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FROM PUBLISHING TO PATENTING : DO PRODUCTIVE SCIENTISTS TURN INTO ACADEMIC INVENTORS ? (*)

Mots-clés :

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I. — INTRODUCTION

Back in October 2000, joining the celebration for Richard Nelson's seventieth birthday in New York, Keith Pavitt asked his audience the following question: What can the rest of the world learn from US theory and practice regarding public policies to support basic research? And what they should not learn? (1).

Among Pavitt's many concerns stood prominently what he called «the newly acquired role of US universities in inventive activities», and the fascination it

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(1) Pavitt's contribution has then been published as Pavitt (2001).

exerted on many European policy-makers. Looking back at the university patent explosion of the last twenty years, Pavitt warned explicitly to use caution before extending recent US policy provisions (such as the Bayh-Dole Act) to different national contexts, in the absence of international comparisons and a detailed assessment of each country's specificities (2).

That warning, recently reiterated by Mowery and Sampat (2004), is still valid. To date, only a recent OECD report has collected cross-section data for quite a few countries, and such data are limited to one year of observation, and to patents owned directly by universities and public labs (3). Only a few national studies have extended the analysis to patented inventions by academic scientists, but owned by business companies, as a result of sponsored academic research (4).

In this paper we pick up Pavitt's research suggestion and explore in depth the Italian case. Besides providing original data, we contribute to the general debate on whether pushing university faculty to patent the results of their research lead to genuine technology transfer efforts, or to a diversion from fundamental research to shorter-term, less general targets (5). In order to shed light on the existence of a possible trade-off, we investigate the relationship between patenting and the academic researchers' core activity, namely the publication of scientific papers on refereed journals.

Our effort is based upon a dataset containing all the patent applications from Italian academic inventors addressed to the European Patent Office, from 1978

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(2) As a proof that Pavitt's concerns regarding the influence of the US example were not unfounded, one can easily take the recent wave of policy measures aimed at increasing university-industry technology transfer via the creation of clear-cut IPRs over the results of public funded research (OECD, 2003).

(3) See OECD (2003). For a comparison of France, Italy and Spain, see also Cesaroni and Piccaluga (2003).

(4) See Meyer (2003) and Meyer *et al.* (2003), for the case of Finland, Carayol (2004) for a large French university, and Saragossi and van Pottelsberghe (2003) for Belgium. Gittelman (2002) compares the contribution of academic scientists to biotech patents in the US and France also on the basis of information on inventors.

(5) By «genuine technology transfer effort» we mean here an additional research effort aimed at developing promising inventions already obtained, as «proofs of concept» or «prototypes», by curiosity-driven, publication-oriented research (that is, «normal» academic science). US legislators passing the Bayh-Dole Act aimed precisely at creating the right system of incentives to solicit that effort, under the presumption that its absence was undermining the more general goal of promoting innovation by funding science (Jensen and Thursby, 2001; on why that presumption was possibly wrong see Colyvas *et al.*, 2002). The same presumption seems nowadays to underline the EU policy-makers who believe in the existence of a «European Paradox», that is of a strong European science base, not coupled to effective technology transfer means (Dosi, Llerena and Sylos-Labini, 2005).

to 1999; and on a dataset on publications authored by those academic inventors and a matched sample of academic scientists with no patents in their CV. In particular, we aim at checking whether more productive scientists are more or less prone to patenting, and whether the orientation towards basic research is at odds with or favours patenting. We are also interested in understanding whether the relationship between publishing and patenting varies across disciplines, and between university-owned and business-owned patents; and whether research co-operation with industry is a pre-requisite for patenting.

In section II we discuss the existing literature on academic patenting and put forward a few testable hypotheses on its relationship to scientific research and publishing. In sections III and IV we present our model and data, while in section V we report results of our analysis. Section VI concludes.

II. — PATENTING AND PUBLISHING: COMPLEMENTARITIES AND TRADE-OFFS

The relationship between patenting and publishing may be investigated at two different levels, one which refers to the dissemination of research results, the other to the research objectives pursued by scientists. Scientists' individual productivity may also explain cross-scientist differences in both the publishing and the patenting activity levels.

In a companion paper, we explore the effects of patenting on academic scientists' subsequent publication record (Breschi *et al.*, 2005). Here we are interested in the opposite causality link, namely how a scientist's publication record may explain her propensity to patent.

We assume publishing to be a routine activity for academic scientists, which occurs much more frequently than patenting (as indeed suggested by all available data (6)). Although any scientist may have a «dry» spell, during which he does not publish any paper, patents are so rare compared to publications that we may consider them as «discrete events» punctuating an ongoing publishing activity. This also suggests that we can measure a scientist's «productivity» first and foremost in terms of publications per year, and discuss whether and how patenting events affect productivity levels.

2.1. Patenting and publishing as dissemination means

At the *dissemination* level, we explore whether scientific papers and patents are complementary or alternative means for the diffusion of research results.

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(6) See Breschi *et al.* (2005), Markiewitz and DiMinin (2004), Murray and Stern (2005), Stephan *et al.* (2004).

Even if both of them put a prize on keeping research results secret for a while (until the submission of a scientific paper to a journal or conference, or the application for a patent), they lead to very different disclosure rules and attitudes towards cooperation. The priority reward system encourages scientists to disclose fully their research achievements, *via* the publication of data, intense codification efforts (neat theorizing and establishment of clear experimental routines), teaching duties, and repeated interaction/discussion with peers (Merton, 1973; Dasgupta and David, 1994). The IPR-based system, on the contrary, may encourage incomplete and selective disclosure. Patent-intensive firms rely heavily on secrecy to appropriate the returns from non-patentable knowledge assets, many of which are produced or acquired along the development phase of a patented invention (Cohen *et al.*, 2000). As long as secrecy complements patenting, academic scientists who are more committed to patent-oriented research may find it difficult to publish all of their research results (7).

At a more practical level, commitment to patenting may push academic inventors to delay the publication of their research results, since placing them in the public domain before filing for a patent would go against the novelty requirement as defined by most patent offices (8).

Commitment to secrecy on patent-related issues and publication delay may both result in a productivity slowdown before (and after) the patenting date (*hypothesis 1*). This effect ought to be stronger for patents owned by business companies, as long as they result from industry-sponsored research; in these circumstances, in fact, it is often the case that scientists hand over their IPRs to the sponsor as part of the contract, and accept to follow the sponsor's guidelines in terms of contents and timing of their publications.

2.2. Objectives of scientific research

At the *research objectives* level, propositions on the relationship between publishing and patenting derive from more fundamental visions of the relationship between science and technology.

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(7) An additional issue relates to patenting of so-called research tools, such as scientific instruments, genetic sequences, and other seminal results. Exclusive licensing and fragmented IPR property over these kinds of inventions may prevent research teams with lesser means from accessing to new research fields, or scare off scientists with fears of infringing some hidden patent. On this point, see the classic paper by Heller and Eisenberg (1998), and the more recent empirical work by Murray and Stern (2005) and Sampat (2005).

(8) In principle, the publication delay may be mitigated by the so-called «grace period» rule, as in the US and Japan. The rule allows academic researchers to publish in advance their soon-to-be-patented inventions, as long as the publication occurs not too early (6 to 12 months before the patent application date). However, the European Patent Office does not allow for any grace period, so that any firm or inventor applying for a US or Japanese patent, but foreseeing to extend it to Europe, cannot exploit the rule (Kneller, 2001).

A common concern regards the contents of academic enquiry, which could be diverted from «basic» towards «applied» research. While the former can be portrayed as the unconstrained exploration of nature and theory, the latter's objectives are limited by the need to achieve results with some degree of «industrial applicability», a crucial pre-requisite for patent applications to be successful. Lack of commitment toward basic research may result either in a lower rate of publications in refereed academic journals, or in less ambitious publications, with a lower impact on the progress of both science and technology. Although never modelled theoretically, the possible existence of a basic-applied science trade-off has been a long-standing concern of both policy-makers and scientists (Bok, 2003).

Alternatively, it has been proposed that close contacts between academic scientists and industry may be beneficial to basic research. The history of science-technology relationships is punctuated by close contacts between university and industry, which have provided scientists with financial resources and free access to expensive scientific instruments, as well as with «focussed» research questions, data, and technical expertise. Answers to research questions raised by technology may be at the same time economically valuable and scientifically relevant, up to the point of opening up new research avenues and disciplines (9).

One further argument suggests that R&D-oriented business companies, especially those active in science-based technologies, are as responsive as academic institutions to scientists' publications. Their R&D staff screen academic publications routinely, publish actively, and participate to conferences and workshops, thus joining the academic community, and sharing its judgements on individual scientists' reputation (Hicks and Katz, 1996; for a survey: Iversen and Kaloudis, 1999). It follows that any academic scientist wishing to access the financial and cognitive resources of large business companies does not give up his publication activity, but on the contrary keeps it up at high levels.

The two alternative visions of science and technology links suggest opposite hypothesis to be tested.

Were the «basic-applied» trade-off argument correct, there would be one more reason to observe a productivity slowdown before the patenting date, possibly more visible for publications in journals devoted to basic science, as opposed to applied research and technology (*hypothesis 2*).

(9) The classic reference on « cognitive » resources is Rosenberg, 1982, ch. 8 (see also Rosenberg, 1990). For some more recent empirical evidence, see Mansfield (1995, 1998) and Siegel *et al.* (2003).

Arguments stressing the complementarities between basic science and applied research may on the contrary suggest that patenting go along with an increase in the productivity of academic inventors, some of which we may expect to observe even before the patenting event (*hypothesis 3*). A long record of scientific cooperation with industry should also increase the probability of patenting; to the extent that this cooperation has brought the scientists in touch with focussed research questions and data sources, we should observe this effect for both patents owned by industry as a result of recently sponsored research, and for patents held by the scientist himself or his university (*hypothesis 3a*) (10).

If, on the contrary, accessing industry's financial resources is the key component of the complementarity link, we may expect these positive effects to be stronger for business-owned patents (*hypothesis 3b*).

In addition, if academic reputation matters for gaining support from industry, we may also expect a positive relationship between a scientist's publication record over the years and his chances to produce a business-owned patent (*hypothesis 3c*). Individual productivity may also produce an effect similar to this (better scientists publish more, and occasionally patent, too), but in this case the effect would not be confined to business-owned patents (*hypothesis 4*).

2.3. Controlling for environmental factors

The probability to observe two equally productive scientists engaged in patenting may also be affected by environmental factors. Gittelman (2002) suggests that the differences between the US and France in university patenting may be largely explained by institutional factors (such as administrative rules on faculty's involvement in start-up companies) and cultural ones (ethical norms on the legitimacy of profit motives in science). The latter are also called in by Feldman and Desrochers (2004) to explain the lower patenting propensity of scientists at Johns Hopkins University, compared to institutions of equivalent scientific pre-eminence in the US. Due to data limitation we can control for just a few of these factors.

We are also interested in understanding whether the relationship between publishing and patenting varies across disciplines, and between university-owned and business-owned patents. We expect the probability to observe a positive relationship between publishing and patenting to be higher in scientific fields wherein basic research is more readily exploitable by industry (the classical example is molecular biology).

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(10) On the role of co-authorship of scientific papers by academic and industrial researchers.

III. — MODEL SPECIFICATION

We explore the relationship between publication activity and patenting by estimating the patenting hazard rate of our subjects, that is the probability that a professor will patent in the current year, conditional upon not having patented so far (the time unit is the year). This is consistent with viewing patents as «discrete events» punctuating scientists' publishing activity, which we regard as academic researchers' «routine» activity.

As we do not have any *a priori* hypothesis on the functional form of the hazard function, we choose to apply the Cox semiparametric approach, which does not impose any specification on the baseline hazard function (that is, on the relationship between time and the probability of the event to occur; Kalbfleisch and Prentice, 2002). This means adopting a proportional hazard model such as:

$$h(t_i \mid x_i) = h_0\,(t_i)\,\exp\,(\beta x_i) \qquad (1)$$

where $h(t_i|x_i)$ is the hazard rate at time t for professor i, conditional upon a set of covariates x_i, which include both time-invariant characteristics of the professor (such as his gender) and time-varying ones (such as all variables related to the number of publications).

Following the discussion in section 2, we propose the following basic specification:

$$\begin{aligned} h(t_i \mid x_i) = h_0\,(t_i)\,\exp(&\beta_1 Productivity_i + \beta_2 Productivity\_variation_i + \\ &+ \beta_3 Industry\_contacts_i + \beta_4 Environmental\_factors_i + \beta_5 Controls_i) \qquad (2)\end{aligned}$$

where *Productivity* refers to professor *i*'s publication record per year up to time *t*, *Productivity_variation* refers to his more recent publication record (deviations from average publication record at time *t* and/or immediately before *t*), and *Industry_contacts* refers to any evidence of professor *i*'s past cooperation with industry. Environmental factors are those listed in section 2.3; control variables will include *i*'s gender and age.

Following the discussion in section 2, Table 1 lists the expected signs of the explanatory variables.

We first estimate the hazard function for a single patenting event, that is we choose professors as the subjects of our exercise and let them in our sample at the latest between the starting year of their career (11) and 1978 (the opening

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(11) For our definition of « start » of a professor's career see section IV.3 below.

Table 1 - Hypothesis to be tested and specification (expected signs)

	Productivity (β_1)	**Prod. Variation** (β_2)	**Industry contacts** (β_3)	
HP1 (Alternative dissemination means)	?	-	?	
HP2 (Basic-applied trade-off)	?	- *	? (+)	* all journals or «basic» journals
HP3 (Basic-applied complementarity)	?	+ *	?	* all journals or «basic» journals
HP3a (Past cooperation with industry provides data/knowledge assets)	?	+	+	
HP3b (Past cooperation with industry makes easier more sponsorship)	?	+	+ *	* only for business-owned patents
HP3c (Academic reputation eases patenting with industry)	+ *	+	+	* only for business-owned patents
HP4 (Individual productivity effect)	+	? (+)	?	

year of the EPO, European Patent Office). Academic inventors exit the sample when they sign their first patent, while observations on non-inventors result truncated in 1999 (12). In other words, we assume professors to be at risk of patenting only from the opening of EPO in 1978, or from when they start their career (if later); and not be anymore at risk once they sign their first patent. Time «at risk» runs from the entry in the sample (13).

We then proceed to check whether our results hold for repeated patenting events. In this case, the professors enter our sample first in 1978 (or when they start their career, if later) and never exit, as they are always at risk of patenting; however, after any patent the time «at risk» re-starts from 1, as we assume each patenting event to be distinct from the previous one. Technically, this means assuming that any professor with $n>1$ patents will enter our analysis as $(n+1)$ distinct subjects, each observed from time 1 onward. As we expect the recurrence times of all events concerning the same professor to be highly correlated (in fact, they are not independent observations), we allow for professor-specific

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(12) Since we do not commit to any functional form for h(.), we are not forced to assume that non-inventors will eventually patent (or never patent) after the truncation.

(13) This means that we assume no left truncation in our data, as 1978 is the earliest possible entry year for all our professors, no matter whether they started their career before then. In other words, we disregard all patents taken at national offices before the opening of EPO as a relevant event for our analysis (none of our professors signed any US patent before 1978). We justify this treatment of our data by observing that very few professors have more than one patent, so the risk of ignoring some previous patenting activity is low; and that the equivalent of a EPO patent before 1978 should be not just any national patent, but a patent extended to all the most important EPO countries, which makes the risk of ignoring it even smaller.

random effects (frailty model; Lancaster, 1979). In other words, we assume the hazard function for all m_i observations referred to professor i to be:

$$h(t_{ij} \mid x_{ij}, \alpha_i) = \alpha_i h_0 (t_{ij}) \exp(\beta x_{ij}) \quad \text{with } j=1...m_i \tag{3}$$

where α_i is a parameter common to all observations, and x_{ij} are specified as in equation (2). As we do not have any *a priori* on the probability density function of α_i, we simply adopt the Gamma specification built in STATA, the software package we used for our analysis. Estimates of the hazard function under the assumption of a Gamma-distributed frailty parameter include an estimate of the distribution variance (θ), upon which all standard errors of the parameters for the covariates are conditional. The «frailty» assumption, that is the assumption of random effects at the professor level, is not rejected as long as $\theta \neq 0$.

We finally check our results for a sample limited to the academic inventors only, for a number of which we know both when they started their academic career and whether they hold a PhD.

IV. — DATA

The core data of this paper come from the EP-INV database, which contains all patent applications to the European Patent Office (EPO) that designate at least one inventor with an Italian address, from 1978 to early 1999. The EP-INV database contains information on 30243 inventors and 38868 patent applications.

Little more than 1400 of these applications come from 919 «academic inventors», namely university researchers and professors who appear both as designated inventors in the EP-INV dataset and in the complete list of academic staff of science and engineering departments on active duty in year 2000 (27844 full professors, associate professors, or assistant professor) provided to us by MIUR, the Italian Ministry of Education and Research. For a full description of the matching methodology and contents of the dataset, see Balconi *et al.* (2004).

In this paper we focus on a few disciplines with a very high share of academic inventors over the total number of professors. These can be found in fields such as Chemical Engineering (*e.g.* technology of materials, such as macromolecular compounds), Biology, Pharmacology, and Electronics (including Telecommunications), for a total of 301 academic inventors and 552 patents (table 2). Many patents are the result of teamwork, with academic and non-academic inventors working together. As for the distribution of patents over time, 75 of them date back to 1979-1985, while the others are quite uniformly distributed over the remaining years. Most of the selected inventors are full professors, born between 1940 and 1960 (more details in Breschi *et al.*, 2005).

Table 2 - Italian university professors in 2000, selected fields

Field	**Professors, active in 2000**	*of which:* **Academic inventors, n. and (%)**
Chemical eng. & Materials tech.	355	66 (18,5)
Pharmacology	613	84 (13,7)
Biology	1359	78 (5,7)
Electronics & Telecom	630	73 (11,6)
Total	2957	301 (10,2)

Source : EP-INV-DOC database

A control sample was then built, by matching each academic inventor to a professor in the same discipline, with the same academic ranking, and of a similar age (14). Each academic inventor was matched to a colleague never designated as inventor in patents applied for either at EPO or the US Patent and Trademark Office (15). When possible, controls were chosen among the academic inventors' department colleagues or from university of similar size and importance, or from the same region. We decided not to adopt stricter matching rules at the level of university/department (such as choosing controls only from the same departments of the inventors), as they would have greatly reduced the sample. For the same reason, we did not match our data on the basis of gender. The rules we followed for matching inventors and controls at the university level provide satisfactory results: as far as summary statistics of university size are concerned, we do not find systematic differences between inventors and controls (see table A2 in the Appendix) (16).

IV.1. Patent data

All the patents included in our sample pre-date the most recent changes in the Italian IPR legislation concerning academic research, as well as the intro-

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(14) The choice of discipline, rank, and age as matching variables follow the best-established results of quantitative studies in the sociology of science (*e.g.* Long *et al.*, 1993).

(15) For academic inventors born between 1950 and 1970, we allowed for no more than 5 years of age difference with the controls. For professors born before 1950 the maximum age difference was 7 years. For academic inventors born after 1970 (just one) the maximum age difference reduced to 3 years. Exceptionally (no more than 10 cases) we matched a full professor (inventor) with an associate professor (control), or an associate professor with an assistant professor; in these cases the age criteria were stricter (maximum age difference: 3 and 5 years, respectively).

(16) On how university and department affiliations may affect scientific productivity, see Allison and Long (1987, 1990). The Italian evaluation system of academic activities does not rank systematically universities and departments according to the quality of their research. In the absence of better measures, we can measure the university size with the total number of professors (in hard science).

duction of IPR regulations and patent offices in the majority of Italian universities. As such, they were mostly the result of *ad hoc* arrangements between the inventors and the university administrations, which used to be quite alien to IPR matters. The most common arrangements left the IPRs over sponsored research entirely in the sponsors' hands (whether public or private). For inventions originated from research funded with general university grants, the university usually paid the necessary fees and retained property, but it was up to the professor to disclose his results and to convince a reluctant administration to engage in the patenting process (quite a different situation from now, when more and more university administrations «chase» for patentable inventions among the faculty ranks) (17).

The distribution of patents across academic inventors is highly skewed; most professors have signed only one patent, and very few more than five (table 3). Most patents belong to business companies, as a result of contractual funding, with little meaningful differences across fields, with the exception of Biology, which records a higher number of both individual and university-owned patents (table 4). We cannot be sure that all academic inventors signed their

Table 3 - Distribution (%) of academic inventors by n. of patents and field

		n. of patents		
Fields	**1**	**2-5**	**6+**	
Chemical eng. & Materials tech.	60,9	32,8	6,3	*100*
Pharmacology	63,1	28,6	8,3	*100*
Biology	70,5	23,1	6,4	*100*
Electronics&Telecom	56,2	31,5	12,3	*100*
Total	62,9	28,8	8,3	*100*

Source : EP-INV-DOC database

Table 4 - Ownership of academic inventors' patents (§) by type of applicant and field; n. of patents (and %)

	Business	**Open Science (1)**	**Individuals (2)**
Chemical eng. & Materials tech.	127 *(76,0)*	22 *(13,2)*	18 *(10,8)*
Pharmacology	200 *(75,2)*	32 *(12,0)*	34 *(12,8)*
Biology	88 *(48,6)*	57 *(31,5)*	36 *(19,9)*
Electronics&Telecom	200 *(78,1)*	40 *(15,6)*	16 *(6,3)*
Total	615 *(70,7)*	151 *(17,4)*	104 *(11,9)*

(1) Universities, public labs and government agencies; both Italian and foreign.
(2) Same applicant's and inventors' names.
(§) Patents owned by more than one applicant were counted more than once.
Source : EP-INV-DOC database

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(17) On the recent wave of reforms and its effects, see Baldini *et al.* (2005).

patents when they were already working in a university: some patents may be the outcome of former jobs as industrial researchers or employees of large public labs. However, we suspect these patents to be very few, as Italian professors usually start pursuing the academic career right after graduating.

As for IPRs over public-funded, targeted research, in principle these belong to the sponsors (most often the MIUR ministry, the National Research Council, and, in the past, ENEA, the National Agency for Alternative Energy). However, until recently, the decision to take the first step towards patenting was usually left to individual grant recipients. This explains why they are relatively few.

A similar explanation applies to the scarcity of patents owned by the universities: until recently, universities decided to take care of the application procedure and expenses to reward, often symbolically, some brilliant researcher, rather than as the outcome of a consistent exploitation strategy. It also happened that many professors took the shortcut of patenting at their own expenses and in their own name: this explains the presence of a few inventors' own patents (18). Finally, some «Open Science» patents come from international collaborations, and are owned or co-owned by US and European universities or consortia.

Table A3 in the Appendix lists the most important applicants as well as the ownership concentration ratios, by field. More than one third of the patents in the Electronics and Telecom field are in the hands of ST Microelectronics, the largest semiconductor company in Italy and one of the very few large hi-tech companies in Italy (19). As for the other fields, ownership is so sparse that the National Research Council (CNR) and the University of Rome, despite holding very few patents, turn out to be ranked highly among patent applicants.

It should be noticed that, in a few cases, the CNR and the universities enter table A4 as co-applicants along with business companies, as a result of public-funded co-operative research projects. In this case we assign the patent to the «business» category.

IV.2. Publication data

For academic inventors and their controls we collected scientific publications from the 2003 web edition of the ISI Science Citation Index (SCI), starting from articles published in 1975.

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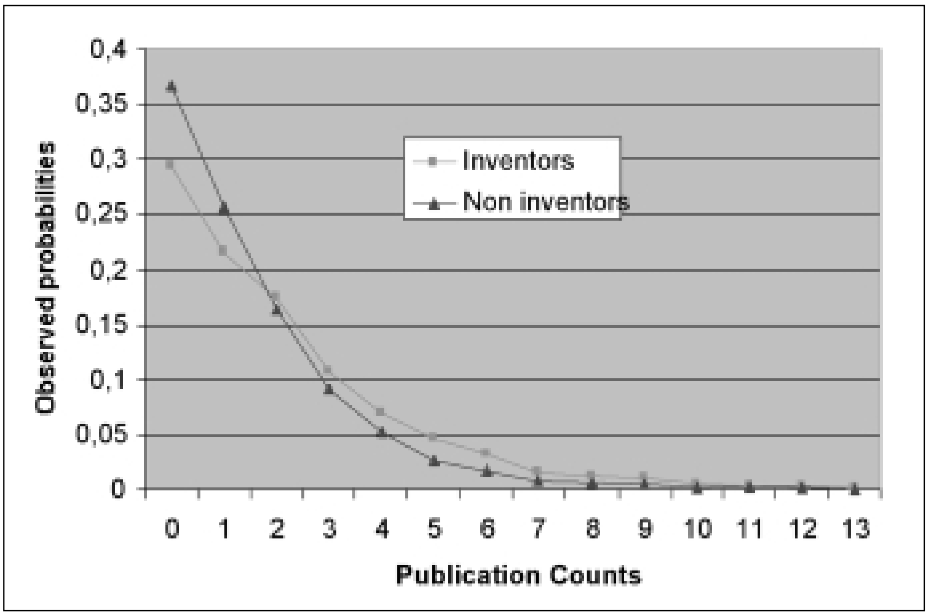
(18) Inventors' own patents, however, are less than suggested by table 3. In fact, whenever an « individual » patent results from teamwork, all co-inventors figure as co-applicants.

(19) In particular, ST Microelectronics has a long cooperation record with, among others, some researchers from the Department of Electronic Engineering of the University of Pavia (Balconi, Borghini and Moisello, 2003). The multinational group ENI plays a similar role in Chemical Engineering, although it has not close relationships with a single university.

Figure 1 - Distribution of publications per year, academic inventors vs controls ; 1980-1999



As a proxy for *Productivity* (see section III), for each professor we compute the average number of publications at each point in time, as the stock of publications divided by the years of activity.

Calculating the number of years of activity requires setting a starting date for a professor's career. In the absence of information on either the graduation year or the first year as assistant professor, we set the starting date as the minimum between the 30th birth-year and the first year of publication activity. This choice will possibly lead to overestimating the publication activity of professors with no papers in the early stages of their career, as those years may be dropped from our analysis. This possibility is most likely to occur for non-inventors, who record a higher number of zero-publication years (see figure 1) and appear in general to be less productive than inventors (table 5). As we will find (section IV) that AVG_PUB indeed is most often positively related to patenting, we conclude that this measurement problem does not undermine our conclusions.

For a subset of 139 academic inventors, additional data are available on their graduation year (which allows to set a more precise entry date in our longitudinal dataset) and on whether they hold a PhD, and when it was completed (from which we build a PHD dummy which takes value 1 from the PhD grant year onward). When limiting our analysis to academic inventors we will make use of these more precise pieces of information.

Table 5 - Publications per year, inventors vs controls, 1975-2003; by field

	N	**Mean**	**Std**	**Median**
Inventors				
Chem.eng. & Materials tech. **	63	2,0	1,75	1,5
Pharmacology *	83	2,2	1,21	2,0
Biology *	78	2,5	2,10	2,0
Electronic&Telecom *	72	1,7	1,04	1,4
All Fields	296	2,1	1,60	1,8
Controls				
Chem.eng. & Materials tech.	63	1,3	1,10	1,1
Pharmacology	83	1,7	1,11	1,6
Biology	78	1,8	1,27	1,5
Electronics&Telecom	72	1,3	1,18	1,0
All Fields	296	1,6	1,28	1,3

* - ** Inventor-control distribution difference significant at .90 - .95 (Kolmogorov-Smirnov test)
(1) Only professor aged 24-70 in current years
Source : elaborations on EP-INV-DOC database and ISI Science Citation Index

As a proxy for *Productivity_Variation* (see section III), we compute it as the difference between the yearly scientific production of a professor, and his current *Productivity* value. We also compute its lagged value.

Information on a professor's research targets (basic vs. applied) comes from a reclassification, produced by CHI Research, of about 90% ISI-recorded journals (Hamilton, 2003). Journals are assigned a score from 1 to 4 on the basis of their contents and scientific field, with score 1 for the most applied kind of research and score 4 for the most basic (20). We calculate *Productivity_(Basic)* and *Productivity_Variation_(Basic)* as the equivalents of *Productivity* and *Productivity_Variation* for the journals with score 3 and 4.

(20) The classification distinguishes between biomedical fields and all the other disciplines. In the first case, the scores correspond to the following definitions of the journals' contents:
l = « clinical observation » (*e.g. Journal of the American Medical Association*)
2 = « clinical observation and investigation » (*e.g. New England J. of Medicine*)
3 = « clinical investigation » (*e.g. Journal of Clinical Investigation*)
4 = « basic biomedical research » (*e.g. Journal of Biological Chemistry*).

In the second case the correspondence is:
l = « applied technology » (*e.g.* Dyes and Pigments)
2 = « engineering science -technological science » (*Journal of AOAC International*)
3 = « applied research -targeted basic research » (Analytical Chemistry)
4 = « basic scientific research » (*J. of the American Chemical Society*).

Finally, in order to assess the extent of pre-existing research co-operation between academic researchers and industry, we have calculated *Industry_Contacts* : for each in point in time, it represents the share of cumulated publications co-authored by each professor with industrial researchers affiliated to companies with at least one EPO patent application (not just Italian ones, but worldwide). Information on the affiliation of professors' co-authors comes again from ISI-Web of Science, while information on worldwide patent applications to EPO comes from the K4I dataset on EPO patents (K4I, 2005).

IV.3. Institutional and personal data

Most informations on individual professors and their institutions come directly from the MIUR list, which contains the professors' dates of birth, as well as their discipline, affiliation, and academic ranking (assistant professor, associate professor, and full professor).

Disciplines are defined according to a classification created for administrative purposes. This classification is very detailed and allows some compression into broader categories, which we refer to as «fields» (see table A1 in the Appendix) (21). It is hardly common for a professor to change discipline over his career, and when this happens, movements can be safely assumed to occur within the same field.

Affiliation refers to the university employing professors in year 2000. For each university we calculate *Faculty_Size* as the number of professors in hard sciences in year 2000; we expect larger university to be better equipped in dealing with technology transfer issues, as they may have some administrative staff devoted to manage intellectual property rights.

In the absence of longitudinal data we will make use of *Faculty_Size* as a control variable throughout our analysis, for all years comprised between 1978 and 1999. We justify this use of our data by pointing out that academic mobility is a very limited phenomenon in Italy, and it is often confined to the very early stages of a professor's career. As for the absolute size of university faculties, this has increased greatly over the years, but the same cannot be said of

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(21) The MIUR list includes only those professors and researchers with tenured position (from now on, we will refer to them simply as « professors »). Thus our data miss fixed-term appointees who, at the time, had been working in one or more universities for one or more years, as well as all the PhD students, post-doc fellows, and technicians. In the current Italian system, assistant professor (called « researcher ») and associate professor positions, despite being only the first two steps of the academic career, are not offered as fixed-term appointments, but as tenured ones. The main differences with the position of full professor lie in wage and administrative power.

Table 6 - Descriptive analysis

Name	Description	Obs.	Mean	Std. Dev.	Min	Max
Productivity $_{j,t}$	Professor *j*'s average number of publications per year, over his career up to year *t*	11482	1.31	1.24	0	13.4
Productivity_ Variation $_{j,t}$	Difference between professor *j*'s publications in year *t* and his current *Productivity* value	11482	0.47	1.58	-6.1	13.9
Productivity_ (Basic) $_{j,t}$	Professor *j*'s average number of publications per year, over his career up to year *t*, basic science journals only	11482	0.96	1.10	0	13.0
Productivity_ Variation_(Basic) $_{j,t}$	Difference between professor *j*'s publications in year *t* and his current *Productivity* value, basic science journals only	11482	0.34	1.30	-4.5	13.6
Industry_Contatcs $_{j,t}$	Share of publication co-authored by professor *j* with inventors from companies with at least one EPO patent, up to year *t*	11482	0.09	0.03	0	1
Age $_{j,t}$	Age of professors *j* in year *t*	11482	41.52	9.96	22	73
Gender $_{j}$	Dummy variable equals 1 for woman professors	11482	0.21	0.41	0	1
Department_ Inventors $_{j,t}$	Share of academic inventors over the total number of a professor *j*'s department colleagues in year *t*	11482	8.27	10.16	0	100
University_Patents $_{j,t}$	Stock of patents held by professor *j*'s university a in year *t*	11482	39.23	47.62	0	225
Faculty_Size $_{j}$	N. of hard science professors in professor *j*'s university in year 2000	11482	893.19	520.35	18	2128

relative size: public universities in Milan, Rome, and a few other large cities have remained the dominant institutions despite all changes. We assume our variables to capture effectively the effects on academic patenting of university size ranking, and to influence positively the propensity of a professor to sign a patent as inventor.

Other control variables we obtain from the MIUR list are the *Age* and *Gender* of professors (=1 for women professors).

By combining our patent data and information on affiliation (in 2000), we have produced two additional control variables: *Department_Inventors*, which measures the percentage of inventors among each professor's colleagues (in the same university and field), at each point in time; *University_Patents*, which measures the stock of patents held by each professor's university at each point in time. We expect both of them to influence positively a professor's propensity to sign a patent as inventor.

Table 6 provides summary statistics for all the explanatory variables.

V. — RESULTS

Table 7 reports our estimates for the coefficients of the single-event hazard function. Equations 1 and 2 are based upon all patents, whether owned by busi-

Table 7 - First patent (single event)
Estimated coefficients of the proportional hazard function (Cox model)

	All patents [1]			Business company [2]		Open Science institution [3]	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Productivity_Variation $_{t}$	-0,003 (0,035)	0,01 (0,035)		-0,02 (0,041)		-0,06 (0,059)	
Productivity_Variation $_{t-1}$	0,10 (0,035)***	0,10 (0,035)***		0,07 (0,040)*		0,11 (0,056)*	
Productivity $_{.t}$	0,11 (0,051)**	0,12 (0,049)**		0,13 (0,056)**		0,14 (0,077)*	
Productivity_Variation_(Basic) $_{t}$			0,03 (0,038)		0,02 (0,044)		0,04 (0,068)
Productivity_Variation_(Basic) $_{t-1}$			0,10 (0,040)***		0,07 (0,047)		0,17 (0,056)***
Productivity_(Basic) $_{t}$			0,09 (0,057)		0,10 (0,070)		0,09 (0,094)
Age $_{t}$	-0,01 (0,010)	-0,01 (0,010)	-0,01 (0,009)	-0,01 (0,010)	-0,01 (0,010)	0,01 (0,016)	0,01 (0,016)
Gender	-0,27 (0,165)	-0,26 (0,160)*	-0,29 (0,156)*	-0,54 (0,184)***	-0,57 (0,184)***	0,20 (0,262)	0,18 (0,261)
Industry_Contacts $_{t}$	2,53 (0,407)***	3,42 (0,254)***	3,33 (0,253)***	4,05 (0,296)***	3,96 (0,297)***	0,92 (0,762)	0,87 (0,758)
Industry_Contacts $_{t}$ * Electronics		-0,91 (0,416)**	-0,62 (0,405)	-1,18 (0,417)***	-0,94 (0,421)**		
Industry_Contacts $_{t}$ * Chemical		-8,52 (4,092)	-5,78 (3,938)	-4,74 (3,627)	-4,21 (3,498)		
Industry_Contacts $_{t}$ * Biology		-1,33 (0,731)*	-1,24 (0,718)*	-1,59 (0,773)**	-1,52 (0,764)**		
Inventor_Status				-0,48 (0,323)	-0,38 (0,317)	-0,30 (0,304)	-0,24 (0,758)
Department_Inventors $_{t}$	0,03 (0,009)***	0,03 (0,008)***	0,03 (0,008)***	0,03 (0,008)***	0,03 (0,008)***	0,01 (0,010)	0,01 (0,010)
University_Patents $_{t}$	0,001 (0,002)						
Faculty_Size $_{t}$	-0,001 (0,0001)						
Electronics dummy	-0,03 (0,172)					0,45 (0,334)	0,58 (0,336)
Chemical dummy	-0,05 (0,176)					0,12 (0,432)	0,16 (0,369)
Biology dummy	0.01 (0,163)					0,87 (0,293)***	0,91 (0,282)***
Wald chi-sq	78,49	342,54	353,66	342,78	324,10	72,07	73,92
Log-likelihood	-1756,52	-1754,19	-1754,42	-1756,12	-1400,74	-572,84	-572,27

*** 99% sign ** 95% * 90% [Breslow method for ties/Std errors adjusted for clustering on inventor]
(1) Obs. 9855 (592 subjects; 296 events)
(2) Obs. 10650 (592 subjects; 235 events)
(3) Obs. 10650 (592 subjects; 94 events, including INDIVIDUAL patents)

ness companies or «Open Science» institutes (22) ; they differ only in the way field dummies are entered (we will come back to this below). Equation 3 also refers to all patents, but publication data refer only to basic-science publications. Equations 4-5 and 6-7 refer to business companies' and «Open Science» patents, respectively. These equations include an additional dummy variable (*Inventor_status*), which takes value 1 for all inventors, starting on the year of their first patent. It controls for the possibility that some inventors with Business patents may also patent for an Open Science institution (or vice versa), and that one patenting experience may affect the hazard rate for the other one. Its lack of significance reflects the low number (18) of academic inventors with both kinds of patents.

All equations suggest a positive association between patenting and publishing. First of all, we notice the positive and significant coefficient of *Productivity_Variation*$_{t-1}$, which implies that the hazard rate increases of about 11-13% with any additional paper published with the respect to a professor's average. It would be inappropriate to assign to this estimate a causal interpretation; however, it suggests that patenting and publishing are not alternative activities, and that patenting does not impose any significant publication delay to academic inventors (23).

This result goes against hypothesis 1 and 2, as it suggests that patenting and publishing are not alternative diffusion means, and that academic patenting does not imply a diversion of the scientist's effort away from basic research. Rather, there seems to be some degree of complementarity between basic research and patenting, as confirmed by Equation (3) in the table, which considers only publications on journals more oriented to basic science [*Productivity_Variation_(Basic)*$_{t-1}$], and finds again a positive coefficient. (Notice that this result is entirely due to Open Science patents (equation 7), as the coefficient of *Productivity_Variation_(Basic)*$_{t-1}$ is not significantly different from zero).

However, these results are not yet sufficient to shed light on the reasons for the patenting-publishing complementarity, that is to distinguish between hypotheses 3a, 3b, 3c, and between hypotheses 3c and 4.

In order to pursue this line of enquiry, we observe the coefficient of *Productivity*, which is positive and quite large. According to equation (1), by adding one paper to a professor's average productivity we obtain a 12% increase of the patenting hazard ratio. The impact of this variable does not

(22) We also add to this category the few patents assigned to individual inventors, as they do not originate from ties with industry and are most likely to result from some tacit arrangement between the academic inventor and her university's administration.

(23) We also tested Productivity_Variation$_{t-2}$, but it never appears significant.

change much when considering business patents as opposed to Open Science ones (equations 4 and 6). This suggests that it is more likely to capture a «productivity effect» at the individual level (as in hypothesis 4) rather than the effect of academic reputation on the chances to patent with industry (as in hypothesis 3c).

In equation (1), the value of the *Industry_Contacts* coefficient implies that a 1% increase in the stock of publications co-authored with industrial researchers (whose employers have at least one EPO patent) increases the hazard rate of about 4%. However, the effect holds only for academic inventors patenting with business companies (compare equations 4 and 6), which confirms hypothesis 3a: past cooperation with industry affects future chances of further contacts with industry (24).

In equation (1) none of the field dummies appears significant (pharmaceutical is the reference case). This excludes a direct effect of a professor's scientific field on the hazard rate. However, we tested for indirect effects, by interacting the field dummies with all the publication-related covariates. Neither the interactions with *Productivity_Variation* nor those with *Productivity* appear to be significant. On the contrary, scientific fields affect significantly the impact of *Industry_Contacts* on the hazard rate. Equation (5) suggests that the highest effect is recorded in the Pharmaceutical field, and the lowest in the Chemical field.

The field dummy for Biology appears to be significant for the Open Science patents (equations 6-7). This reflects the uneven distribution of patents between the Business and Open Science category, with the latter hosting a larger proportion of patents by Biology professors. This may also explain why $\mathit{Productivity\_Variation\_(Basic)}_{t-1}$ has a significant coefficient only for Open Science patents, as publications in molecular biology may at the same time refer to fundamental discoveries, and lead to patenting (a joint occurrence much less likely, in Chemical engineering).

All together, these results suggest that complementarity between patenting and publishing is largely due to individual productivity effects (as in hypothesis 4) and, for business patents, to the industry's support of scientific research (as in hypothesis 3b). Evidence on hypotheses 3a (industry provides knowledge assets) and 3c (academic reputation may be spent with industry) is less conclusive (see table 8).

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(24) This effect may be stronger than it looks at first sight: publications are count data, and one or two publications more with industrial co-authors may mean much more than a mere 1% increase in *Industry_Contacts* (for example, a mere 5% increase in *Industry_Contacts* means a 19% increase of the hazard rate).

Table 8 - Hypothesis to be tested and specification (expected signs)

	Productivity	Productivity Variation	Industry contacts	
HP1 (Alternative dissemination means)	?	- *	?	* stronger effect for business patents
HP2 (Basic-applied trade-off)	?	- *	? (+)	* all journals/«basic» journals
HP3 (Basic-applied complementarity)	?	$\boxed{+\ *}$	?	
HP3a (Past cooperation with industry provides knowledge assets)	?	$\boxed{+\ .}$	+	
HP3b (Past cooperation with industry makes easier more sponsorship)	?	$\boxed{+\ .}$	$\boxed{+\ *}$	* only for business-owned patents
HP3c (Academic reputation eases patenting with industry)	+ *	$\boxed{+\ .}$	?	* only for business-owned patents
HP4 (Individual productivity effect)	$\boxed{+.}$	? (+)	?	

NB Cells marked with $\boxed{.}$ refer to positive test results

The control variables also provide some interesting results. No age effects are observed, while a gender effect is detectable, with the disadvantage of women totally confined to Business patents. Many studies in the sociology of science have pointed out a negative gender effect on scientific productivity. What we have here is an additional gender effect on the probability of patenting with industry: women may be less likely to patent not only because they have a lower publication record (Long *et al.*, 1993), *but also* because they are at a disadvantage in getting support from industry.

At the level of institution, the share of academic inventors over the total number of a professor's department colleagues (*Industry_Contacts*), exerts some positive effect on the hazard rate, albeit a very limited one (a 50% higher share of academic inventors in the department means only a 1,5% increase of the hazard ratio). Once again, the effect is detectable for business-owned patents only. No other variable at the institution level is significant.

In table 9 we check for the robustness of our results by considering multiple events, that is by modelling the hazard rate for both the first patents and the following ones (25).

A few differences appear from table 7. The coefficient for *Productivity_Variation*$_{t-1}$ for Business patents is no more significant. This may be due to the fact that multiple Business patents are more frequent than Open

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(25) The Inventor_status dummy used in table 7 is here replaced by Patent_Stockt-1, that is the number of patents signed by the inventor up to t-1. This variable affects only the hazard rate for Open Science patents.

Table 9 - All patents (multiple events) - Estimated coefficients of the proportional hazard function (Cox model), by applicant type

	All applicants (1)	**Business companies (2)**	**Open Science inst.(3)**
Productivity_Variation $_t$	0,02 (0,022)	-0,001 (0,025)	0,06 (0,037)
Productivity_Variation $_{t-1}$	0,05 (0,022)**	0,04 (0,025)	0,07 (0,038)*
Productivity $_{,t}$	0,13 (0,037)***	0,12 (0,046)***	0,36 (0,107)***
Age $_t$	-0,01 (0,006)	-0,01 (0,008)	-0,01 (0,015)
Gender	-0,39 (0,145)***	-0,71 (0,193)***	0,15 (0,348)
Industry_Contacts $_t$	1,89 (0,668)***	2,51 (0,813)***	-1,14 (2,501)
Industry_Contacts $_t$ * *Electronics*	0,64 (0,80)	-0,11 (0,977)	-2,64 (3,849)
Industry_Contacts $_t$ * *Chemical*	-1,67 (1,059)	-2,62 (1,175)***	-24,3 (14,09)
Industry_Contacts $_t$ * *Biology*	-0,03 (0,916)	-0,61 (1,113)	4,33 (3,102)
Patent_stock $_t$	0,03 (0,015)**	0,02 (0,016)	0,07 (0,034)**
Department_Inventors $_t$	0,02 (0,004)***	0,03 (0,005)***	0,02 (0,010)*
University_Patents $_t$	0,003 (0,001)***	0,004 (0,001)***	-0,001 (0,003)
Faculty_Size $_t$	-0,0001 (0,000)	-0,0002 (0,000)	0,0006 (0,001)**
Theta	0,35 (0,140)***	1,09 (0,262)***	6,83 (1,522)***
Wald chi-sq	190,86	130,88	60,46
Log-likelihood	-3495,39	-2929,44	-965,07
N. of subjects	1143	1144	1147
N. of failures	561	472	163
N. of obs.	11482	11482	11482
N. of groups	592	592	592

*** 99% sign ** 95% * 90%

science ones, and most often appear at a very short time distance (usually at no more than 1 or two years of distance). Exploration of the data suggest that in these cases no further increase of publication activity occurs after the first patent.

We also notice that the coefficient for *Productivity* is much higher for Open Science patents. The causes of this result are unclear. It may suggest a selection bias affecting university patents: due to the reluctance of universities and the other public research institutes to engage in patenting, only the most highly reputed scientists may convince their administration to pursue patenting.

Finally, table 10 reproduces equation (1) of table 9 only for a subset of 134 academic inventors, whose BA and PhD graduation years we recovered through interviews. The exclusion of the non-inventors gives much more weight, in the regression, to patenting events beyond the first one.

The role of *Productivity* is confirmed, but the time structure of *Productivity_Variation* looks somehow altered, as it is now the coefficient for current publications to affect significantly the hazard rate.

The gender effect disappears, while the field dummies enter the regression in a different way (for ease of exposition, Biology is now the reference case). We first notice that both the dummies for Electronics and Pharmaceuticals affect the hazard rate directly, as a result of the higher number of multiple patents by academic inventors in the two fields. The field variable again interact with *Industry_Contacts*, but now it is the coauthorship within the field of Biology that seems to affect most the hazard rate (Chemicals is still the field whether coauthorship matters less). Finally, the field dummies interact with the PhD dummy: holding a *PhD* affects more heavily the hazard rate of Biology professors than of any other else.

VI. — DISCUSSION AND CONCLUSIONS

Back in 1998, Keith Pavitt warned science and technology policy analysts not to rely on patent counts for measuring universities' contribution to technical change. Academic research contributes to technology advancement in many more ways than just through patenting. Alongside with the training of young scientists, the publication and dissemination of research results stand out as universities' key contribution to society. If patenting were to pose a threat to scientists' publication activity, we should certainly recommend to avoid granting IPR protection to academic research results.

Our results, however, suggest that no major trade-off exists between patenting and publishing: academic inventors do not publish less than their colleagues with no patents, not even right before the patenting event, and do not show any bias towards more applied, less basic science. If possible, our results indicate the opposite, that is the existence of a positive link, by which more productive professors are more likely to end up signing one or more patents. In this respect, our paper confirms the results obtained by Stephan *et al.* (2004) for the US case and Carayol (2004) for France, while are at odds with Agrawal's and Henderson's (2002) findings in their case study of MIT.

Table 10 - All patents (multiple events) - Estimated coefficients of the proportional hazard function (Cox model); inventors only

Productivity_Variation $_{t}$	0,05 (0,025)**
Productivity_Variation $_{t-1}$	0,01 (0,028)
Productivity $_{,t}$	0,06 (0,028)**
Industry_Contacts $_{t}$	4,86 (1,517)***
Industry_Contacts $_{t}$ ** Electronics*	-3,36 (1,531)**
Industry_Contacts $_{t}$ ** Chemical*	-5,90 (4,290)
Industry_Contacts $_{t}$ ** Pharma*	-4,58 (1,684)**
PhD	0,91 (0,1857)***
PhD Electronics*	-0,84 (0,369)**
PhD Chemical*	-1,09 (0,386)***
PhD Pharma*	-0,86 (0,364)**
Age $_{t}$	0,002 (0,011)
Gender	-0,19 (0,186)
Patent_stock $_{t}$	0,02 (0,027)
Department_Inventors $_{t}$	0,02 (0,004)***
Electronics dummy	0,82 (0,210)***
Chemical dummy	0,43 (0,219)**
Pharma dummy	0,55 (0,220)**
Wald chi2(22)	209,11
Log pseudo-likelihood	-1236,05
N. of subjects	384
N. of failures	254
N. of obs.	2541

*** 99% sign ** 95% * 90%

We also find that professors who exhibit, in a given year, an higher-than-average productivity are more likely to patent in the following year, which suggests that patents are most often the by-product of a fertile research project. If confirmed, this interpretation may also suggest that professors manage to publish (some of) their research results even before patenting, thus avoiding too long a publication delay. This association between patenting and publishing in the short run is in line with findings by Azoulay *et al.* (2004), and Markiewitz and DiMinin (2004). As for the latter we find evidence (albeit limited) of a weaker publishing-patenting association for business-owned patents as opposed to university-owned ones.

Former scientific collaboration with industry, in the form of co-authored papers, affects the probability to patent with Business companies. Academic fields such as Biology and Pharmaceutical, whose research results are more directly exploitable by industry, are those for which the effect is stronger. This result is in line with the broader literature on the importance of university-industry scientific partnership in the Pharmaceutical industry, and more generally in the science-based technology fields (Cockburn and Henderson, 1998).

An unforeseen result of our analysis point at an additional gender gap when it comes to patenting: women scientists, who have been often shown to be at a disadvantage in publication-based academic careers, suffer of additional difficulties when it comes to patent their research results with the support of industry. This is possibly due to women scientists' disadvantage at getting support from business companies.

As most of the patents signed by Italian academic inventors belong to industry, we cannot conclude that encouraging university patenting is advisable. In order to do so, we should first be reassured about the capability of university administrations to handle IPR issues wisely. Nor we can exclude that patenting inhibit cumulative research on published-and-patented research (as discussed in the Introduction). However, we can conclude that patenting does not seem to affect academic scientists' research targets, nor to inhibit their propensity to publish their research results. Patents by academic inventors are just a by-product of good research.

REFERENCES

AGRAWAL A., HENDERSON R. (2002), « Putting Patents in Context: Exploring Knowledge Transfer from MIT », *Management Science* 48, pp. 44-60.

AUTM (2003), « Licensing Survey 2003, Association of University Technology Managers », Northbrook IL.

AZOULAY P., DING W., STUART T.(2004), « The Effect of Academic Patenting on (Public) Research Output », paper presented at the NBER Summer Institute: « Academic Science and Entrepreneurship: Dual Engines of Growth ? », 23 July, Cambridge MA.

BALCONI M., BORGHINI S., MOISELLO A. (2003), « Ivory Tower vs Spanning University: il caso dell'Università di Pavia », *in* BONACCORSI A. (ed.), « Il sistema della ricerca pubblica in Italia », Franco Angeli.

BALCONI M., BRESCHI S., LISSONI F. (2004) « Networks of inventors and the role of academia: an exploration of Italian patent data » , *Research Policy* 33, pp. 127-145.

BALDINI N., GRIMALDI R. SOBRERO M. (2005), « Institutional changes and the commercialization of academic knowledge: A study of Italian universities' patenting activities between 1965 and 2002 », *Research Policy* (forthcoming).

BOK D. (2003), « Universities in the Marketplace », *Princeton University Press*.

BRESCHI S., LISSONI F., MONTOBBIO F. (2004), « Open Science and University Patenting: A Bibliometric Analysis of the Italian Case », paper presented at the 4th EPIP Conference on « European Policy and Intellectual Property », Paris Dauphine University, Paris, France, 1-2 October 2004.

CAMPBELL E.G. *et al.* (2002), « Data Withholding in Academic Genetics: Evidence From a National Survey », *Journal of the American Medical Association* 287, pp. 473-480.

CARAYOL N. (2004), « Academic incentives and research organization for patenting at a large French university », working paper (http://cournot2.u-strasbg.fr/EEAAS/carayol/research.htm).

CESARONI F., PICCALUGA A. (2003) « L'attività brevettuale degli enti pubblici di ricerca in Italia ed in Europa. Rilevante? In crescita? Utile ? », *in* : BONACCORSI A. (ed.), « Il sistema della ricerca pubblica in Italia », Franco Angeli, Milano.

COCKBURN I.M., HENDERSON R.M. (1998), « Absorptive capacity, coauthoring behavior, and the organization of research in drug discovery », *Journal of Industrial Economics XLVI*, pp. 157-182.

COLYVAS J., CROW M., GELIJNS A., MAZZOLENI R., NELSON R .R., ROSENBERG N., SAMPAT B.N. (2002), « How do university Inventions Get into Practice ? », *Management Science*, 48(1), pp. 61-72.

COHEN W.M, NELSON R.R, WALSH J.P. (2000), « Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not) », NBER Working Paper w7552, February.

DASGUPTA P., DAVID P.A. (1994), « Toward a New Economics of Science », *Research Policy* 23, pp. 487-521.

DOSI G., LLERENA P., SYLOS-LABINI M. (2005) « Science-Technology-Industry Links and the « European Paradox » : Some Notes on the Dynamics of Scientific and Technological Research in Europe », LEM Papers Series 2005/02, Scuola Superiore Sant'Anna, Pisa.

FELDMAN M.P., DESROCHERS P. (2004), « Truth for Its Own Sake: Academic Culture and Technology Transfer at Johns Hopkins University », Minerva 42, pp. 105-126.

GITTELMAN M. (2002) « The institutional origins of national innovation performance: Careers, organizations, and patents in the United States and France », mimeo.

HAMILTON K.S. (2003), « Subfield and Level Classification of Journals », CHI No. 2012-R, CHI Research Inc.

HELLER M. A., EISENBERG R.S. (1998), « Can Patents Deter Innovation ? The Anticommons in Biomedical Research », *Science* 280 (May) pp. 698-701.

HICKS D.M., S.J. KATZ, (1996), « Where is Science Going ? », *Science, Technology and Human Values* 21, pp. 379-406.

IVERSEN E.J., KALOUDIS A. (1999), « The changing role of patents and publishing in basic and applied modes of organised research », STEP Report series 1999/06.

JENSEN R., THURSBY M. (2001), « Proofs and Prototypes for Sale: The Licensing of University Inventions », *American Economic Review* 91/1, pp. 240-258.

K4I (2005), EP-INV dataset, http://www.k4i.it.

KALBFLEISCH, J.D., PRENTICE R.L. (2002), « The Statistical Analysis of Failure Time Data », John Wiley & Sons, New-York.

KNELLER R. (2001), « Technology Transfer: A Review for Biomedical Researchers », *Clinical Cancer Research* 7, pp. 761-774.

LONG J. S., ALLISON P. D., McGINNIS R. (1993), « Rank Advancement in Academic Careers: Sex Differences and the Effects of Productivity », *American Sociological Review* 58, pp. 703-722.

MANSFIELD E. (1995), « Academic research underlying industrial innovations: sources, characteristics », and financing *Review of Economics and Statistics* 77, pp. 55-65.

MANSFIELD E. (1998), « Academic research and industrial innovation : An update of empirical findings », *Research Policy* 26, pp. 773-776.

MARKIEWICZ K.R., Di MININ A. (2004), « Commercializing the Laboratory : The Relationship Between Faculty Patenting and Publishing », Econ 222/PHDBA 297-T: Seminar On Innovation, Haas School of Business.

MERTON R.K. (1973), « The Normative Structure of Science », *in* : STORER N. W. (ed.), « The sociology of science: Theoretical and empirical investigations », University of Chicago Press.

MEYER M., 2003. « Academics patents as an indicator of useful research ? A new approach to measure academic inventiveness ». *Research Evaluation*, vol. 12, numero 1, pp. 17-27.

MEYER M., SINILAINEN T., UTECHT J.T., 2003. « Toward hybrid Triple Helix Indicators: A study of university-related patents and a survey of academic inventors ». *Scientometrics*, vol. 58, pp. 321-350.

MOWERY D., NELSON R.R., SAMPAT B. N., ZIEDONIS A. (2004), « Ivory Tower and Industrial Innovation: University-Industry Technology Transfer Before and After the Bayh-Dole Act in the United States », Stanford University Press.

MOWERY D., SAMPAT B.N. (2004), « The Bayh-Dole Act of 1980 and University-Industry Technology Transfer: A Model for Other OECD Governments ? », *Journal of Technology Transfer* 30, pp. 115-127.

MURRAY F., STERN S. (2004), « Do Formal Intellectual Property Rights Hinder the Free Flow of Scientific Knowledge? Evidence from Patent-Paper Pairs », paper presented at the NBER Summer Institute: « Academic Science and Entrepreneurship: Dual Engines of Growth ? », 23 July, Cambridge MA.

NELSON R.R. (2001), « Observations on the Post-Bayh-Dole rise of patenting at American universities », *Journal of Technology Transfer* 26, pp. 13-19.

OECD (2003), « Turning Science into Business: Patenting and Licensing at Public Research Organisations », OECD, Paris.

PAVITT K. (1998), « Do Patents Reflect the Useful Research Output of Universities ? », *Research Evaluation* 7/2, pp. 105-112.

PAVITT K. (2001), « Public Policies to Support Basic Research: What Can the Rest of the World Learn from US Theory and Practice? (And What They Should Not Learn) », *Industrial and Corporate Change* 10, pp. 761-79.

ROSENBERG N. (1982), « How exogenous is science ? » *in* : « Inside the Black Box », Cambridge University Press.

ROSENBERG N. (1990), « Why Do Firms Do Basic Research (with Their Own Money) ? », *Research Policy* 19, pp. 165-174.

SAMPAT B.N. (2004), « Genomic Patenting by Academic Researchers: Bad for Science ? », mimeo (http://mgt.gatech.edu/news_room/news/2004/reer/).

SARAGOSSI S., van POTTELSBERGHE, de la POTTERIE B. (2003), « What Patent Data Reveal about Universities: The Case of Belgium », *Journal of Technology Transfer* 28, pp. 9-15.

SIEGEL D. S., WALDMAN D., LINK A. (2003), « Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study », *Research Policy* 32, pp. 27-48.

STEPHAN P.A., GURMU S., SUMELL A.J., BLACK G. (2004) « Who's patenting in the University? Evidence from the Survey of Doctorate Recipients », paper presented at the workshop on The empirical economic analysis of the academic sphere, BETA - Université Louis Pasteur, Strasbourg, March 17th.

APPENDIX

Table A1 - Disciplines (SSD) and fields; conversion table

Bio-chemistry (E05A)	Biology
Molecular biology (E05B)	Biology
Applied biology (E06X)	Biology
Human physiology (E04B)	Biology
Materials science and technology (I14A)	Chemical engineering & Materials technology
Macromolecular compounds (I14B)	Chemical engineering & Materials technology
Applied physics-chemistry (I15A)	Chemical engineering & Materials technology
Chemical engineering (I15B)	Chemical engineering & Materials technology
Industrial chemistry (I15E)	Chemical engineering & Materials technology
Electronics (K01X)	Electronics&Telecommunications
Electromagnetic fields (K02X)	Electronics&Telecommunications
Telecommunications (K03X)	Electronics&Telecommunications
Pharmaceutical Chemistry (C07X)	Pharmacology
Applied Pharmacology (C08X)	Pharmacology

Table A2 - Institutional and personal variables, inventor vs. control sample year 2000

	University size (1)		**Weight of the discipline in the univ. (2)**		**University weight in the discipline (3)**	
	Controls	**Inventors**	**Controls**	**Inventors**	**Controls**	**Inventors**
Chemical eng. & Materials tech.	909 *	784	1,2	1,5 *	8,9	8,9
Pharmacology	947 *	910	2,0	2,1	4,9 *	4,6
Biology	896 *	869	2,6	3.0 *	3,9	4,0 *
Electronics&Telecom	834	939 *	2,7 *	2,0	5,2	5,7 *
All fields	898 *	879	2,0	2,2 *	5,5	5,6 *

(1) n. of professors in the university (all scientific discipline); avg values
(2) n. of professors in the discipline in the univ. / n. of professors in the university (%); avg values
(3) n. of professors in the discipline in the univ. / n. of professors in the discipline, all Italian univ. (%); avg values
(*) Mean value significantly higher at .90 (t test)
Source : elaborations on EP-INV database and ISI Science Citation Index

Table A3 - Personal variables, inventor vs. control sample year 2000

	Gender (1)		**Age (2)**	
	Controls	**Inventors**	**Controls**	**Inventors**
Chemical eng. & Materials tech.	14 (22,2%)	9 (14,3%)	51.55	51.60
Pharmacology	32 (38,6%)	27 (32,5%)	51.84	51.26
Biology	29 (37,2%)	20 (25,6%)	50.83	50.79
Electronics&Telecom	5 (6,9%)	2 (2,8%)	47.77	47.95
All fields	80 (27,0%)	58 (19,6%)	50.52	50.40

(1) n. of females (and % of total professors in the discipline)
(2) avg values
Source : elaborations on EP-INV database and ISI Science Citation Index

Table A4 - Top applicants of patents by academic inventors and patent concentration index, by field

Field/Applicant	**n. of patents**	***% over field***
Chemical eng. & Materials technology		
ENI Group	34	21,1
Montedison Group	16	9,9
Novartis AG	9	5,6
CNR (National Research Council)	9	5,6
Sisas Spa	8	5,0
	Herfindhal index (1-100)	*6,91*
Pharmacology		
Mediolanum Farmaceutici	19	8,4
SkyePharma PLC	17	7,5
Pfizer	14	6,2
CNR (National Research Council)	11	4,8
Lisapharma	8	3,5
	Herfindhal index (1-100)	*2,96*
Biology		
Instituto Angeletti	13	7,8
CNR (National Research Council)	11	6,6
MIUR (Ministry of Education & Research)	6	3,6
	Herfindhal index (1-100)	*2,13*
Electronics&Telecom		
ST Microelectronics	91	37,4
Optical Technologies	14	5,8
Selenia industrie elettroniche	12	4,9
Siemens AG	12	4,9
niversita degli studi di Roma «La Sapienza»	11	4,5
	Herfindhal index (1-100)	*15,55*

NB. Patents owned by more than one applicant were counted more than once; total number of patents in this table > actual total number
Source : EP-INV database