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Chapter 4. Open Science and University Patenting: A Bibliometric Analysis of the Italian Case

Stefano Breschi[1]*, Francesco Lissoni*[1,2]*, and Fabio Montobbio*[1,3]

[1] *Cespri, Università Bocconi, Milan, Italy*

[2] *Università degli studi di Brescia, Italy*

[3] *Università degli studi dell'Insubria, Varese, Italy (corresponding author: fabio.montobbio@uninsubria.it)*

4.1 INTRODUCTION

This chapter addresses the issue of university patenting and its impact on the scientific activity of academic researchers. The issue is highly debated in Europe where legislators are trying to design policy instruments to support the technological transfer form university to industry and to create an optimal set of incentives to stimulate scientists' productivity. The relationship between patenting and publishing may be controversial because there are as many arguments claiming that the relationship is beneficial to both university and industry as reasons to fear that patenting may hinder the free diffusion of scientific knowledge or bias the scientists' choice of research topics.

We address the issue empirically with data at the individual level. We compare the number of scientific publications of a sample of 296 academic inventors and a sample of 296 matched controls, with patenting as a treatment variable. Section 2 qualitatively identifies the empirical model considering the different causal mechanisms that may explain a positive or a negative relationship between patenting and publishing. The empirical work exploits two datasets: one contains information on Italian 'academic inventors' (that is Italian academic researchers designated as inventors on patent documents); the other is based upon the *ad hoc* collection of publication data for both these 'academic inventors' and a sample of their 'non-inventor' colleagues, from the on-line version of ISI's *Science Citation Index*. Section 3 provides both a description of the data and the descriptive evidence. Section 4 presents the econometric exercise. Section 5 concludes.

4.2 THE RELATIONSHIP BETWEEN PATENTING-PUBLISHING AT THE INDIVIDUAL LEVEL

The relationship between patenting and publishing may be negative at the individual level mainly for two reasons[1]. There may be a 'publication delay' effect and/or a 'basic-applied trade-off'. Firstly, publication delays may be necessary to meet the novelty step requirement in all patent legislations throughout the world: only new ideas can be patented, and ideas that entered the common pool of knowledge (no matter how recently, and no matter by which means) through a published output are not new. Academic researchers that aim at taking a patent, either in their own name, or in the name of their universities or a business partner, should keep their inventions secret as long as the patent application has not been filed (Akers, 1999; p.144)[2].

Secondly, the diversion of a researcher's attention from basic research to more applied targets may result in lower rates of publications in refereed journals, or in less ambitious publications with a lower impact on the scientific community. This can be expected to exert non-negligible effects only if it patenting is non-occasional, especially if resulting from business-oriented research. Thus, we expect academic inventors with prolonged contacts with industry and more than one patent to be the most affected by the trade-off[3] (for a discussion, see Breschi *et al.*, 2005a).

There are at least three counter-arguments against the existence of a patenting-publishing trade-off at the individual level. First, there may be a 'resource effect'. This argument suggests that the individual researcher who chooses to address her/his research to IPR-relevant objectives does so in order to access additional resources. Scientists can access not just *financial* resources and expensive scientific instruments, but also 'focussed' research questions (*cognitive* resources). Answers to research questions raised by technological puzzles may be at the same time economically valuable and scientifically relevant, up to the point of opening up new research avenues and disciplines (Mansfield 1995, 1998; Rosenberg, 1990,). 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). It may not be easy to tell the 'resource effect' apart from the 'publication delay' effect, despite their opposite impact on publication activity.

The two other counter-arguments against the publishing-patenting trade-off derive from long-debated questions in the sociology of science. We may label them the 'productivity fixed effect' and the 'augmented Matthew effect'. Both of them suggest that academic inventors may be among the most productive scientists, namely those with the highest publication rates. The 'productivity fixed effect' argument simply suggests that both patents and publications are proxies of a scientist's productivity. The 'augmented Matthew effect' builds upon the classic remarks by Merton on tendency of the priority reward system to benefit highly productive scientists, especially precocious ones, with a number of cumulative advantages, ranging from higher visibility and reputation, to ever-increasing ease of access to research opportunities and resources (Merton, 1988; for an empirical appraisal: Allison *et al.*, 1982).

4.3 DATA AND DESCRIPTIVE EVIDENCE

In this section we outline the main characteristics of the data. Data on patenting activity on academic professors come from the EP-INV-DOC data set, which lists 919 Italian academic inventors. The EP-INV-DOC dataset originates from the complete list of professors and researchers who, in 2000, held a position in a scientific or technical discipline in an Italian university (including medical and engineering schools): names and surnames in that list were matched to names and surnames in the EP-INV database, which contains all patent applications to the European Patent Office which designate at least one inventor with an Italian address, from 1978 to early 2000. Overall, the EP-INV database contains information on 30,243 inventors and 38,868 patent applications (for a more comprehensive description, see Balconi *et al.*, 2004). For sake of simplicity, we will refer to patent applications simply as ‘patents’.

The list of professors was provided by the Ministry of Education (MIUR). It contains little more than 30,000 names, complete with age, affiliation, discipline, and academic ranking (‘researcher’, associate professor, and full professor). Disciplines are defined according to a classification created for administrative purposes (to define candidates’ profiles when new positions were offered); it is very detailed and allows some compression into broader categories, which we will refer to as ‘fields’[4]. We focus on four disciplines with a very high share of academic inventors over the total number of professors in the discipline. These are: Chemical Engineering (this includes technology of materials, such as macromolecular compounds), Biology, Pharmacology, and Electronics and Telecommunications, for a total of 301 academic inventors and 552 patents (see Table 4.1 and Table 4.A1).

We have selected for our exercise 296 academic inventors[5]. A control sample was then built, by matching each academic inventor to a professor in the same discipline, and possibly with the same academic position (Full professor, Associate professor, or Researcher), age, and academic affiliation (in this order of importance).

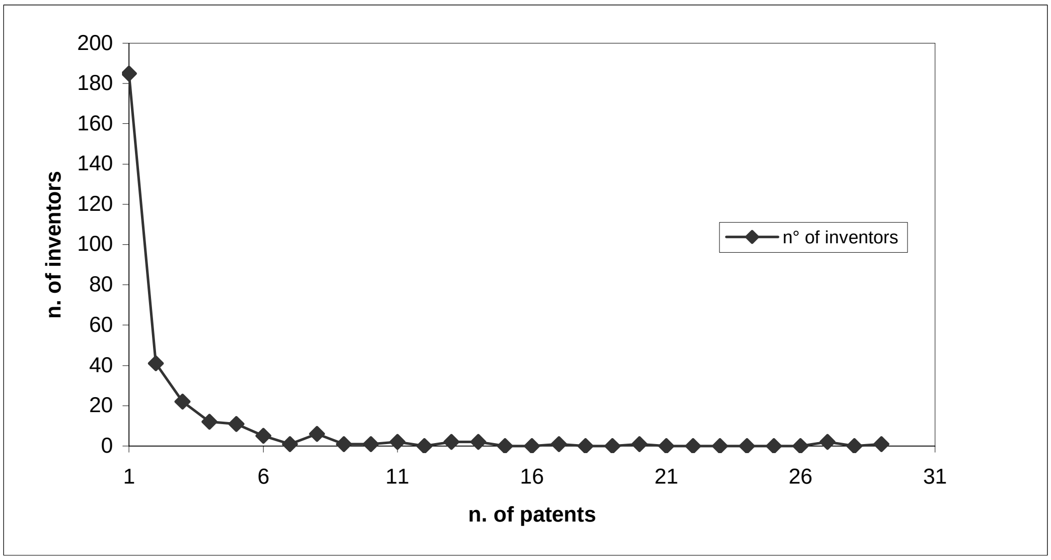
Table 4.1 University professors in Italy and academic inventors in the selected fields

Field	Professors, active in 2000	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 (10.4)*

4.3.1 Patent data

The distribution of patents across academic inventors is highly skewed; most professors have signed only one patent, and a very few more than five (Figure 4.1 and Table 4.2). This pattern is very similar to the well-established evidence on professors' publication records, which invariably shows the co-existence of a small number of hyper-productive 'superstars', and a large number of professors with very few or no publications. The distribution would be even more skewed if we considered also the non-patenting professors (see again Table 4.1).

Figure 4.1 Distribution of the sample of academic inventors by n. of patents



Source: EP-INV database

Table 4.2 Distribution (%) of academic inventors by n. of patents and field

Fields	n. of patents 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

Most patents belong to business companies, as a result of contractual funding, with little meaningful differences across fields (Table 4.3). 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 (the definitive answer will anyway come from the ongoing interviews). 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 grant recipients, and if taken, the step may have met some bureaucratic resistance.

A similar explanation applies to the scarcity of patents owned by the universities: until recently, universities decided to take charge of the application procedure and expenses more 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 explain the presence of a few inventors' own patents.

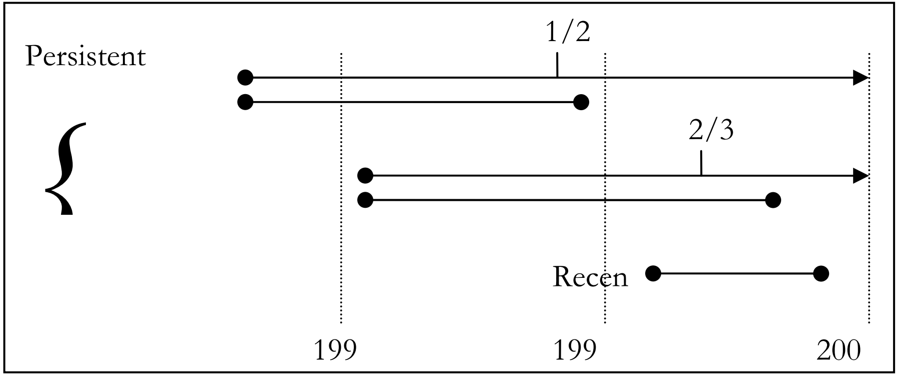
Table 4.3 Ownership of academic inventors' patents[§] by type of applicant and field; n. of patents (and %)

	Business companies	'Open Science' institutions[1]	Individuals [2]	Others (n.e.c.)	All applicant types
Chemical eng. & Materials tech.	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 & 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)*

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

We also classify the inventors in two groups: 'occasional' and 'persistent'. The limited number of patents per inventor, and the limited commitment of universities in patenting their employees' findings, suggest that most academic inventors (as opposed to industrial researchers working for large R&D labs) are involved in the patenting process on a occasional basis. All inventors with just one patent belong to the 'occasional' category. As for the others, we distinguish between those whose patenting activity is concentrated in a few years (and whose patents are very likely to stem from just one research project) and those whose patents are separated by long time lags (which we suspect to have patented the results of more than one research project).

Figure 4.2 Persistent inventors: definition



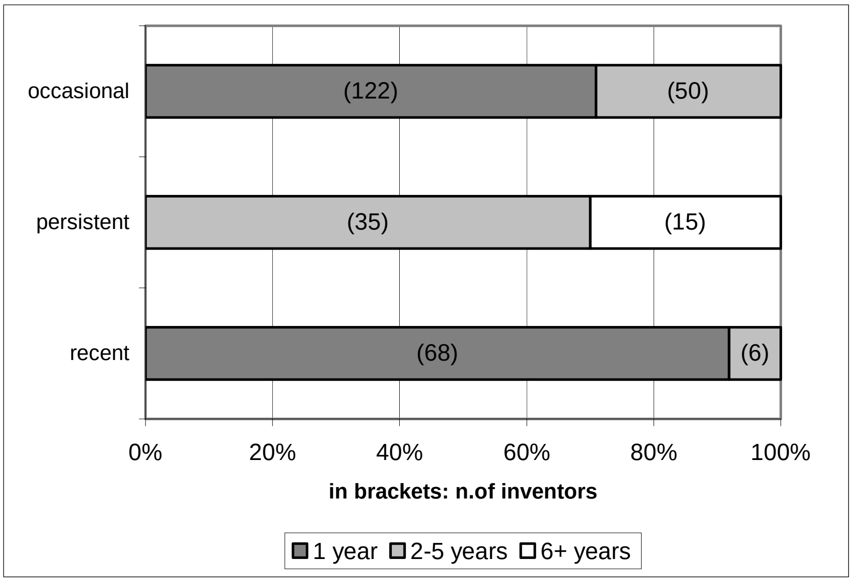
●---●: first patent – time span – last patent
●→: first patent – time span – right censoring

We distinguish also between those who patented for the first time before 1990 and those who patented for the first time between 1990 and 1995: for the former to be defined ‘persistent’, we require the lag between their last and first patent to be no less than half the time interval between their first patent and year 2000 (right censoring); for the latter we require the lag between their last and first patent to be no less than two thirds of the time interval between their first patent and year 2000. One additional category of inventors (‘recent’ inventors) gathers all inventors whose first patent is dated after 1995, and whose persistency we cannot judge (see Figure 4.2).

Figure 4.3 and Table 4.4 illustrate the distribution of the academic inventors in our sample according to the above-mentioned categorization, by field and number of ‘patenting years’ (years in which the inventor signed at least one patent). All inventors with more than five years of activity fall in the ‘persistent’ category. 35 scientists (out of 91) with two to five years of activity also belong to the ‘persistent’ category.

In synthesis, inspection of data on academic inventors suggests that neither academic inventor in the chosen fields, nor their universities, seem to have pursued an active patenting policy. Patents signed by academic inventors are most often the result of contract research agreements between individual professors and a large number of business companies, which retain all the intellectual property rights over the research results. It follows that academic inventors’ patents ought possibly to be seen as proxies of the involvement of professors in contract research projects: if continuative (‘persistent’ innovators), this involvement may indeed generate a positive ‘resource’ effect on the academic inventors’ publication rate. At the same time, this suggests that business partners may have the final say over the academic inventors’ publication tactics, and impose non-negligible publication delays.

Figure 4.3 Academic inventors, by frequency of invention and number of patenting years



296 obs, source: EP-INV database

Table 4.4 Academic inventors, by frequency of invention and field (sample values)

	Occasional inventors, n. and % (by field)	Persistent inventors, n. and % (by field)	Recent inventors, n. and % (by field)
Chemical eng. and Materials tech.	36 (*57.14*)	8 (*12.70*)	19 (*30.16*)
Pharmacology	50 (*60.24*)	17 (*20.48*)	16 (*19.28*)
Biology	50 (*64.10*)	10 (*12.82*)	18 (*23.08*)
Electronics & Telecom	36 (*50.00*)	15 (*20.83*)	21 (*29.17*)
All field	172 (*58.11*)	50 (*16.89*)	74 (*25.00*)

4.3.2 Publication data

Publication data were collected from the 2003 on-line version of ISI's *Science Citation Index* for both 296 of the 301 of the academic inventors in the selected fields, and 296 'control' professors. The latter were chosen according to their academic position (which was required to match exactly that of the reference academic inventor), and age (control professor had to be preferably no more than 5 year younger/older than their counterparts). Controls were chosen from the same university of the academic inventors, or a near one. A detailed description of the matching procedure can be found in Breschi *et al.* (2005a).

First, we calculated the average number of total publications of the inventors and their controls from 1975 to 2002. The average number of publications of the inventors is sensibly higher then their controls. Average figures are significantly higher in all fields (Table 4.5). 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 by number of publications is usually found to be highly skewed to the right. Our data make no exception. Table 4.5 shows that all fields show a positive skewness index for both the inventors' and the controls' distribution. This table also shows that the average number of publications of the inventors is always higher than the controls' mean value, and that the same holds for the median number of publications: together, these statistics suggest that the inventors' figures compare favourably against the controls' not because of some hyper-productive outlier, but as a result of a truly higher scientific productivity. We also notice that persistent inventors compare more favourably to their controls than occasional ones.

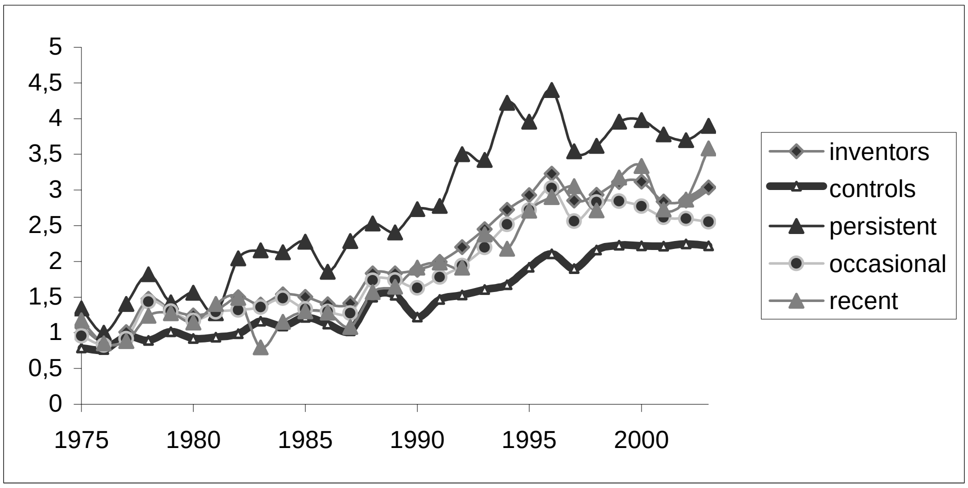
Table 4.5 Inventors vs. control sample, publications (mean values and distribution skewness); by field and type of inventor, 1975-2003

	Controls			Inventors				
	Mean (1)	Median (2)	Skewness	Mean (3)	Median (4)	Skewness	(3)-(1)	(4)-(2)
Field								
Chem.eng. & Materials tech.	33.06	27	1.67	52.58	38	3.01	19.52	11
Pharmacology	44.56	41	1.09	57.37	50	1.14	12.81	9
Biology	48.12	36	1.95	68.62	52.5	2.74	20.5	16.5
Electronics & Telecom	30.05	22.5	2.08	38.93	37.5	0.89	8.88	15
Inventor Type								
Occasional	39	33	1.83	50.68	42	2.53	11.68	9
Persistent	44.1	35.5	1.27	76.78	59.5	2.95	32.68	24
Recent	37.5	30	2.08	49.6	40	1.93	12.1	10
All inventors	39.52	32	1.77	54.83	44	3.05	15.31	12

Source: elaborations on EP-INV database and ISI Science Citation Index

The superior productivity of inventors is confirmed when moving to yearly publication data. Figure 4.4 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. It suggests that the average scientific productivity of both inventors and controls has increased over time: whether this can be regarded as an hard fact or the mere result of the increasing propensity of Italian academic to publish on English-language SCI-monitored journals remains to be seen, but it is a not crucial concern of our research. More important it is pointing at the clear superiority of academic inventors vs. their controls, a superiority that roughly measures up to 1.5 paper per year.

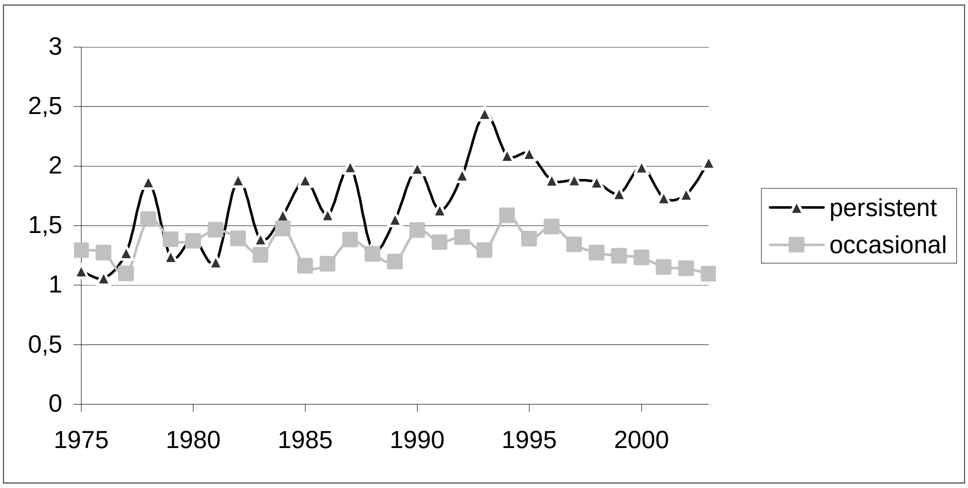
Figure 4.4 Average number of yearly publications; inventor vs. control sample, 1975-2003



Source: elaborations on EP-INV database and ISI Science Citation Index

Once again, persistency in invention looks like being associated to an even higher productivity: Figure 4.4 also reports the mean figures for the subgroups of persistent, recent and occasional inventors and it shows that the former are consistently more productive than all other inventors; the occasional ones are in the bottom position (among the inventors). As for comparing each type of inventor to its control group, Figure 4.5 reports the ratios between the average number of yearly publications of the persistent and occasional inventors' vs. their controls' groups: persistent inventors compare more favourably to their controls than occasional ones do. Figure 4.5 also shows that controls apparently catch up with inventors in the late 1990s: one possible explanation for this trend could be the failure of many inventors to patent again during those years (notice that for recent inventors any catching-up is visible only in the last two years); alternatively, it may be some of our controls have turned into inventors, by signing patents in between 2000 and 2002 (the spell of time not covered by our data).

Figure 4.5 Average number of publications; inventor/control ratio, by inventor type, 1975-2003



Source: elaborations on EP-INV database and ISI Science Citation Index

4.4 A PANEL DATA ANALYSIS OF SCIENTISTS' PUBLICATION ACTIVITY: THE EFFECT OF PATENTING

In this section we use the longitudinal nature of our data to explore further the relationship between patenting and publishing. We perform a three steps exercise:

1. First we regress the yearly number of publications of each professor (inventors and controls alike) on his/her individual characteristics such as experience and disciplinary field, as well as on the characteristics of her/his academic institutions (size and prestige of her/his department)[6]. In particular we include each professor's status, whether she/he is an inventor or not. This tests directly whether inventors display on average higher scientific productivity than their controls. Regressions include also a full set of time dummies.

2. Second we use the patenting event as a treatment variable and we test whether *becoming* an inventor has a positive impact on the publication activity of a scientist. We build a variable ($postpat_{it}$) which is equal to one if $t \geq t_0$ and zero elsewhere. t_0 is the year of the first patent.
3. Finally, we test the impact of patenting on publication activity for the years immediately before and after the year in which the patent occurs. We use dummies to explore this dynamic behaviour and add seven time dummies, one for each year around the event, starting 3 years before the patent priority date (Dp_j , with j=-3,…,+3; Dp_0 corresponds to the patent priority date). The coefficients can be interpreted as deviations of the number of yearly publications after controlling for time variant and individual (time invariant) heterogeneity: if there is a relationship between patenting and publishing, an unexplained pattern related to patenting activity should remain in the error terms and should be caught by the dummies variables.

We estimate the following four specifications:

$$E(P_{it} \mid x) = \exp\left\{ \beta inv_i + \sum_j \gamma_j ex_{ij} + \sum_j \delta_j sett_{ij} + \gamma Size\_dep_i + gender_i + \tau_t \right\} \tag{1}$$

$$E(P_{it} \mid x) = \exp\left\{ \beta postpat_i + \sum_j \gamma_j ex_{ij} + \sum_j \delta_j sett_{ij} + \gamma Size\_dep_i + gender_i + c_i + \tau_t \right\} \tag{2}$$

$$E(P_{it} \mid x) = \exp\left\{ \sum_{j=-3,+3} \beta_j Dp_{ij} + \sum_j \gamma_j ex_{ij} + \sum_j \delta_j sett_{ij} + \gamma Size\_dep_i + gender_i + c_i + \tau_t \right\} \tag{3}$$

$$E(P_{it} \mid x) = \exp\left\{ \begin{array}{l} \sum\limits_{j=-3,+3} (\beta_j * I_{OCC}) Dp_{ij} + \sum\limits_{j=-3,+3} (\beta_j * I_{NO\_OCC}) Dp_{ij} \\ + \sum\limits_j \gamma_j ex_{ij} + \sum\limits_j \delta_j sett_{ij} + \gamma Size\_dep_i + gender_i + c_i + \tau_t \end{array} \right\} \tag{4}$$

The explanatory variables we include in the regressions are:

- *inv_i*: a dummy variable equal to 1 for inventors,

- ex_{ji}: a set of binary variables for age categories; in particular we have four age categories (the base age is [25, 29]): ex_{1i} if age is in the interval [30, 39], ex_{2i} if age is [40, 49], ex_{3i} if age is [50, 59] and, finally, ex_{4i} if age [60, 70].
- c_i: unobserved individual time constant effect,
- $sett_{ji}$: a set of binary variables for the disciplinary fields of the professors. In particular $Dsett_1$=1 for Biology, 0 elsewhere; finally, $Dsett_2$=1 for Electronics& Telecommunications, 0 elsewhere. $Dsett_3$=1 for Pharmacology, 0 elsewhere; Chemical Engineering and Materials Technology is the base category.
- $gender_i$: this variable is one for women, zero elsewhere.
- $Size\_dep_{it}$: is the number of professors within the scientist's department divided by the total amount of professors in the scientific fields within the scientist's university. This controls for the size and importance of the department.
- Dp_j , with j=-3,…,+3; dummies starting 3 years before the patent priority date. Dp_0 corresponds to the patent priority date.
- I_{OCC}: is a dummy variable equal to one if for occasional inventors and zero elsewhere.
- $I_{NO\_OCC} = 1 - I_{OCC}$: is a dummy variable equal to one if for non occasional inventors and zero elsewhere.
- All the regressions contain a full set of time dummies (τ_t) to control for time varying unobservables that are common across individuals.

Notwithstanding many qualitative limitations of our data, these variables are very much the same proved to be relevant by the sociological analysis of scientific productivity (Allison and Long, 1990; Long *et al.*, 1993; see also Turner and Mairesse, 2004).

Our panel is composed of 592 individuals for a maximum of 20 years. We selected the time period between 1980 and 1999 for which our patent data are more reliable. Moreover we do not have the precise date in which our professors started their academic career. Therefore we started including them in the sample when they are 25 years old. The panel therefore is unbalanced. Specifications (2), (3) and (4) are firstly estimated using fixed effects (LSDV) to control for unobserved individual heterogeneity. All time invariant variables in this case are dropped from the within estimation. In this case the dependent variable is re-calculated as $p_{it}=log(1+P_{it})$: P_{it} is the number of individual publications at time t. This is done because for some individual observations the number of publications is zero and the log of zero is not defined. Since publications are nonnegative integers, any fixed effects model using least squares could create a bias in the estimated coefficients. We then use also a count data model. Since the distribution of individual publications is highly skewed, with significant overdispersion and a large number of zeros, specification (1) is also estimated using a Negative Binomial model, and specifications (2), (3) and (4) are also estimated using a Fixed Effects Negative Binomial model (Hausman *et al.*, 1984). In this case the dependent variable is P_{it}.

4.4.1 First step: inventors vs. non inventors.

Table 4.6 (columns 1 and 2) reports the results from the regressions of the first specification. Our estimates confirm that inventors have a significantly higher propensity to publish. In particular the coefficient of inv_i is equal to 0.32 in the negative binomial regression. This means that being an inventor increases the expected number of articles by 38%, holding other variables constant. Conversely being a female scientist decreases it by 23%, holding other variables constant.

In both regressions our time dummies (not reported) show that publications follow a non-linear quadratic trend over the 20 year period considered. Moreover with respect to the base age, scientists display as expected significantly higher values of their publication levels, this effect decreases with age. Finally publications in Pharmacology ($sett_3$=1) and Biology ($sett_1$=1) are significantly higher than the base category and Electronics and Communications. Finally $size\_dep_{it}$ is significantly positive. This indicates a positive department effect.

Table 4.6 Results of the estimation of specification (1) and (2)

Dependent variable: Log(Publications) in column (1) and (3); counts of publications in column (2) and (4)

	OLS - Pooled cross-section. (1)	Negative Binomial (2)	Within (3)	FE Negative Binomial (4)
inv_i	0.17**	0.32**	-	-
	(0.12)	*(0.62)*		
$postpat_{it}$	-	-	0.15**	0.15**
			(0.02)	*(0.03)*
$gender_i$	-0.14**	-0.26**	-	-
	(0.02)	*(0.08)*		
$Size\_dep_i$	0.02**	0.04*	-	-
	(0.00)	*(0.02)*		
ex_1 [30-39]	0.34**	0.68**	0.32**	0.77**
	(0.02)	*(0.07)*	*(0.02)*	*(0.05)*
ex_2 [40-49]	0.33**	0.67**	0.29**	0.77**
	(0.02)	*(0.08)*	*(0.04)*	*(0.07)*
ex_3 [50-59]	0.23**	0.54**	0.21**	0.70**
	(0.02)	*(0.11)*	*(0.05)*	*(0.09)*
ex_4 [60 +]	0.11**	0.36*	0.14*	0.68**
	(0.04)	*(0.15)*	*(0.07)*	*(0.12)*
$Sett_1$ (Biology)	0.21**	0.34**	-	-
	(0.02)	*(0.11)*		
$Sett_2$ (Elec. & Tel.)	-0.09**	-0.21*	-	-
	(0.02)	*(0.10)*		
$Sett_3$ (Pharmacology)	0.19**	0.24**	-	-
	(0.02)	*(0.09)*		
Cons.	Yes	yes	yes	Yes
Time dummies	Yes	yes	yes	Yes
Individuals	592	592	592	590
Years	1980-99	1980-99	1980-99	1980-99
Observations	10,696	10,696	10,696	10,673
R2 within	0.1463		0.1451	

** 99% sig. level; * 95%; $^+$ 90%; †85%. Standard errors in parentheses.

ex(base)=1 if 25<=age<=29, 0 elsewhere; $sett_{ji}$: The base is Chemical Engineering.

4.4.2 Second step: a treatment effect.

Columns 3 and 4 of table 4.6 show the results from specification 2. In this specification we use both linear and negative binomial fixed effect to control for individual heterogeneity. We find a positive impact of our treatment variable with both linear and count methods. The size of the coefficient is equal to 0.15. This means that becoming an inventor could improve the scientific productivity, holding other variable constant, of approx. 14%. These results are similar to what found by Markiewicz and DiMinin (2004) and Azoulay *et al.* (2004) on US data. As we show in a companion paper (Breschi *et al.*, 2005b) this results may be affected by endogeneity because past publications might increase the probability of becoming an inventor. However preliminary results using instrumental variables and the work of Azoulay *et al.* (2004) show that this result is robust to different specifications.

4.4.3 Third step: dynamic effects around the patent.

Table 4.7 illustrates the results from specification 3 (columns 1 and 2) and 4 (columns 3a-3b and 4a-4b). In columns (1) and (2) we notice that the dummy variables are negative until 2 years before the patenting event (even if they cannot be considered significantly different from zero), and positive afterwards, with a peak on years, -1, +1 and +3. This suggests that the regressions presented in section 4.4.1, despite considering the impact on scientific productivity of being (at the present time or in the future) an academic inventor, tend to overestimate academic inventors' publication activity until two years before the patenting event, and underestimate it one year before, one year after and three years after the patent. These results suggest the existence of either a strong publication delay effect, and/or a resource effect.

Table 4.7 Results of the estimation of specification (3)

Dependent variable: Log(Publications) in column (1), 3a and 3b; publications counts in (2), (4a) and (4b)

			Occasional		Non-occasional	
	Within (1)	Fixed Effects Negative Binomial (2)	Within (3a)	Fixed Effects Negative Binomial (4a)	Within (3b)	Fixed Effects Negative Binomial (4b)
Dp_{-3}	-0.04	-0.08	-0.00	-0.03	**-0.11** $^{+}$	**-0.19** $^{+}$
	(0.03)	*(0.06)*	*(0.04)*	*(0.07)*	***(0.06)***	***(0.10)***
Dp_{-2}	0.05 †	0.05	**0.10****	**0.10** $^{+}$	-0.06	-0.07
	(0.03)	*(0.05)*	***(0.04)***	***(0.06)***	*(0.05)*	*(0.10)*
Dp_{-1}	**0.09****	**0.11***	**0.14****	**0.16****	-0.00	-0.01
	(0.03)	***(0.05)***	***(0.04)***	***(0.06)***	*(0.05)*	*(0.09)*
Dp_{0}	**0.07****	**0.06** †	**0.08***	0.04	-0.02	-0.02
	(0.02)	***(0.04)***	***(0.04)***	*(0.06)*	*(0.05)*	*(0.08)*
Dp_{+1}	**0.10****	**0.09***	**0.10****	**0.10** $^{+}$	**0.11***	0.10
	(0.03)	***(0.05)***	***(0.04)***	***(0.06)***	***(0.05)***	*(0.08)*
Dp_{+2}	**0.08***	0.06	0.05	0.02	**0.14****	**0.13** $^{+}$
	(0.03)	*(0.05)*	*(0.04)*	*(0.06)*	***(0.05)***	***(0.07)***
Dp_{+3}	**0.10****	**0.09** $^{+}$	0.05	0.00	**0.17****	**0.21****
	0.03	***(0.05)***	*(0.04)*	*(0.07)*	***(0.05)***	***(0.07)***
Individuals	592	590	592	590		
Years	1980-99	1980-99	1980-99	1980-99		
Observations	10,696	10,673	10,696	10,673		

All other estimated regressors omitted. Coefficients in (3a) and (3b) are obtained interacting Dp_{-i} with a dummy for occasional and non occasional inventors. The same occurs for columns 4a and 4b.
** 99% sig. level; * 95%; $^{+}$ 90%; †85%. Std errors in brackets.

In columns 3a, 4a, 3b and 4b estimations of specification 4 are presented. We examine more closely the dummies around the patenting year interacting them with a dummy for ‘occasional’ inventors (with only one patent), as opposed to ‘non occasional ones’ (for these individuals we consider only the first patent). The differences are quite relevant and suggest that the nature of the relationship between patenting and publishing is different in the two cases. Occasional inventors have a peak in their publications one year before the patent. Patents probably are an occasional by-product of a successful research project. In the second case when there is a more persistent patenting activity, inventors reach their peak in the publications later at year +1, +2 and at year +3. It looks as if the beneficial effect of patenting on publication rates lasted longer for persistent innovators, which is entirely consistent with the resource effect explanation and probably associated with a continuous patenting activity over time. Moreover for non occasional inventors coefficients are significantly negative 3 years before the patent. Again this is compatible with a resource effects but cannot exclude however the possibility of a publication delay effect.

4.5 CONCLUSIONS

Our work shows that Italian academic inventors are highly productive scientists, indeed more productive than their non-inventor controls. The difference is particularly relevant for persistent inventors, namely those scientists who patent more than once over a long time period. The econometric exercise confirms the superiority of the scientific productivity of inventors relatively to non-inventors. Moreover we show that patents have a significantly positive impact in terms of increased number of publications within the scientist's academic career. Becoming an inventor could improve the scientific productivity, holding other variables constant, of approx. 14%. Finally the use of dummy variables in the dynamic analysis of the number of publications around the year of the patent shows that there is a pattern that is left unexplained by the individual heterogeneity, time dummies and by the treatment effect. This dynamic analysis shows that publishing activity tends to increase around the year of the patent. However the nature of the relationship between publishing and patenting seems to be different for persistent and occasional inventors. For the latter the increase in the publishing activity starts two years before the patent and lasts only one year after. For the former there is a positive effect that extends also three years after the patent and there is no positive effect before the patent.

Taken together our evidence points at the existence of a ‘productivity fixed effect’ at the individual level and a ‘resource effect’, both of them creating a positive link between patenting and publishing activities. On the negative side, we cannot exclude the existence of some ‘publication delay effect’. An important institutional specificity of the Italian case is that 75% of the patents signed by at least one academic inventor belong to business companies. Those patents are often the result of research contracts, by which the business company retains all the intellectual property rights over the research results. It follows that our evidence suggests that contract research may generate a positive ‘resource’ effect on the academic inventors’ publication rate, in particular when it expands over long time periods. Despite the institutional differences these results match closely those reached by Markiewicz and Di Minin (2004) and Azoulay *et al.* (2004) for the United States, the only other studies explicitly dedicated to the patenting-publishing trade-off outside Italy we are aware of[7]. As for the superior productivity of academic inventors, this is confirmed by Stephan *et al.* (2004), who suggest the existence of a strong ‘productivity fixed effect’.

It is impossible to derive any policy conclusion from our study. Of all the possible ‘liaisons’ between patenting and publishing we have studied the least dangerous, namely those occurring at the individual level. 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.

We can say, however, that European legislators and university technology transfer offices should look closely at the specificity of the institutional environment before pushing academic scientists towards patenting their results (either in their own name or in the name of their universities). For the Italian case it may be that it is not patenting *per se* that boosts scientific productivity, but individual heterogeneity plus the advantage derived from solid links with industry, which in turn might require leaving IPR matters in the business partners’ hands. If this conjecture turns out to be confirmed in our subsequent work, then legislators and technology transfer officers - wishing to strengthen those links - should avoid forcing university administrators and scientists to claim their own share of IPRs at all costs. The expected returns from any foreseeable license are much less than the opportunity costs of putting the links with industry at risk.

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APPENDIX

Table 4.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

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[1] In this section we briefly summarize the major causal links, focusing upon the individual level. However there is a recent growth in the empirical literature addressing the impact on scientific activity of the increase in the patenting practice by universities, in particular after the Bayh-Dole Act. Henderson *et al.* (1998), Mowery and Ziedonis (2002), Agrawal and Henderson, 2002, Surlemont *et al.* (2003), Markiewicz and DiMinin (2004), Azoulay *et al.* (2004), Mowery and Sampat (2004) and Lerner (2004) discuss many aspects of the issues we touch upon in this section.

[2] The publication delay may be mitigated by the so-called 'grace period' rule, which is in force in the US, Canada, Australia, and has been urged by many for European patents as well. The rule allows academic researchers to publish in advance their soon-to-be-patented inventions, as long as the publication occurs not too early (in the US, within 12 months of the patent application date).

[3] Publication data may not be adequate to test the 'basic-applied trade-off' argument, as long as many journals are in fact dedicated to applied research. Some indicators of the orientation of the journal towards basic vs. applied research (such as classifications by experts, or cruder measures such as ISI's Impact Factor or Cited Half Life) ought to be employed to weigh each published article. An even better weight is provided by the number of citations received by each article, which are also made available by ISI: next drafts of this paper will indeed make use of them (see Breschi *et al.*, 2005a).

[4] The major limitation of the MIUR list and, as a consequence, of the EP-INV-DOC database, is that it includes only those professors and researchers who had passed a competitive examination for a tenured position (from now on, we will refer to them simply as 'professors'). Thus our data miss the large number of 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.

[5] For a more detailed description of the sample and matching methodology we refer to Breschi *et al.* (2005a) where we provide data cross-tabulations by field, age and amount patents. Most of the selected inventors are full professors, aged between 40 and 60. The mean age of both the inventors and their patents increases slightly in the Chemical Engineering field, while the opposite holds for inventors in Electronics and Telecommunications.

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[6] In principle, the characteristics of institutions may vary, either because the institutions themselves gets smaller or bigger, and gain or lose prestige, or because professors move from one university to another. However, we have data on universities only for 2000, and no data on the professors' career before then. So, also the characteristics of institutions appear as fixed effects in our regression.

[7] On Italy, see Calderini and Franzoni (2004). Data on academic inventors, but not yet on their publications, can also be found in Meyer *et al.* (2003), for the case of Finland.