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THE SCIENTIFIC PRODUCTIVITY OF ACADEMIC INVENTORS: NEW EVIDENCE FROM ITALIAN DATA

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We investigate the scientific productivity of Italian academic inventors, namely academic researchers designated as inventors on patent applications to the European Patent Office, 1978–1999. We use a novel longitudinal data set comprising 299 academic inventors, and we match them with an equal number of non-patenting researchers. We enquire whether a trade-off between publishing and patenting, or a trade-off between basic and applied research exists, on the basis of the number and quality of publications. We find no trace of such a trade-off, and find instead a strong and positive relationship between patenting and publishing, even in basic science. Our results suggest, however, that it is not patenting *per se* that boosts scientific productivity, but the advantage derived from solid links with industry, as the strongest correlation between publishing and patenting activity is found when patents are owned by business partners, rather than individual scientists or their universities.

Keywords: Scientific productivity; Academic inventors; University patents

JEL codes: O34; O31

1 INTRODUCTION

The phenomenon of university patents has recently attracted a good deal of attention, not just from within the specialized fields of the Economics of Innovation, IPR Law Studies, and the Sociology of Science, but also from policy-makers and university administrators.

Fascinated by the impressive growth of patents granted to US academic institutions, as well as by a number of success stories involving a few US universities' wise handling of IPR issues, many European governments have both reformed national IPR legislation concerning academic research and encouraged universities to undertake pro-active technology transfer policies.[1]

New laws have been issued, which modify the IPR regime of academic scientists' inventions, with the declared intention of providing the right economic incentives for individual scientists

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[1] On the growth of US university patents, see Mowery *et al.* (2004). Cross-sectional evidence on European countries can be found in OECD (2003); the report also provides information on the policy trends with respect to IPR matters in universities. On IPR management by US universities see Thursby *et al.* (2004).

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to undertake more 'useful' (that is 'patentable') research.[2] In the same spirit, universities are encouraged to introduce more pro-active IPR management strategies, witness the support provided to the creation of university technology transfer offices all over Europe (Schmiemann and Durvy, 2003).

Universities end up dealing with IPR matters also when engaging in contract research for, or co-operative research with business partners, two practices which have also been greatly encouraged. R&D-intensive companies seek patent protection more often nowadays than before, and universities increasingly value those companies both as research sponsors and as co-applicants for public funds. It may follow that scientists give increasing weight to the 'patentability' of research results, when choosing their objectives and drafting their projects.[3]

The increasing attention devoted to university patenting, and to the patenting of academic research results in general, has not been met without controversy. Fears that increasing commercialization of academic science may lead to restrict the free circulation of ideas within the academy are widespread. Are scientists engaged in patent-oriented research forced to suspend their publication activities, to publish selectively, or to limit informal exchanges with their colleagues? Or to twist their research efforts, moving away from the pursuit of basic science (and research results of general interest), towards proving the industrial applicability of their discoveries (a matter of exclusive interests of technologists, venture capitalists, and patent examiners)? Outlined at first in the US, especially within the field of biomedical research, such fears are now reaching Europe.[4]

In this paper, we present a few stylized facts from a new dataset on the publication scores of Italian academic inventors, which challenge those fears but also raise a number of questions for future research. By 'academic inventors' we mean those university scientists who have been designated as inventors on patent applications filed by the scientists themselves, their universities, or, most often, a business company. The productivity of academic inventors is compared to that of their colleagues with no patents in their curricula.

In section 2, we discuss the possibility that academic inventors may face a trade-off between patenting and publishing or between the basic and applied nature of their research. We also present a counter-argument to the existence of both kinds of trade-offs, namely the possibility for academic inventors to be better funded and address more challenging research questions. We consider also the possibility that academic inventors simply are more brilliant scientists than their colleagues, so that they manage to achieve a higher number of results, possibly also of greater relevance, which are both publishable and patentable.

Section 3 provides a description of data and methodology. We describe how we built a novel longitudinal data set comprising 299 Italian academic inventors, matched to an equal number of non-patenting researchers, by combining three different sources: the EPO-CESPRI database, which contains all patent applications to the European Patent Office (EPO), 1978–1999; a list of university professors' names and affiliations, which we obtained from the Italian Ministry of Education; and publication data from ISI Web of Science.

In section 4, we provide evidence of a higher-than-average scientific productivity of academic inventors. We also observe that patents are discrete events that seem to be associated with an increase in the productivity of individual scientists.

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[2] For example, the German and Danish legislators have recently abolished the so-called 'professor's privilege', by which university professors differed from other public and private employees, in that they retained all the IPRs over their own discoveries (PVA-MV, 2003). At the same time, the Italian government introduced a law going in the opposite direction, and established the 'professor's privilege' in a country where it had never existed before.

[3] On the increasing propensity to patenting of business firms, see Hall (2004), who suggests that the trend has been the strongest in the US, but noticeable also in the EU and Asia.

[4] For a comprehensive survey of studies finding negative effects of university–industry links on the quality of academic biomedical research see Bekelman *et al.* (2003). A general feeling of how sensitive US biomedical researchers are to this subject matter can be derived from reading Gelijns and Thier (2002), and the reactions it spurred among the readers of the Journal of the American Medical Associations.

In the Conclusions, we compare our results with the existing empirical evidence on the same topic, and sketch open issues for future research.

2 PATENTING–PUBLISHING TRADE-OFF: ARGUMENTS AND COUNTER-ARGUMENTS

In this section, we outline a few reasons why we could expect to observe a negative relationship between patenting and publishing, and a few reasons why we may expect the contrary. We discuss the implications of each argument for the scientists' observed publication trends.

2.1 The Publication Delay and Basic/Applied Trade-offs

The most intuitive argument against patenting academic research results stresses the possibility of a direct trade-off between patenting and publishing. In its mildest form, the trade-off can appear as a 'publication delay' dilemma: researchers concerned with patenting may be forced to wait before publishing any news on those discoveries, and keep them secret as long as the patent application has not been filed, in order to avoid burning the 'novelty step' of the application. Not only submitting a paper to a journal, but also discussing it at conferences and workshops could invalidate the effort to obtain a patent (Loughlan, 1998; section D).[5]

A deeper concern regards the contents of academic enquiry, which may be diverted from 'basic' towards 'applied' research. While the former can be portrayed as the unconstrained exploration of nature and theory, the focus of the latter is closer to 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.[6]

More generally, patents are the result of an incentive scheme at odds with the priority reward system which has governed the scientific community since the XVIII century, as described by Merton (1973). Even if both systems 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 have very different disclosure rules and attitudes towards cooperation. The priority reward system forces 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 (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). Firms wishing to market their technologies offer jointly licences on fully codified, IPR-protected inventions, and complementary services based upon tacit skills protected by secrecy (Arora *et al.*, 2002). More generally,

[5] 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).

[6] Relying on Nelson's words: 'The loose defining of goals at the basic research end of the spectrum (vs. the applied research end) is a very rational adaptation to the great uncertainties involved and permits a greater expected payoff from the research dollar than would be possible if goals were more closely defined' Nelson, 1959; p. 300.

restrictions on informal discussion of research results may apply. As long as secrecy complements patenting, academic scientists who are more committed to patent-oriented research may find it difficult, or not convenient, to publish all of their research results.[7]

With the data in our possession, we track academic inventors' publication activity over time and check whether it slows down right before the patent application date, possibly to bounce back right afterward; if these were the case, we could then cautiously interpret such pattern as compatible with the *publication delay hypothesis*. More rigorous testing of the hypothesis would require information not just on the publication date of academic papers, but also and especially on the submission date, to be compared with the application date of patents. Unfortunately, submission dates are available only for a few journals and cannot be easily derived from the publication dates taking into account refereeing time: the latter varies greatly across fields and journals, and we are not aware of any reliable methodology for calculating it.

In order to test the 'basic-applied trade-off' argument, we need additional information on the quality of publications, such as a classification of journals according to their topics and/or information on the citation impact of the inventors' publications (section 3). One may suspect academic inventors to be scientists who have built their career upon applied research objectives (in which case the quality of their scientific production should be lower than their controls' throughout their career). Alternatively, one may presume that academic scientists engage in more applied projects on an occasional basis: by dealing with patents as 'discrete events' we manage to focus on a window of time during which, if the basic-applied trade-off argument was correct, a shift towards more applied research should appear.

2.2 Resource Effect and Individual Productivity Effect

Patenting and publishing may also be positively related as a result of a 'resource effect'. This suggests that the individual researcher addresses his/her research (or part of it) to IPR-relevant objectives in order to access additional resources. The history of science–technology relationships is punctuated by co-operative efforts between scientists and industry, which have provided scientists not just with financial resources and free access to expensive scientific instruments, but also with 'focussed' research questions, data, and technical expertise (cognitive resources). 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: as far as an academic scientist's patenting record is a good proxy of the scientist's involvement with industry in project with high scientific content, we should expect a positive association between patents and publications (both in quantity and quality).[8]

We test the resource effect looking at the publication behaviour of scientists around the filing date of the patent. We expect to observe an increase of the inventor's publication rate right before or after the application date of the patent. Additional information on patent applicants may improve our analysis. To the extent that industry may provide the university scientist with additional funds, instruments, and interesting questions, we expect the resource effect to show up much more clearly for patents applied for by business companies, with the scientists appearing just as designated inventors, rather than by the scientists themselves or their universities (or public funding agencies). We also expect the most significant increase in the number

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[7] More threats to the overall quantity and quality of scientific publications come from the increasing cost of accessing research tools (Heller and Eisenberg, 1998), or the scientists' bias when testing products and technologies owned by their business sponsors (as in clinical tests; Campbell *et al.*, 2002).

[8] The classic reference on 'cognitive' resources is Rosenberg, 1982, ch.7. For some recent empirical evidence, see Mansfield (1995, 1998) and Siegel *et al.* (2003).

of publications to occur when an inventor signs a 'string' of related patents in a short spell of time, as a result of a prolonged technology-oriented research effort.

It may not be easy to tell the 'resource effect' apart from the 'publication delay' one, despite their opposite impact on publication activity. In both cases, we expect publications to increase right after the patent, in one case because the technology-oriented research effort has been very fruitful, in the other because the scientist has finally re-gained the freedom to publish. Notice also that the two effects may complement each other, since it may well be that scientists are willing to delay their publications in exchange for additional resources. However, a publication delay should also cause a reduction of the number of publications *before* the patent (which is not the case for the resource effect hypothesis); while the resource effect, if strong, could lead to a more sustained spell of high publication activity after the patent.

One further reason for observing an association between patenting and publishing is provided by what we call the 'individual productivity effect' argument. This hypothesis simply suggests that both patents and publications are proxies of a scientist's ability and productivity. We may expect highly productive scientists to have more chances to come out with patentable ideas than their less brilliant colleagues. We refer here to individual characteristics, which we presume to mark the scientist's propensity to publish irrespectively of the resources the scientist may have derived from each patent: we should then observe that academic inventors exhibit higher-than-average levels of publication activity, throughout their career, well before and after the patenting years.

3 THE DATA AND MATCHING CRITERIA

In this paper, we use data from the EP-INV-DOC database which is a subset of the EP-INV database (for a comprehensive description, see Balconi *et al.*, 2004). The EP-INV database contains all patent applications to the EPO which designate at least one inventor with an Italian address, from 1978 to early 1999. The EP-INV database has information on 30243 inventors and 38868 patent applications.

The EPO-INV-DOC database is dedicated to 'academic inventors', namely university researchers and professors who appear as designated inventors on one or more patents in the EP-INV dataset. The database is obtained by crossing the EP-INV dataset with the complete list of academic staff of science and engineering departments in year 2000 (27844 individuals). The EP-INV-DOC database is composed by 919 Italian academic inventors. The list of professors was provided by MIUR, the Italian Ministry of Education and Research and contains information on the individuals' age, affiliation, discipline, and academic ranking ('researcher', associate professor, and full professor). Disciplines are defined according to a classification created for administrative purposes; the classification is very detailed and allows some compression into broader categories, which are referred to as 'fields' (see Tab. A1 in the Appendix).[9]

In this paper, we focus on a few fields with a very high share of academic inventors over the total number of professors. The fields are 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 (Tab. I).

[9] 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 I Italian university professors in 2000, selected fields.

Field	*Professors, active in 2000*	*of which: Academic inventors, no. and (%)*
Chemical engineering and materials technology	355	66 (18.5)
Pharmacology	613	84 (13.7)
Biology	1359	78 (5.7)
Electronics and telecom	630	73 (11.6)
Total	2957	301 (10.22)

Source: EP-INV-DOC database.

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 (see Tab. A2 in the Appendix). Most of the selected inventors are full professors, born between 1940 and 1960 (see Tab. A3 in the Appendix).

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.[10] Each academic inventor was matched to a colleague never designated as inventor on either an EPO or an USPTO patent.[11] When possible, controls were chosen among the academic inventors' department colleagues or from universities 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. 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 find very limited differences between inventors and controls (see Tab. A4 in the Appendix).[12]

3.1 Patent Data

The distribution of patents across academic inventors is highly skewed; on average 63% of professors have signed only one patent, and only 8% more than six (Tab. II). 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

[10] 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).

[11] For academic inventors born in between 1950 and 1970, we allowed for no more than five years of age difference with the controls. For professors born before 1950, the maximum age difference was seven years. For academic inventors born after 1970 (just one), the maximum age difference reduced to three years. Exceptionally (no more than ten 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: three and five years, respectively).

[12] 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 have measured the university size with the total number of professors (in hard science). We have also calculated the weight of each professor's discipline within that professor's university, as the ratio between the number of professors in the discipline in the university and the university size; this may be indicative of the importance (and resources) attached to that discipline by the university. We have also calculated the weight of a professor's university in the professor's discipline at the national level, as the ratio between the number of professors in the discipline in the university and the total number of Italian professors in the same discipline; we take this weight as indicative of the prestige of the professor's university within his discipline. The absence of major differences between inventors and controls with respect to these indicators suggest that we are avoiding comparing individuals from marginal colleges with colleagues coming from top institutions.

TABLE II Distribution (%) of academic inventors by no. of patents and field.

	No. of patents			
Fields	*1*	*2–5*	*6+*	
Chemical engineering and materials technology	60.9	32.8	6.3	100
Pharmacology	63.1	28.6	8.3	100
Biology	70.5	23.1	6.4	100
Electronics and telecom	56.2	31.5	12.3	100
Total	62,9	28.8	8.3	100

Source: EP-INV-DOC database.

TABLE III Ownership of academic inventors' patents† by type of applicant and field; no. (%) of patents.

	Business companies	*'Open Science' institutions*‡	*Individuals*¶	*Others (n.e.c.)*	*All applicant types*
Chemical engineering and materials technology	125 (78,1)	18 (11.3)	15 (9.4)	2 (1.3)	160 (100)
Pharmacology	192 (85,0)	24 (10.6)	10 (4.4)	–	226 (100)
Biology	91 (54.5)	43 (25.7)	30 (18.0)	3 (1.8)	167 (100)
Electronics and telecom	199 (81.9)	28 (11.5)	13 (5.3)	3 (1.2)	243 (100)
All fields	607 (76.3)	109 (14.2)	68 (8.5)	8 (1.0)	796 (100)

†Patents owned by more than one applicant were counted more than once.
‡Universities, public labs and government agencies; both Italian and foreign.
¶Same applicant's and the inventors' names.
Source: EP-INV-DOC database.

individual and university-owned patents (Tab. III). We cannot be sure that all academic inventors signed their 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, since Italian professors usually start pursuing the academic career right after graduating.

As for IPRs over public-funded 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, and could meet some bureaucratic resistance by the funding institutes.

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. As a result, few patent applications from public-funded research are completed, and even less are extended outside the national level (so they do not appear in our dataset). It also happens that many professors take the shortcut of patenting in their own names: this explains the presence of a few inventors' own patents.[13]

Table A5 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 belong to ST Microelectronics. In Italy, it is the largest semiconductor company and one

[13] 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.

of the very few large hi-tech companies.[14] 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 high among patent applicants. However, it should be noticed that, in many cases, the CNR and the universities enter Table A5 as co-applicants along with business companies, as a result of public-funded co-operative research projects.

3.2 The Publication Data

Our data on the scientific publications of both the academic inventors and their controls come from the 2003 web edition of the ISI Science Citation Index (SCI), starting from articles published in 1975. For each article, the same source provided us with all the forward citations up to 2003, which we used for weighing the quality of each professors' publications.

Information on a professor's research targets (basic vs. applied) come 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. Score 1 refers to the most applied kind of research and score 4 to the most basic.[15]

The publication dataset we assembled following these criteria has two main drawbacks. First, it is left-censored: we do not have information on when our professors started their research careers, as we do not know when they completed their studies or got their first academic job.[16] An individual with zero publications in a given year may be either a future scientist whose career has not yet started, or an active scientist experiencing a productivity slowdown. To solve this problem, we decided to include in each year's sample only the academic inventors who were at least 25 year old in that year, and the related controls (e.g. a professor born in 1965 and his control are included in the sample only from 1990).[17]

We also set an upper age limit at 70: this is because a few professors active in 2000 were already near that age, and we presume them not to have been any more active later on. We also experimented with a lower limit, but this led to the loss of too many publications after 1995. These rules bear no relationship with the inventor/control status, therefore they should not affect the conclusions we reach. But, it is important to use our data only for comparing academic inventors to their controls, and not for other purposes, such as observing a time trend in scientific productivity.

A second issue is related to the use of ISI-SCI as a source of information, both at a general level and for the Italian case. In general, we may expect the number of publications per-capita to change over time, simply because the composition of journals included in the ISI-SCI

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[14] In particular, ST Microelectronics has a long cooperation record with the Department of Electronic Engineering of the University of Pavia (Balconi *et al.*, 2003). The multinational group ENI plays a similar role in Chemical Engineering, although it does not exhibit similarly close ties with one speficic university.

[15] 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: 1 = 'clinical observation' (eg. Journal of the American Medical Association) 2 = 'clinical observation and investigation' (eg. New England Journal of Medicine) 3 = 'clinical investigation' (eg. Journal of Clinical Investigation) 4 = 'basic biomedical research' (eg. Journal of Biological Chemistry) In the second case the correspondence is: 1 = 'applied technology' (eg. 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)

[16] Notice also that most Italian professors born before 1960 had no PhD at all: those pursuing an academic career simply served as teaching and research assistants of their B.A. thesis supervisors for a few years, while attending seminars and studying on their own. Thus, we may expect that older professors started publishing earlier than younger ones, who more frequently went on taking a PhD after completing their undergraduate studies. In addition, the Italian system is such that young graduates may hold a research assistant and post-doc position (often as informal jobs) for a long while before securing an academic job such as those listed in our database.

[17] Italian students leave high school at 19 and most degrees requires five years of courses, and a final dissertation (which in a few cases may be a non-negligible piece of research). This makes 25 the earliest possible graduation age; in addition, we noticed that by choosing even a slightly later age, too many publications in the time interval 1975–1985 went lost.

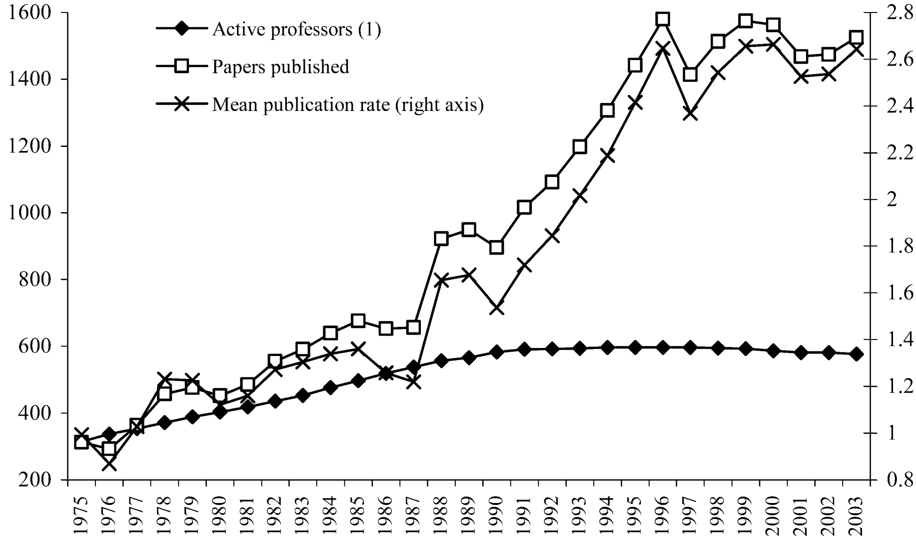

FIGURE 1 Number of professors and publications per year, 1975–2003.
(1) Active professors = professors aged between 25 and 70.
Source: EP-INV-DOC database.

database may change. As for Italy, until recently, the academic career system did not reward high publication rates, even less publications in English. Besides, until the 1980s, it was still a rare event for Italian graduates engaging in academic careers to complete their PhD and to publish their first papers abroad. These two facts conjure up to make the ISI-SCI a much more reliable source of information on the scientific productivity of later cohorts of professors, rather than the early ones.

In figure 1, the left axis reports both the number of professors aged between 25 and 70 in each year since 1975 (inventors and controls together), and their publication numbers; the right axis reports yearly publications per capita. The number of professors in our sample increases at a much slower rate than the number of publications, until about 1997. As a result, the number of publication per capita increases dramatically, especially in 1988 and after 1990: the later cohorts of professors we add progressively to the database have in fact a much larger number of papers listed in the ISI-SCI database than professors from earlier cohorts. After 1997, the number of publications in our database stops increasing altogether.

4 ANALYSIS

In this section, we first compare the scientific productivity of inventors and controls over the 1975–2003 time interval. We then move to examine the influence on scientific productivity of individual patents as 'discrete events', by comparing the scientific productivity of inventors and controls over a seven-years time interval around each patent.

4.1 The Scientific Productivity of Inventors and Controls: General Patterns

The differences between the publication rates of inventors and controls are displayed in Table IV. They reveal the superior productivity of the academic inventors. The mean number of cumulated publications of the inventors from 1975 to 2003 is sensibly higher for the inventors relatively to their controls. The non-normality of distributions suggested to test whether the differences between inventors' and controls' cumulated publications are significantly different

TABLE IV Cumulative publications 1975–2003; by field and type of inventor.

	Inventors			*Controls*			
	Mean	*Median*	*Skewness*	*Mean*	*Median*	*Skewness*	*N*
Fields							
Chem. eng. and Materials tech.**	51.2	36	3.1	32.3	26	1.7	64
Pharmacology**	57.1	51	1.1	44.3	40	1.0	84
Biology	66.8	51.5	2.7	47.4	35	2.0	78
Electronics & Telecom**	38.2	37	0.9	29,8	22	2.1	73
All Inventors**	53.7	43	3.0	39.0	32	1.8	299

*- **Inventor-control distribution difference significant at 0.90-0.95 (Kolmogorov–Smirnov test).
Source: elaborations on EP-INV-DOC database and Science Citation Index.

from zero using a non-parametric test: p-values for the Kolmogorov–Smirnov statistics show the differences to be always significant, at 0.95, with the exception of the Biology field.[18]

However, both the empirical literature on scientific productivity and the theoretical fundamentals of the sociology of science suggest that looking at mean comparisons may be misleading, since the distribution of professors over the number of their publications is usually found to be highly skewed to the right. Our data make no exception. Table IV shows that all fields but Pharmacology exhibits a skewness index greater than 1 for both the inventors' and the controls' distribution; notice also that for all fields and all classes of inventors the median number of publications is well below the mean.

Table IV also shows that, with the exception of the field of Chemical Engineering, the inventors' skewness index is never higher than the controls' index: this result suggests that the inventors' mean figures compare favourably against the controls' not because of some hyper-productive outlier, but as a result of a widespread phenomenon.

The superior productivity of inventors is confirmed when moving to yearly publication data. Figure 2 provides a snapshot of the mean number of publications for both the academic inventors and the control sample, for each year from 1975 to 2003. Dark grey areas indicate that the differences between inventors and controls publications per capita are significantly positive at the 0.95 significance level (light grey areas: 0.90).

This suggests a clear superiority of academic inventors over their controls, even in early years (such as those before 1985), that is before most of the academic inventors had signed their first patent (see especially 1978, 1979, and 1982). However, academic inventors' superiority is particularly evident during the 1990s, for which our sample of inventors is more representative, and the publication data more reliable.

Calculations by field suggest minor differences across disciplines (Tab. A6 in the Appendix). In particular, differences between inventors and controls over the 1970s and early 1980s are more significant for the chemical field, wherein patents by academic inventors are indeed slightly older than average. In contrast, over the same years, inventors in the electronic field (many of whom had not yet signed any patent) appear to be less productive than controls. Patterns in pharmaceuticals and biology are respectively more similar to electronics and chemicals. These observations mitigate the impression of a superiority of academic inventors due only to their status (individual productivity effect): the farther we move from the 'patenting years', the less the superiority appears undisputable.

We move then to compare citation-weighted publications. Each publication is multiplied by the number of forward citations received since the publication date up until 2003. Once again,

[18] However, we also computed t-tests for all fields and types of inventor, which suggest differences to be always highly significant.

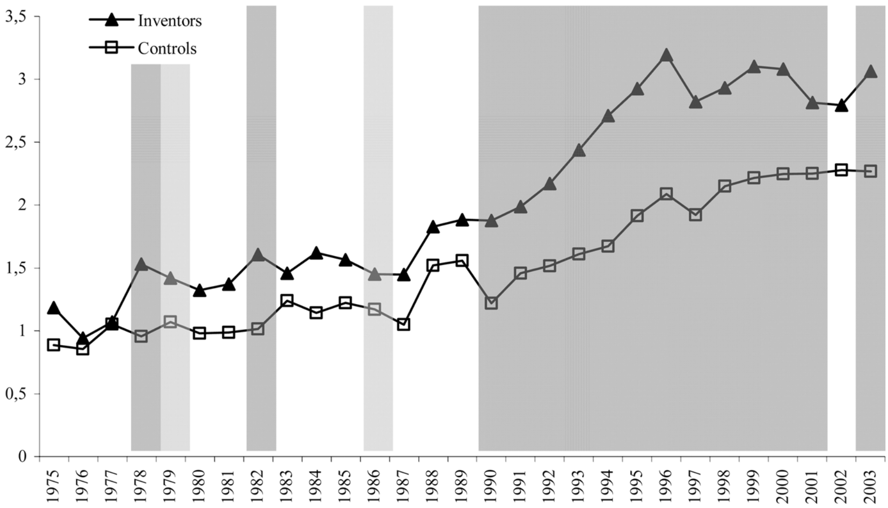

FIGURE 2 Yearly publications per capita, academic inventors vs controls; 1975–2003.
Dark (light) grey areas: inventor-control distribution difference 95 (0.90) significant; Kolmogorov-Smirnov test.
**Obs. range from 148 in 1975 to 298 in 1997 (284 in 2003).
Source: elaborations on EP-INV-DOC database and ISI Science Citation Index.

this means that our figures provide a useful comparison of the impact of academic inventors' publications with their controls'. However, they cannot be used to measure changes of that impact over time (late publications have so far received less citations that earlier publications of similar quality; and early publications appear to receive less publications simply because the older ISI-SCI editions monitored fewer citing journals).

Figure 3 confirms the academic inventors' superiority, but only up until 2000. After then, the citation impact of academic inventors seems to decline precipitously. We do not have found any explanation for this trend, but we observe that it is entirely due to one field: biology. In all other fields, citation-weighted publication rates exhibit the same patterns as un-weighed publications, and confirm the superiority of academic inventors even in late years (see again Tab. A6 in the Appendix). We also calculated the citation ratio (all forward citations to publications in year i/publications in year i) for each scientist: a comparison of mean values suggests that inventors' publications have a significantly higher impact than those of controls in 1978 and throughout the 1990s; the opposite holds in 2000 and afterwards, with academic inventors in biology again responsible for the decline (data available on request).

In order to control for the 'basic science' contents of publications, we calculated the number of yearly publications per capita using only the journals that have a 3 or 4 score in the CHI classification, that is journals oriented to basic science.[19] Even with this limitation, the inventors' superiority is confirmed, although with lower significance of distribution differences, especially for years before 1990 (Fig. 4).

4.2 The Scientific Productivity of Inventors and Controls: Patents as 'Discrete Events'

In this section, we treat patenting as a discrete event and check whether its occurrence coincides with a visible alteration of the academic inventor's publication rate. We calculate the 'inventor/control ratio' that is the ratio between the yearly number of per capita publications of the inventors and the number of per capita publications of the controls. An 'inventor/control'

[19] Limiting the comparison to 4-scored journals forced us to drop too any observations for any comparison to be meaningful.

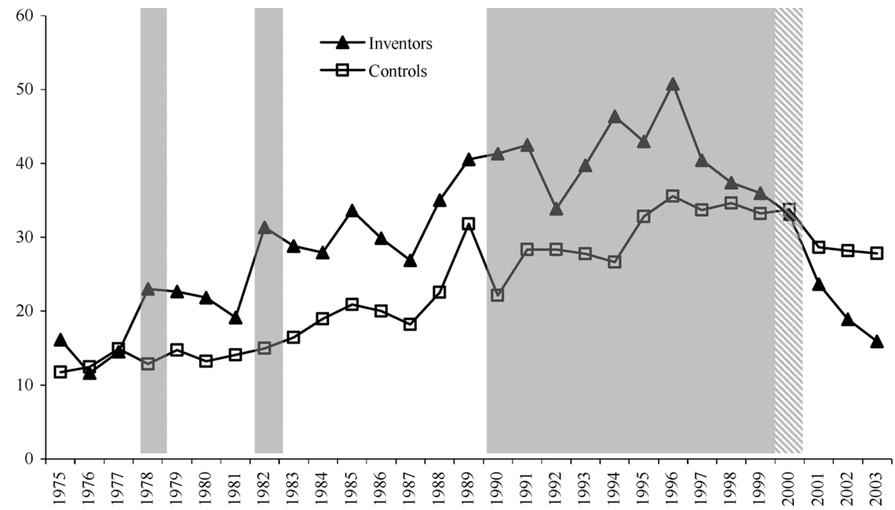

FIGURE 3 Yearly citation-weighted publications per capita, academic inventors vs controls; 1975–2003.
*Dark grey areas: inventor-control distribution difference 95 significant (striped areas: same significance, but in favour of controls); Kolmogorov-Smirnov test.
**Obs. range from 148 in 1975 to 298 in 1997 (284 in 2003).
Source: elaborations on EP-INV-DOC database and ISI Science Citation Index.

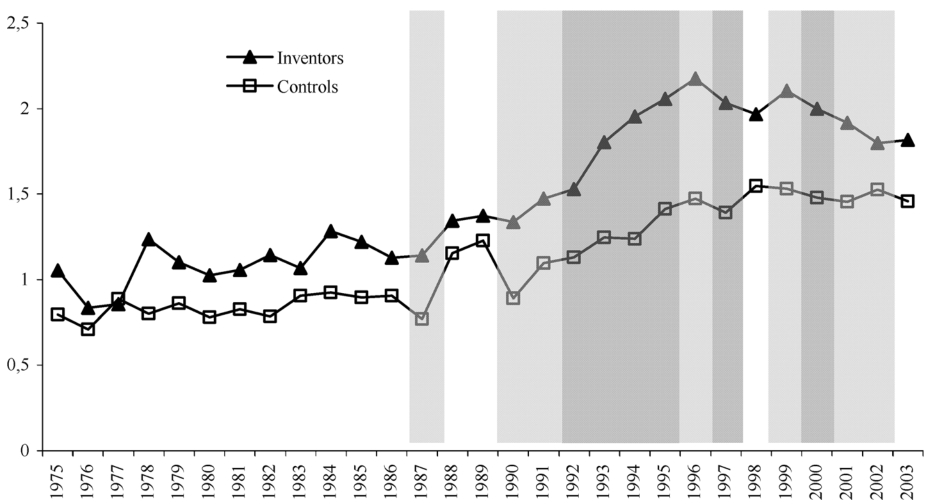

FIGURE 4 Yearly publications per capita, acad. inventors vs controls; basic science journals; 1975–2003.
*Dark (light) grey areas: inventor-control distribution difference 95 (0.90) significant; Kolmogorov–Smirnov test.
**Obs. range from 148 in 1975 to 298 in 1997 (284 in 2003).
Source: elaborations on EP-INV-DOC database and ISI Science Citation Index.

ratio higher than 100 (in percentage terms) indicates that an inventor is more productive than his/her control.

In particular, we examine the values taken by the 'inventor/control' ratio over the three years immediately before and after each patenting year. The patenting year is re-scaled at 0 (zero); the years before and after the patenting are re-scaled accordingly, from −3 to +3. If more than one patent is signed by an inventor in the same year, we include that inventor in our sampling only once. As before, we include in our calculations only inventors of age comprised 25 and 70, and so we do with the controls.

In this exercise, we do not consider citations because we pool publications from different time periods and the trend of the citations count is affected both by historical time and by the number of journals comprised in the ISI-SCI database: to correct for such trend (in order to avoid any interference with the effects of patenting) goes beyond the scope of this paper. We also set aside the distinction between applied and basic journals, as results in Section 4.1 suggest that counting only basic journals does not provide significantly different empirical evidence.

What we take into great account, on the contrary, is the type of patent around which we calculated the inventor/control ratios. As made clear in section 3, while most academic inventors sign just one patent, others sign more than one; besides, some of the patents appear as 'series' of two or more applications signed in a few years time.

4.2.1 'Stand-alone' Patents vs. Series of Patents

Thus, in what follows, we consider separately what we call 'stand-alone' patents (patents signed by inventors who signed only that patent); 'first-of-two' and 'last-of-two' (first and last patent by an inventor with two patents); 'first-in-a-series', 'last-in-a-series' and 'in-between' patents (first and last patent by an inventor with more than two patents, and the patents in between).

Figure 5 considers stand-alone patents and patents from series of two, as well as the whole patent sample. The inventor/control ratio calculated over all patents exhibits an increasing trend, which we suspect to derive from the characteristics of our data (from the 1980s and throughout the 1990s, the yearly publication gap between inventors and controls has greatly increased, possibly because the ISI-SCI data have become more accurate; see section 3). A similar trend, albeit much more tenuous, is observed for the sub-sample of stand-alone patents. Taking into account this trend, stand-alone patents do not seem to affect much the inventor/control ratio, which remains always greater than 100, and does not vary much before

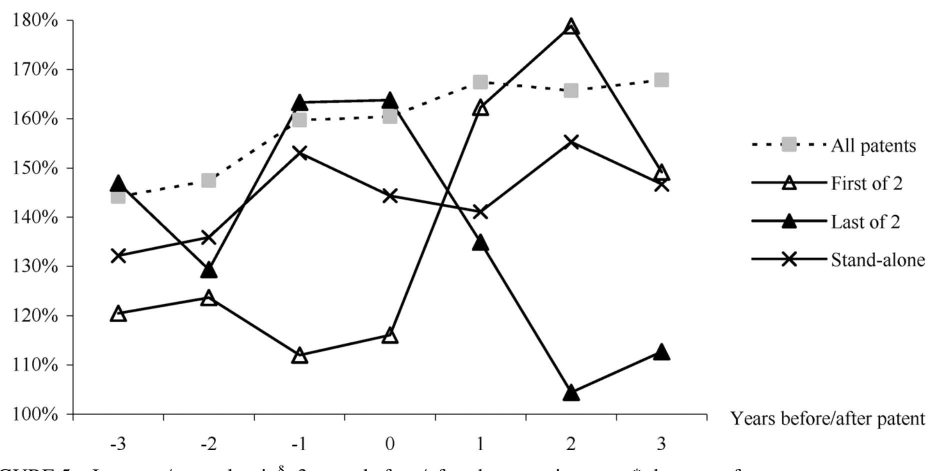

FIGURE 5 Inventor/control ratio§, 3 years before/after the patenting event*; by type of patent.
§Yearly no. of per capita publications of the inventor/yearly no. of per capita publications of the control (mean values).
*Patenting year = 0.
1. First/Last patents (50 obs) = First/Last patents by inventors with two patents.
2. Stand-alone patents (176 obs) = Inventor's only patent.
3. All patents: 546 obs.
Source: elaborations on EP-INV-DOC database and ISI Science Citation Index.

or after the patenting year. Notice also that the values of the inventor/control ratio for stand-alone patents are always inferior to the values calculated for all patents.

Patents coming from strings of two affect much more extensively the publication activity of inventors. As for 'first' patents, we detect a slight decrease of the ratio one year before the patent application, and a sharp increase afterward, for about two years. On the contrary, after 'last' patents, we observe a sharp decrease right after the patenting year; as for the decrease of the inventor/control ratio two years before the patent application, we presume that it is the same trend already captured by 'first' patents, as most of the patents in a series of two are very close in time (applications in two subsequent years).

We may presume that the first and last patents stem from the same research project, as many of them belong to the same applicant. This suggests that projects with higher impact may generate both more than one patent, and a stronger effect on the publication activity of inventors. We also notice that the value of the inventor/control ratio for first/last patent reaches that for all patents only during peak times.

This impact is compatible with both a resource effect (especially considering that stand-alone patents seem not to exert much influence) and a publication delay effect. As for the latter, however, caution applies as we do not know when the publications were first submitted to the journals (see the methodological remarks in section 3.2).

Similarly, although less clear-cut evidence comes from the examination of patents from longer series (Fig. 6). Here we observe a decrease of the inventor/control ratio two years before the first patent application (first in a series), and a much sustained increase afterward. Similarly, we notice a decreasing trend after the last one (last in a series). Values around the in-between patent applications exhibit a steady increase, much steeper than what was discernible for all patents. The inventor/control ratio for in-between and last patents is always higher than what observed for all patents, thus suggesting a strong impact on the inventors' scientific productivity of the research projects underlying the patent (the opposite occurs for occasional patents and for patents that are first and last in a series of two).

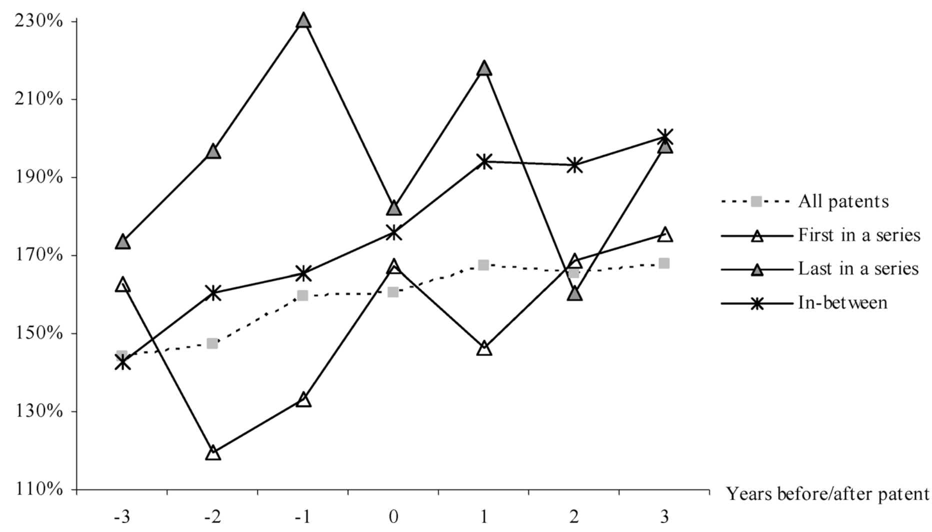

FIGURE 6 Inventor/control ratio§, 3 years before/after the patenting event*; by type of patent.
§Yearly no. of per capita publications of the inventor/yearly no. of per capita publications of the control (mean values).
*Patenting year = 0.
1. First/Last patents (55 obs) = First/Last patents by inventors with two patents.
2. Stand-alone patents (160 obs) = Inventor's only patent.
3. All patents: 546 obs.
Source: elaborations on EP-INV-DOC database and ISI Science Citation Index.

4.2.2 Business-Owned vs. University-Owned Patents

We finally observe the impact of patents owned by different applicants, namely business companies ('private technology' patents) and open science institutions (Fig. 7). The inventor/control ratio around 'open science' patents increases sharply before the patenting year, to decline right afterwards, while the trend around 'private technology' is strictly increasing. We also notice that the value of the inventor/control ratio for open science patents never reaches that of private technology ones, except for the peak year.

On the one hand these results may be explained by the different size and composition of the two groups of patents; on the other hand, the results suggest that the nature of the relationship between patenting and publishing at the individual level may be different in the two cases. Open science patents are fewer, and they are either of the stand-alone or first/last-from-two kind, with the latter largely responsible for the peak on the patenting year. Almost all of the patents from long series belong to the 'private technology' group, which explains the higher level of the inventor/control ratio; as for the ever-increasing trend around the patenting year, this is largely set by the high number of in-between and stand-alone patents. However, the nature of the relationship between patenting and publishing may be different in the two cases. Open science patents seem to be linked to a particularly successful research project and to a specific increase of the number of publications. Private technology patents suggest (in particular when they come in a series) that a (stable) relationship with firms is in place and this is associated to a particularly high inventor control ratio.

Overall, the results presented in this section suggest that there is a role for the 'resource effect. Patents that come in series, possibly from the same research project or a continuative relationship with industry, are associated with both a stronger effect on both the inventors' productivity trend and level. We observe that non-occasional patents seem to lead to an increase, and then decrease, of the inventor/control ratio around the patenting period (see Fig. 6), which we take as a suggestion of a correlation between the patenting event and some further productivity gain for academic inventors. This is a possible evidence that behind the contemporary productivity rise and patenting event there is a strong research project, possibly with industry, for which cognitive and financial resources are higher than usual. Patents applied for by universities appear to exert a positive effects around the patenting year. However, when we consider open science patents, the inventor control ratio is on average lower.

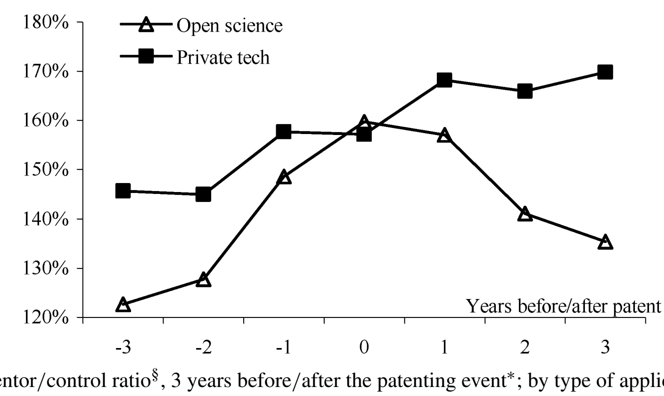

FIGURE 7 Inventor/control ratio§, 3 years before/after the patenting event*; by type of applicant.
§Yearly no. of per capita publications of the inventor/yearly no. of per capita publications of the control (mean values).
*Patenting year = 0.
1. Open science patents (86 obs).
2. Private technology patents (430 obs).
Source: elaborations on EP-INV-DOC database and ISI Science Citation Index.

We finally notice that (with the only exception of the second year after patenting, for first-of-two patents, Fig. 5), the inventor/control ratio is always well above 100. This suggests that even at some distance in time from the patenting 'event', academic inventors are more productive than their colleagues: their superiority seems to be there before, and to last well after they signed a patent, one more indication of the possible existence of an 'individual productivity effect'. Comparing the inventor control ratios by type of applicants we cannot exclude a possible role for self-selection. It may be that some particularly productive scientists start collaborating with firms and as a result we have selected particularly productive researchers. As a consequence, we cannot tell whether these scientists would have published more had they not patented. This effect may be higher for private technology patents and persistent inventors.

5 CONCLUSIONS

Our analysis suggests that Italian academic inventors are highly productive scientists, indeed more productive than their non-inventor controls.

Academic inventors exhibit superior productivity not just around the patenting event, but also well before then. This suggests that an 'individual productivity effect' may be at play, by which more productive scientists both publish more than their colleagues and end up patenting some of their research results.

We have also observed that the academic inventors' superior productivity increases further in the years immediately after non-occasional patents, and in a few cases also one or two years before. Such evidence points at the existence of a 'resource effect', by which professors engaged in research projects which lead to patenting experience benefit from financial or cognitive resources from being engaged in technology-oriented projects. This 'resource effect' is more clearly visible when patents are applied for by business companies.

On the negative side, we cannot exclude the existence of some 'publication delay effect', but a more accurate judgement would require further data on the submission date of publications. As for the 'basic-applied research' trade-off argument, we do not find any hint of its validity. On the contrary, academic inventors are found to publish more than their controls even when we consider only basic-science-oriented journals.

These results match closely those reached by Markiewicz and Di Minin (2004) and Azoulay *et al.* (2004). As for the superior productivity of academic inventors, this is confirmed by Stephan *et al.* (2004), who suggest the existence of a strong 'individual productivity effect'. An earlier study by Agrawal and Henderson (2002) found more mixed evidence, namely no association between patent and publication counts, and a positive effect of patenting activity on citation rates. On the contrary, our citation-based analysis suggests some weaknesses of academic inventors' scientific production, although only for Biologists, from 2000 onward.

It is premature to conclude from these results that the relationship between patenting and publishing is necessarily a positive one. First, among all possible liasons between academic research and IPRs, we have studied the least dangerous, namely those affecting individual scientists' publication rates. It remains possible that, by patenting their research results, academic inventors contribute to make them less accessible to other scientists, thus limiting the research effort at the systemic level (Murray and Stern, 2005). Second, more accurate econometric testing is required to confirm the conclusions we reached here, as they are based mainly on a descriptive examination of publication trends. The analysis should focus (i) on the possibility that the most productive scientists have greater chances to turn into academic inventors, as their reputation may attract more research funds both from the public and the private sector (selection effect); and (ii) on the possibility that academic inventors, despite being more productive than other scientists, will divert their long term research efforts from publication-oriented goals, thus experiencing in any case a patenting–publishing trade-off. We explore issue (i) in Breschi *et al.* (2005) and will soon take on issue (ii) as well.

Finally, our data suggest that university patenting is a rare phenomenon in Italy, as opposed to academic inventions patented by business companies. This result is line with recent findings on how the institutional features of academic systems of continental Europe stand in the way of a direct involvement of university in IPR management, even when academic research produces patentable inventions (see Gittelman, 2002, for France; Goldfarb and Henrekson, 2003, for Sweden). Further data collection on other European countries, already under way, will help us working also on this research issue.

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