) show that the distribution of licences is skewed to the left with many institutions with a very low number of licences (the median number of licenses across TTOs is only 4.5). This confirms the evidence provided by OECD (2003) that the majority of PROs negotiates a very small number of licences each year. OECD (2003) underlines also that a large share of licence 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 UK TTOs are more developed however Chappel et al. (2005) find that in U.K. 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 underline the necessity to enhance the skills and capabilities of U.K. TTO managers and licensing professionals. Similarly Conti et

[13] ProTon Europe has been supported as a thematic network under the 5th Framework Programme of the European Commission. At the end of July 2006, ProTon Europe had more than 230 direct members employing about 2000 knowledge transfer professionals. ProTon Europe and its partner national associations cover more than 500 transfer offices in Europe.

al. (2007) estimate the determinants of number of licences for the respondent to the ASTP and find that skill composition of a TTO plays an important role in determining its productivity. In particular they claim that employing PhDs appears to reduce the coordination costs arising from interactions between the TTO and academic researchers.

5.3 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 affect importantly this variation. Faculty involvement in the development phase emerges also clearly 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 emphasise that most of the evidence we have surveyed come from top universities in the most advanced country. The ability to generalize to other countries with different level 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 exploit systematically their intellectual property. For example in Europe it seems particularly important that TTOs develop hiring technically competent staff. Moreover in the evidence I have surveyed some factors like commercial orientation, the availability of venture capital funds, or the presence of an incubator do not seem to be major determinant of commercialization in term 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. IP on public research: Conclusion and open issues for developing innovation systems

This paper summarizes the recent empirical literature in economics that has analysed the role of patents in universities and PROs in facilitating knowledge transfer. Assessing empirically whether IP 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 complicated to build counterfactuals. The large number of empirical works on this topic has focused mainly on the US experience where patenting public research has been increasingly 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 a lot of different forms of interaction. Most of the research has focused on life sciences and biotech 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 scientific field, to the stage of development of the invention and across regions because they adapted to different institutional setting 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. Geographical proximity and co-location between an 'anchor tenant' firm and the research institutions seem to be particular 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 a lot 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 developing innovation systems we can expect to have companies specialised in more traditional, less science-intensive sectors and a research system less mature with less 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, IP in public research probably plays a less relevant role. It is worthwhile reiterating the Mowery and Sampat (e.g. Mowery and Sampat, 2005) point that the explosion of university patenting in the US is to great extent related to the biotechnology revolution that in turn has is 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 university and PROs and the absorptive capacity of companies. It is important that in developing innovation system, universities reach high standards in education and training 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 IP is becoming a central aspect of cooperation with industry - they need careful handling to avoid unintended consequences in particular when collaboration is exploratory. In this vein Sampat (2003) and Mowery and Sampat (2005) criticise the movement to mimic the BDA to improve the "entrepreneurial" nature of the university system in developing countries. They suggest that disseminating new knowledge broadly is the comparative advantage of universities and PROs in these countries and "policies - like the Morrill Act of 1890 - which created incentives for U.S. 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, Nesta, 2006, OECD, 2003; ProTon, 2007). To win the 'Jackpot' is an extremely rare event, in particular for small universities with little economies of scale and a limited number of research projects. Also in the US it is difficult to say whether many TTOs generate profit for their universities since licenses revenues often does not outweigh the operating costs of the TTOs. Moreover the TTOs appear to be particularly efficient when are staffed with competent and well paid people and in specific context 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 costly institutional entities.

In particular this discussion suggests that TTOs fixed cost could be conveniently spread building "central brokers" (e.g. at the regional level). Transfer activities and learning could take place over a relatively larger 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 geographical proximity that facilitates informal interactions and close working between faculty members and employees of individual PROs and universities.

Thirdly, faculty involvement is extremely important for a 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 they may perceive transfer activities as a dangerous diversion from their publication activity because there can be high costs of 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 the invention coming from university research. In this respect the European experience is that industry-university cooperation evolves adapting to specific institutional settings and research systems. Changing the design of IP may disrupt the established practices of cooperation. In Denmark the *abolition* of professor's privilege in 2001 and the new attitude of universities towards IP may have caused biotechnology companies to change research partners and move some research projects in Sweden (where the privilege is maintained). Conversely in Italy the *introduction* of the professor privilege in 2001 caused concern among universities and companies because of the different treatment of researchers from private and public sectors in a context where the majority of university-invented patents are owned by business companies. This reinforces the intuition 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 the control of IP over strategic technologies (in agriculture or health) for public interest or policy reasons.

This survey discusses also the potential 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 suggests that academic patenting is not fatally undermining the scientific system (Murray and Stern, 2007a; Murray and Stern 2007b, Cohen at 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 rule 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 have bargaining power with other scientists. University patents may therefore become an important currency to spend in the global scientific college. This currency may be particular expensive for individuals and institutions that are traditionally in a weak bargaining position.

While many universities and research centres 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 e.g. the controversy about AIDS blood test patents in Murray and Stern, 2007b), great attention must be placed in order to safeguard knowledge access and limit restrictions to the use of research tools and materials. This is particular 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 advanced countries may have no incentives to undertake the necessary R&D investments. National legislations should therefore ensure adequate disclosure in the research system and protect scientist from the most aggressive types of IP licensing. In this respect inventions from public science should 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 application for the patent and publication of the research. Finally the reduction of the number of bad quality patents (e.g. raising the "non obviousness bar") in the US could help alleviating 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 university 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 efforts between these two types of institutions) depends upon (1) the amount of knowledge generated within university and PROs (i.e. the scientific productivity of individual scientists and researchers), (2) on the type of knowledge disclosure (3) on the nature and type of their research and (4) on the absorptive capacity and demand for new knowledge by companies. All these four aspects are affected by the specific IP design differently 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. A lot of work here has to be done to build reliable databases on patents invented by university professors. As it happens 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 match a database with the names of individual professors and a database with 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 IP is expected to play some role only in specific disciplinary fields. It could be also interesting to evaluate the effects of recruitment policies in universities and PROs that introduce IP or other forms of technology transfer to evaluate researchers activity (as it happens for example in the Mexican "Sistema Nacional de

Investigadores[14]") and to enquire the effects of these policies on scientists' activity, their promotions and career paths.

In this vein another interesting topic largely under-researched is the relationship between IP and labour mobility. Mobility of scientists is extremely relevant for developing countries because on the one side the brain drain affects the scientific productivity of local universities, on the other side, 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 differential scientific productivity of this sub sample of researchers - whether they face restrictions on the use and diffusion of their discoveries (often from labs situated in foreign countries), and how, if at all, IP protections affects this process. Here again important differences may emerge across different disciplinary fields. For instance, is there an effect of patents on research tools on the incentives 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 intellectual property protection? Is it more likely to share materials and data with the original university in such cases? Are mobile scientists more productive and more likely to take patents out of 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 IP and licensing are not independent from other means of technology transfer, like scientific publications, consultancy, 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 IP 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 the scientists' choices. Scientists choose their research projects and the way they disclose their findings and possibly 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 – like in the professor's privilege case - or the institutions) or changes in the regulation within universities or creation of TTOs.

At the university level is always difficult (also in Europe and the US) to have a quantitative account of the costs and benefits of the use of IP in universities and PROs. To collect data on TTOs costs, application fees and opposition costs and, on the other side, on revenues from licensing or other forms of transfer would greatly help to assess the impact of IP on the knowledge transfer activity of these institutions.

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[14] http://www.conacyt.mx/SNI/Index_SNI.html

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 be also interesting to observe the scientific activity at the lab 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 No 10.973, December 2nd, 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 the 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, the generality or basicness - may be measured using patent citations.

It would be also interesting to have detailed understanding, again through case studies in specific fields or surveys, on how patenting in research tools create 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 elsewhere is protected. In addition cross-country comparisons could help to disentangle the effects of different norms regarding research exemption, grace period and non obviousness standards. The underlying research question is always to disentangle how different forms of knowledge spillovers are conditioned by the intellectual property regime in the country in specific industries.

Moreover IP on the research results in many developing countries may be motivated by public interest. It is important for many government in developing countries that the research results are widely used and correctly exploited in particular in crucial sectors like food and health. In this respect how IP is and 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 companies are more likely to engage in cooperative agreement with universities and how these relationship are affected by different IP regimes. Some countries have undertaken in the last twenty years profound processes of liberalization and privatization. Does the changing competitive environment requires different IP arrangements to promote technology transfer and cooperation ? Do privatized companies invest less in university-based research? Is this related to IP issues?

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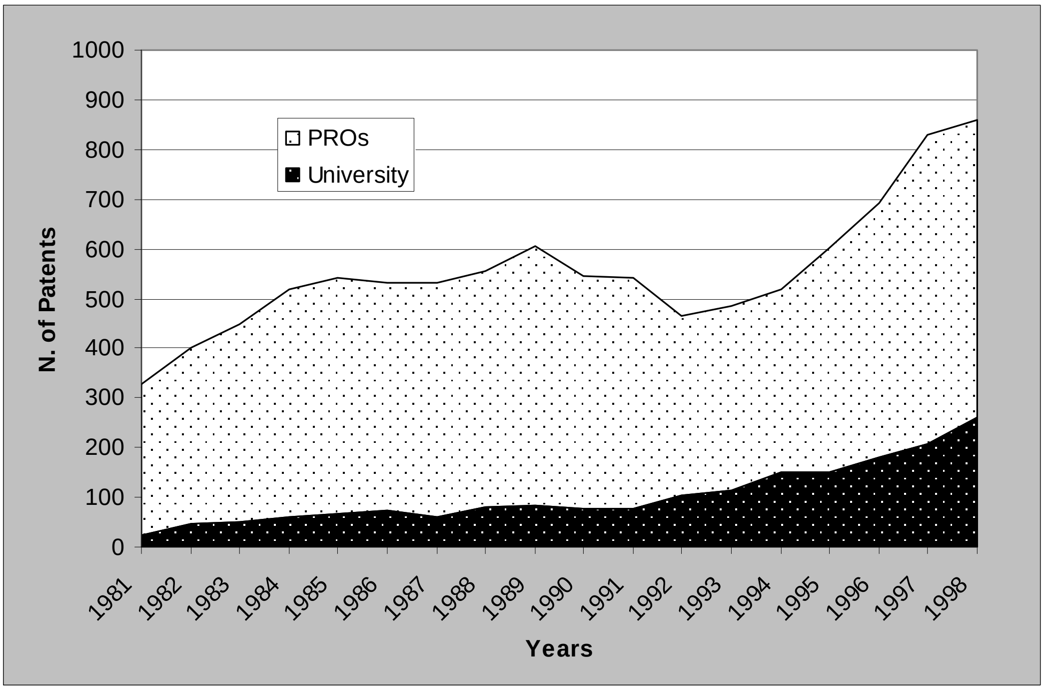
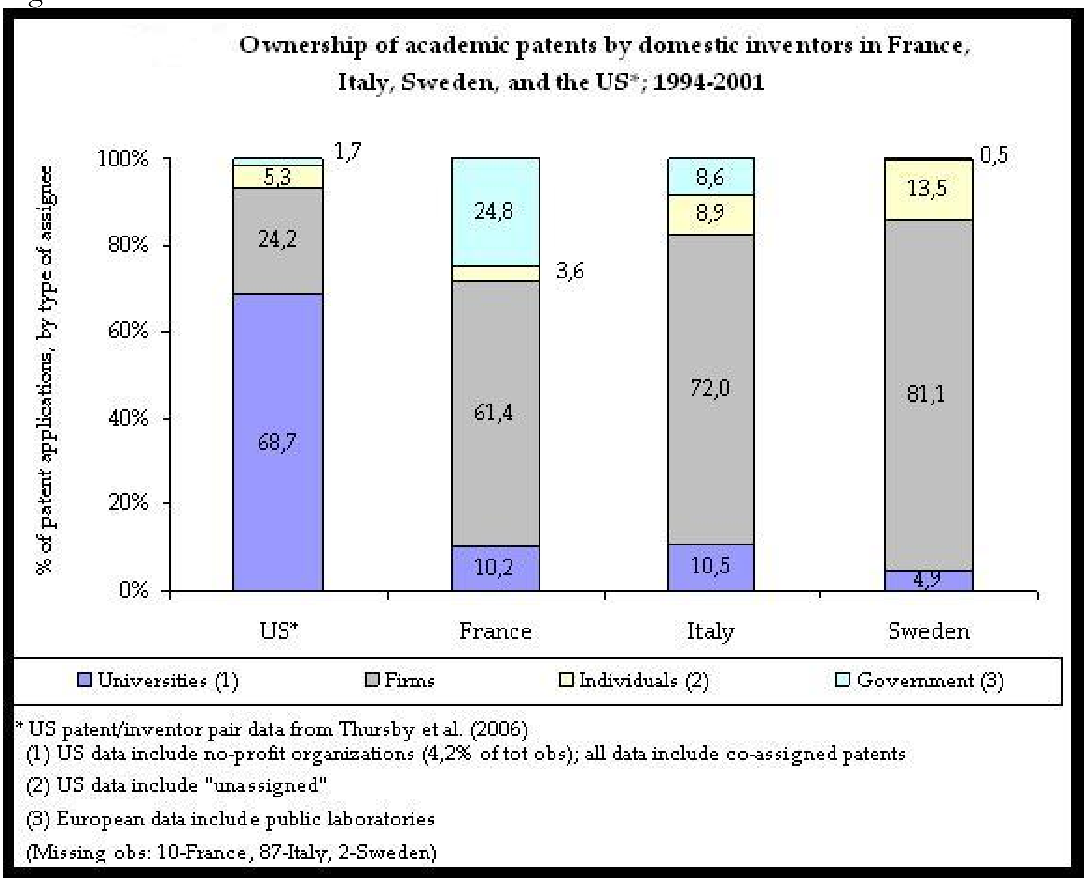
Figure 1.



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

Figure 2.



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