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Starting from the late 1970s, a decline in the competitiveness of US high-technology firms, challenged by Japanese industry, induced a major re-examination of the US technology policy. Several experts asserted that US firms were not commercializing university-based technologies at a sufficiently rapid rate to maintain the nation's technological leadership. While such inventions had been achieved using public monies, they served no economic purpose unless they were taken to the market. Incentives to commercialize new knowledge depend critically on the investor having property rights to that knowledge. The Bayh-Dole Act of 1980 allowed universities and other non-profit institutions automatically to retain title to patents derived from federally-funded R&D, and encouraged them to license inventions to industry. Supporters of the Bayh-Dole Act defended their institution by saying that it enhanced the investment returns on public research and restored corporate competitiveness. On one hand, ex-ante grant of an exclusive license is not strictly necessary to motivate this work – e.g. the Cohen-Boyer basic technology in biotechnology. On the other hand, it is clear that the Bayh-Dole Act led universities to advertise their inventions more actively, and university-industry partnerships appear to accelerate technological diffusion.

The increasing constraints on public research funds following the end of the Cold War, and the enforcement of the Maastricht criteria for joining the common currency, prompted a shift in scientific and technological policies of the European Union, too, from basic research to increased concern over its industrial application. In the last few years, several European countries, including Germany, re-examined their Intellectual Property laws to encourage ownership of inventions by the institutions in which the researches are performed, thus echoing the landmark Bayh-Dole Act.

Such resource constraints, which encouraged policymakers to make university patenting technically possible, also increased the academia's sensibility towards alternative and complementary strategies to raise funds. The new opportunities, opened by changes in the patent laws, led universities to explore additional means of enhancing the economic value of knowledge by moving it along the development process closer to the market in expectation of increasing its value.

In so doing, university have been facilitated by the recent scientification of knowledge: in some key industries, such as semiconductors and biotechnology, theoretical advance can occur in tandem with the invention of new devices, tools and processes. New rules and new roles are defined and legitimated; formats for collaborative arrangements are institutionalized in legal and customary formats, e.g. the U.S. cooperative research and development agreements; moreover, the university now has interface capabilities such as technology transfer offices and incubator facilities to manage and market knowledge produced by its faculty.

Starting from a review of more than 50 papers (see methodology in the Appendix), this work will present a detailed overview of threats stemming from university patenting activity, then it will draw some policy implications and it will conclude with some suggestions for further research.

Patenting activity leads to increased secrecy and reduced willingness to share data with colleagues. Several studies focusing on the life sciences by David Blumenthal and colleagues show that restrictions on sharing information regarding R&D breakthroughs with colleagues and prohibition or delay of publication of research results coming from university-firm R&D interactions have become a common and accepted practice. Increased disclosure restrictions have several effects: they compromise the norm of open science valued by researchers as an end in itself; more importantly, they

undermine the quality of academic research by diminishing the extent to which research methods and results are subjected to professional review and criticism; furthermore, restrictions both increase wasteful duplication of research efforts and reduce the likelihood that research will contribute to further work; last but not least, they apparently block the most important media through which universities contribute to technical advance. There are numerous disputes between faculty members who prefer an accessible open license for their discovery, which would maximize the breadth of knowledge dissemination, and universities that seek a more lucrative, exclusive license.

Steven Rosenberg suggests that withholding research data can indeed provide a competitive edge. External pressures on scientists, such as evaluations for promotion and the need to secure funding, increase the tendency to view competition in the medical area as against other scientists rather than against the disease. Rates of denial are significantly higher for faculty who had provided highly visible services to their discipline.

In a famous article published on Science in 1998, Michael Heller and Rebecca Eisenberg applied the metaphor of the anticommons to biomedical science. Threats to future scientific investigation can be particularly severe when the university licenses exclusively or narrowly a development that is potentially of wide use, or where it is limiting the right to take a particular development further to one or a few companies in circumstances where there still is sufficient uncertainty regarding how best to proceed to make participation by a number of companies in that endeavor socially desirable.

However, seventy interviews by John Walsh and colleagues (2003) among U.S. attorneys, business managers, and scientists from firms, universities and PROs, showed that, despite the increased complexity, almost none of the actors involved reported commercially or scientifically promising projects being stopped because of issues of

access to IPRs on research tools. Moreover, industrial and university researchers seem to be able to develop working solutions that allow their research to proceed: the members of a research community are somewhat reluctant to assert their intellectual property against one another if that means they will sacrifice the goodwill and information sharing that comes with membership in the community. Changes in the institutional environment, particularly new U.S. Patent and Trademark Office guidelines and some shift in the courts' views toward research tool patents, as well as pressure from powerful actors such as the U.S. National Institute of Health, also appear to have further reduced the threat of breakdown.

Patents cause delays in publication. Pertaining this aspect, it is important to notice that while U.S. Patent and Trademark Office grants a one-year grace period (during which scientific publications are included in the non-prejudicial disclosures, thereby allowing researchers to patent their already published research), this is not the case elsewhere, thus forcing inventors wanting to patent outside the US to comply with more stringent patent laws.

Universities' entrepreneurial transformation has been criticized as a prelude to a substitution of basic research with market-driven one, thus endangering and fundamentally altering the societal role of public research. Several studies, however, contradicts this statement. Scientific excellence, as measured by publication and citation patterns, is highly correlated with patent productivity at the individual researcher level, as well as the whole university level (e.g. Lach and Schankerman, 2003). Furthermore, a case study by Bart van Looy and colleagues (2004) on the Catholic University of Leuven (Belgium) suggests that scientific excellence (as measured by number and nature of publications) and entrepreneurial performance (as measured by revenues) mutually reinforce thus resulting in a compound Matthew-effect

Moreover, a theoretical model by Richard Jensen and Marie Thursby showed that, if faculty viewed both basic research and applied research as goods, then it is not obvious whether policy changes that created incentives for the commercialization of university research have resulted in a substitution of applied for basic research. The effect depends on how such changes influence individual researchers' marginal rates of substitution between basic and applied research and between either type of research and income.

Patents not only spur faculty to reduce time to basic research, but also to research tout-court. Scientists engaging in patenting activity need to acquire competences in intellectual property issues, new languages in writing the patent applications and the claims, and the ability to recognize and distinguish between scientific and legal versions of the novelty of their work.

The student-teacher relationship can also suffer in four common ways. First, teaching is not associated with a heavy weighting in the assessment of the performance of university professors, thus teaching has a low impact on their careers. If patent output is to be used in the academic evaluation process (as is already happening in a some countries and as is being promoted by some policy reviews), this will create incentives for researchers to reduce their time and commitment to some of their activities, and, given the current weighting scheme, teaching will be the activity likely to suffer the highest time reduction. However, effects on quality of education are uncertain: the theoretical model by Richard Jensen and Marie Thursby showed that the effects of policy changes that created incentives for commercialization of university research on the quality of education depend on how they influence the teaching load and the amount of patentable knowledge used in education.

Secondly, Paula Stephan suggests that a professor could very easily direct a student into topic areas that are useful for his/her firm, thereby using the student as a low-paid employee, or could transfer the unpublished results of a student's work or ideas to his/her company. Moreover, several students and fellows receiving training grants or scholarships from industry report that firms limit their choice of research topics, require them to perform some work in return for the support, or require them to work for the supporting company after completing their training. For better or worse, there is a lot of money surrounding inventions, specially biomedical ones, and this has changed the relationship of trust that many students assume exists between them and their faculty advisers.

Thirdly, in addition to classes, students learn through their work in laboratories and through informal discussions with other faculty, staff, and students. Paula Stephan reports anecdotic evidence suggesting that joint university-industry research and commercialization may limit learning from these less formal interactions as well.

Fourthly, based on a 1985 survey of almost 700 life science graduate students and post-doctoral fellows at six research intensive universities in the US, Michael Gluck and colleagues suggested that industry funding can hinder students' publication activity. In fact, students with direct support from industry were found to report significantly fewer publications on average than do those with no industry support or those whose faculty advisors receive funds from industry.

Such results are somewhat questioned by a later survey from Teresa Behrens and Denis Gray, who surveyed a stratified sample of 482 graduate students from largest (in term of R&D performed) universities participating to the Nation Science Foundation's Industry-University Cooperative Research Centers Program. The analysis of two engineering departments, chemical and electrical, showed that the most striking

differences observed were not between industry- and government-supported projects but between sponsored projects and projects with no external sponsor. Students engaged in research with no external sponsor are involved in their research for shorter time (compared to government), perceive their project to be more short term in its goals and produce fewer publications.

Among possible negative effects from universities engaging in patenting activity, some relates to industry. An exploratory study involving 20 managers by Donald Siegel and colleagues suggests that firms are concerned with university wrangling over IPRs, and particularly with the time delays this may cause. Also, they are worried that even though they fund research up front, they are forced into unfavorable negotiations over IP when something of value emerges. Second, companies participating to university-industry research centers fear that the centers they support will share some vital information with their competitors, because several firms normally participate in a single center.

Thirds, Paula Stephan underlines the case of bioinformatics, where technology transfer led to the process of industry eating the seed corn for a new field. Universities were slow to start new programs in this area, because when the need was identified in industry, the first response of industry was to go to academy and hire away the star faculty and in so doing eat the seed corn required to train additional individuals in the field.

Finally, Jeannette Colyvas and colleagues analyzed eleven inventions from Columbia University and Stanford University for which the universities sought and obtained IPRs. Their study suggests that IPRs are unimportant for non embryonic inventions, and indeed may hinder their transfer, by increasing the inventions' cost to allow the universities to collect revenues.

As emerged from this brief but comprehensive review, it is difficult to arrive at simple policy prescriptions. Among the reasons, the fact that effects of incentives for the commercialization of university research depend on individual characteristics, as shown by Jensen's and Thursby's theoretical model. While some first-order guides to the appropriate tax rate on income-generating activities have been proposed, more analyses are certainly needed on this topic.

Nevertheless, several policy lessons emerge from this review. First, policymakers must recognize that there is no one best way to stimulate innovation. Emulating best practices of different countries' innovation systems or designing a common policy for the whole public research sector ignores how legislative and organizational changes interact with specificities of the local context to form a coherent system. At the same time, the heterogeneity of laws of different in Europe nations governing IPRs on publicly-funded inventions may restrain international collaborations. Second, limiting the scope of patents over research tools and techniques should be considered as a solution to one of the most urgent threats to an efficient and effective advance of the frontier of science.

Third, introducing a one-year grace period in other major patent systems, like the European one, would contribute to reduce the trade-off between publication and patenting activity. Fourth, the evidence that investigators who withhold data from others are more likely than other faculty to be denied access to their colleagues' data suggests that the exchange of information in the academic scientific enterprise may be governed by unwritten and informally enforced rules. Professional associations and funding agencies may assist researchers in gaining access to other's results by passing resolutions policies that encourage the data-sharing and limit withholding.

Fifth, a shift towards entrepreneurial values should be approached very carefully. This implies that efforts to achieve a value shift towards a more entrepreneurial culture within universities will have to be accompanied by a re-education of the society as a whole and of faculty in particular as to the changing realities of university funding. The institutionalization of new norms and practices is the first step toward a conscious management of patenting and licensing activities, since it serves as an important ideal which acts as a constraint on the actions of universities and scientists. The process of institutionalization and legitimation is when conditions and methods of work are defined.

Sixth, actions specifically targeted to raise awareness of and support for technology transfer by university faculty should be undertaken. A supportive environment inside the university has proven to be important to stimulate patenting and licensing activities. Seventh, initiatives to inform academics of both possibilities and limitations related to the commercialization of technology from the universities should be promoted. the development and the enforcement of strict ethical codes of conducts is a requisite that should precede the university's engagement in patenting and licensing activities. academia should not expect income from its technology transfer activities to replace normal research funding. However, it should expect a fair payment, fair terms and conditions where all parties benefit, the researcher, the external partner and the university.

Finally, a key policy issue concerns the need to reconcile the objectives of the different actors involved in the technology transfer, i.e. those of the universities, the faculty, the industry, and the society as a whole.

While most universities have been investing their resources to create internal conditions to support the commercialization of their research results, there are still some

major concerns that need to be addressed. Universities that choose to embrace closer research links with the corporate sector must be prepared to devote the resources needed to manage those programs effectively as a necessary cost of business. In Europe there is an urgent need for the development of codes of conduct that would help researchers to manage conflicting pressures. To my best knowledge, there are no studies analyzing the diffusion, the content and the effectiveness of such ethic codes. This topic is worth to be further investigated.

University research has been characterized by invisible colleges, small cooperative networks of information sharing with a high relevance of informal linkages that traditional overcome boundaries of public research: another suggestion for further research is to investigate possible differences in collaboration propensity of patenters vs. non-patenters, and to the impact that successful patenting has on the researchers' openness to the community and on the circulation of knowledge and ideas.

While theoretical model by Jensen and Thursby (2004) is an important contribution on the impact of faculty engagement in patenting activity on students learning and education, evidence on this topic is almost anecdotic and an improvement in this direction is needed. More generally, management scholars should continue to investigate the effect of adding the third mission of economic development on the two traditional missions of research and education, as significant changes may appear only in the long run. On this specific topic, Europe is well behind U.S.

Finally, some studies (e.g. Stephan, 2001) feared that increased disclosure restrictions apparently block the most important media through which universities contribute to technical advance and that industry can be severely damaged by the shortage of university spillovers: systematic on this topic still lacks.

Appendix.

Data were gathered using a three-stage strategy. First, I queried two subscription databases: ABI/INFORM and EconLit, both of which are available through most universities and PROs, using as key-words “university”, “patent”, “license”, “Bayh-Dole”, “triple helix”, “secrecy”, “open science”, “spin-off”, “incubator”. The timeframe utilized dated from 1980 to 2004. Secondly, from these results and from my previous knowledge of the topic, I drafted a list of peer-reviewed scientific journals with impact factor on which it was most likely to find papers pertaining to this review: IEEE Transactions on Engineering Management, Industrial and Corporate Change, International Journal of Industrial Organization, Issues in Science and Technology, Journal of Economic Behavior and Organization, Management Science, Minerva, R&D Management, Research Evaluation, Research Policy, Science Technology and Human Values, Scientometrics, Technovation. Due to their relevance, three more journals were added, Journal of Association of the University Technology Managers, Journal of Technology Transfer, and Science and Public Policy, and a well-known working papers database, that managed by the U.S. National Bureau of Economic Research (http://www.nber.org). The abstract of all papers in each issue on the previous list was read in order to find relevant papers, limitedly to those published from 1995 to 2004. Thirdly, I reviewed some interesting papers that were cited in the studies collected during the first two stages. While several papers can be found on the broad topic of the patenting university and related issues, this review will limited to those contributions analyzing problems stemming from university patenting and licensing activities.

Recommended readings

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