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Evidence from five European countries

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The ownership of academic patents and their impact. Evidence from five European countries

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Abstract:

The paper compares the value and impact of academic patents in five European countries with different institutional frameworks: Denmark, France, Italy, the Netherlands, and Sweden. An academic patent is defined as such when at least one university professor appears among its inventors, irrespective of ownership. Most academic patents are assigned to business companies, followed by universities, public research organizations, and individual inventors. The distribution of ownership across these categories (i) differ greatly across country, due to a combination of legal norms on IP and institutional features of the university system; (ii) and it is associated with the value of patents, as measured by forward citations. Company-owned academic patents tend to be as cited as non-academic ones, while university-owned tend to be less cited. Academic patents in the Netherlands are more cited than non-academic ones, irrespective of their ownership, while university-owned patents get fewer citations in both Italy. We propose an explanation of these results based on the different autonomy enjoyed by universities in the countries considered. We also find that company-owned academic patents in Sweden get many fewer citations than non-academic. Individually-owned academic patents are more cited than non-academic patents similarly owned by their inventors.

Keywords: Academic patents, Academic entrepreneurship, Patent citations, University system, Technology Transfer, Professor privilege

JEL Classification: O31, O32, O33, O34

1. Introduction

Following the sustained growth of university patenting in the US since the 1980s (Mowery et al., 2004), European policy makers and university administrators have been increasingly interested in the use of Intellectual Property Rights (IPRs) to protect and commercialize academic research results. A lively debate is ongoing on the importance of patents as a vehicle for university-industry technology transfer (Jensen and Thursby, 2001, Sampat et al., 2003, Agrawal and Henderson, 2002), their potential as a source of licensing revenues for academic institutions (Thursby and Thursby, 2007, Siegel et al., 2007) and their usefulness as a bibliometric indicator, especially for the part that attains the evaluation of "usefulness" or "transferability" of research results (Meyer, 2003)[1].

Going back in history, we find that academic scientists have often been involved in the inventive process, and filed patents to protect their inventions (see for instance: Mowery and Ziedonis 2002, Murmann 2006, and MacLeod 2012). But we also find great changes in the property distribution of such patents. Throughout the XIX century it was common for academic inventors to file patent applications in their own name, a tradition later upheld by the "professor privilege" typical of German and Scandinavian countries (Lissoni et al., 2009; Damsgaard and Thursby, 2012). In the US, not-for-profit patent brokers specialized in academic patents, such as WARF or the Research Corporation, also played an important role (Mowery and Sampat, 2001). After Second World War, many Western governments, through their ministries or funding agencies, found themselves in the position of patent-holders over academic inventions resulting from large, publicly funded programmes (as in the case of the National Research Development Corporation, later on transformed into the British Technology Group; Keith, 1981; Rothwell, 1985).

It was only during the last quarter of the XX century that academic institutions gained importance as patent assignees. In the US, the introduction of the Bayh-Dole Act in 1980 explicitly encouraged universities to file patent applications over the results from publicly funded research, and the share of US university-owned patents over total US domestic patents raised from around 2% to around 4% in a decade. The same did not happen in Europe, despite many steps taken by the European legislators to imitate the US ones (Mowery and Sampat, 2005). European universities are still nowadays more reluctant or less able than their US counterparts to engage in IPR management. As a consequence, most patents over inventions from European academic scientists are still in the hands of business companies, while many are owned by individuals and not-for-profit or governmental organizations. At the same time, important cross-country differences exist, which depend both on each country's IP legal framework and on the institutional characteristics of each research and higher education systems (Lissoni 2012).

In this paper, we explore to what extent the economic value of academic patents is associated with the patents' property regime. We focus on five European countries (Denmark, France, Italy, the Netherlands, and Sweden), which exhibit remarkable legal and institutional differences. We make use of a unique database of academic vs. non-academic patent applications at EPO, the European Patent Office, from 1995 to 2001. Academic patents are defined as having at least one university professor among the inventors, irrespective of their ownership. Following the existing literature, we measure the economic value of patents by counting the citations they receive from other patents (forward citations); we also use citation-based measures of a patent's generality and originality (Jaffe and Trajtenberg 2002; chapters 2 and 3 in Frietsch et al. 2010). By means of descriptive statistics we find that, overall, academic patents in the five countries considered are more general and more original than non-academic ones, thus confirming established results for the US. By means of count data econometric models, we also show that academic patents are in general as cited or less cited than non-academic ones, as opposed to what found for the US. These

[1] Another line of debate relates to the systemic effects of IPR diffusion on the cumulative process of scientific enquiry; for surveys: Nelson (2004) and Foray and Lissoni (2010; section 4.3). Although very important, this is a topic we do not deal with in our paper.

results, however, depend upon the type of academic patent ownership and the inventor's country. The observed difference can be explained by legal and institutional cross-country differences.

The paper is structured as follows. Section 2 defines in detail the concept of academic patenting and its relationship to that of patent value, as mediated by patent ownership. It also discusses the related literature. Section 3 describes our data and methodology. In section 4 we present and discuss our econometric results. Section 5 concludes.

2. Background literature and research questions

2.1 Academic patents: definition and ownership

We define *academic patents* all those patents that cover inventions to which academic research has contributed to some degree (*academic inventions*). Empirically, we identify such patents as those that have at least one university scientist among the inventors. We refer to this scientist as an *academic inventor*. Academic patents may be owned or co-owned by the inventors, their universities, a governmental agency or public research organization (with whom the inventor may have collaborated), or a business company (again as a result of collaboration, but also, possibly, of contract research or consultancy).

Early studies on academic patents focussed entirely on university-owned academic patents, as they resulted from US scholars' interest in evaluating the impact of the Bayh-Dole Act[2]. As explained by Franzoni and Lissoni (2009), the US academic system is unique in the autonomy it grants to universities (whether public or private) and in the control the universities retain over the intellectual property stemming from their faculty's research results. US academic scientists have the duty to disclose their inventions to their employer (the university), which in turn has exclusive rights over such inventions (Lach and Schankerman, 2004). The principle may be mitigated by the scientist's right to a share of the licensing royalties, or to engage in private consulting or collaborative research with industry, from which separate IPRs may emerge. Still, a study of US academic inventors run by Thursby et al. (2009) reveals that almost 70% of US academic patents are owned by universities.

Europe stands at the opposite end of the spectrum, most of its universities not having the same autonomy of the US ones, their tenured staff being civil servants (that is, government's employees rather than university's), and their administrations being much less geared towards fund-raising and asset management[3]. As civil servants, they have no or limited disclosure duties towards their universities' administration; and even if they had it in principle, their administration would find it difficult to enforce it, a professor's career being largely determined by procedures defined and managed by the government, not the university. A few countries, until recently, were also characterized by the "professor privilege", a legal institution of German origin that explicitly exempts university professors from the application of IPR laws regulating the employer-employee relationship. Under the privilege regime, the professor is the exclusively proprietary of her own inventions, and at most she has to discuss matters with the research sponsor (public or private), not the university administration. Of the countries we examine in this paper, Denmark upheld the professor privilege until 2000, Sweden still has it, Italy introduced it in 2001 (Lissoni et al., 2009).

Another important difference between the US and several European countries is the dominant role played by PROs in the public research system. In France, in particular, research activities within universities are influenced

[2] For a detailed description of the Bayh-Dole Act and its subsequent amendments, see Schacht (2011).
[3] For a definition of the concept of autonomy, when applied to universities, and an overview of its application in several European countries see Estermann and Nokkala (2009)

by CNRS (the National Centre for Scientific Research) and other large public research organizations, which contribute to finance and staff the best university laboratories, and have a claim on resulting intellectual property.

The studies by Meyer (2003), for Finland, and Balconi et al. (2004), for Italy, were the first to adopt the definition of academic patenting reported above. They also introduced the name-matching methodology now commonly used to identify academic inventors given a list of university staff. Following the same methodology, Lissoni et al. (2008) extended the analysis to France, Sweden, and Italy, while Lissoni et al. (2009) did the same for Denmark. These studies show that over 60% of academic patents in the countries considered are owned by business companies; and that academic patents owned by individual scientists are particularly numerous in Sweden and in Denmark, prior to the abolition of the professor privilege. Neither in France, Italy, Sweden or Denmark, universities own more than 10% of academic patents. In the Netherlands and the UK, where universities have a longer and stronger tradition of autonomy, the share of university ownership is quite higher (Baselli and Pellicciari, 2007; Sterzi, 2012). Ownership patterns differ between technological fields, with ownership of academic patents by universities, PROs, and individual scientists being more common in Biotech, Pharmaceuticals, and Scientific Instruments, and company ownership dominating all Engineering fields, including Electronics, Organic Chemistry, and Materials.

More recently, institutional differences between the US and Sweden have been explored by Damsgaard and Thursby (2012), with reference to IP-based entrepreneurship. They compare the probability of successful commercialization and academic start up in the two countries. The relative success of the two IP regimes in promoting academic entrepreneurship and commercialization of research results is shown to depend on a number of factors, which interact in a complex way: the existence or absence of the professor privilege, the relative advantage of established firms over faculty start-ups, the search cost in finding an established firm and the relative TTO advantage in finding licensees, the inventor's relative preference towards basic research, and the return to scale in the development phase. This confirms the importance of undertaking a comparative analysis of different systems of commercialization of academic inventions.

2.2 Characteristics, ownership and value of academic patents

Most of the studies in the available literature attempt to measure these characteristics of academic patents by means of patent citation counts, and related indexes [4] [5]. In particular, research has tested the hypothesis by which academic patents are more important and more general than non-academic ones, where "importance" is measured by the number of forward citations and is considered a proxy for economic value, and "generality" is measured by the number of technological classes where these citations come from. These two characteristics, in turn, would depend on the knowledge base of academic inventions, which would differ from that of non-academic ones in at least two respects:

1. Inventions stemming from academic research are likely to have a broader scope than inventions produced by corporate R&D, because academic scientists are trained and have a personal interest to undertake more basic research, whose results are susceptible to applications across different disciplinary fields (Henderson et al., 1998, Lacetera, 2009).

[4] Patent citations are used not only in the literature concerning academic patents, but, more generally, in all studies dealing with patent value Hall et al. (2005) show that patent citations are associated with the market value of firms, while Harhoff et al. (1999) show that the number of citations is correlated with the reported value of the inventors and with the payment of patent renewal fees.

[5] Notice that citations to academic patents are also extensively used to measure the impact of academic research and technology transfer activities on innovation in industry. For example, Rosell and Agrawal (2009) examine the "diffusion" and "diversity" premiums enjoyed by US university-owned patents over corporate ones, the former being measured by the number of organizations citing a focus patent, the latter by the number of organizations cited by the focus patent. For a critical analysis of this use of citations, see Roach and Cohen (2011).

2. Academic patents often happen to be a by-product of large research projects, rather than the results of dedicated inventive efforts (Murray and Stern, 2007). In this case, academic scientists decide to file a patent *after* they realize that their research may lead to commercial applications, and not to bend their research *ex ante* to commercial objectives, witness the high scientific productivity of most academic inventors, when compared to their non-inventing colleagues (Azoulay et al., 2007, Breschi et al., 2007).

However, it may be the case that scientists also engage in contract research or consultancy for a business partner. Here we expect the latter to exert more control on the research agenda, which will result in inventions of lesser scope, based on a more targeted and applied research efforts.

The contrast between academic inventions stemming from scientists' own agenda and those resulting from more subordinate instances of collaboration with industry is likely to be mirrored by the ownership distributions of academic inventions. In one case, we expect universities or the scientists themselves to appear as owners of the academic patents (due to the public nature of all or part of the research funds, and a strategic interest in the inventions). In the other, we expect academic patents to be owned by the business partners who funded the research, set the agenda, and have a strong interest in controlling the related property rights.

A theoretical discussion in this vein is provided by Aghion and Tirole (1994), who apply their model of innovation management to university-industry partnerships involving universities, with special emphasis on the impact of IPR allocation between the partners. The model implies that if the relative marginal impact of the university's research effort is large, the firm is likely to leave ownership to the university; however, the relative bargaining power of the two parts also affects who of the two owns the patents. A market failure (sub optimal social value of the innovation) may arise if the company owns the patent due to the university's low bargaining power and cash constraints (see also Verspagen 2006). The latter appear to be the case in several European countries, whose institutional framework limit the universities' capability to control the property rights over their academic inventors' output.

One should also remark that the economic value of patents, as measured by their importance, depends not only on the intrinsic characteristics of the inventions, but also on how successful their commercialization is. A widely licensed patent may originate several citing patents, which cover inventions produced by the licensees in order to develop further the licensed technology. Alternatively, a patent may be exploited internally by a company, and attract several imitation attempts, which also generate citing patents. To the extent that universities and business companies (or other types of assignees) differ in their commercialization abilities, a patent with the same potential may end up receiving more or less citations depending on its ownership. To be specific, it may be that universities are worse patent managers than business companies, especially in countries (such as several European ones) in which universities have been confronted only recently with IPR management issues.

So we face three complications: (i) academic inventions may or may not be originating from fundamental research, from which differences from non-academic ones may stem; (ii) patent ownership reflects only imperfectly whether academic inventions are different from (more basic than) non-academic ones; (iii) patent ownership may interfere with the causality link that goes from the nature to the value of the inventions.

Early findings by Henderson et al. (1998), for US university-owned academic patents (that is, a subset of all academic patents), confirmed the basic hypothesis of higher value of academic inventions, and were coherent with a knowledge-base explanatory framework. In particular, the authors observed a decline in both the generality and importance premiums of academic patents, a trend which they explained in two ways:

i. the increasing production of less original patents by smaller universities, attracted by the new commercialization possibilities, but with not much experience in patenting and

ii. a general decline of the average patent quality (with many patents receiving zero citations), due to academic research turning more and more applied and oriented to inventions of immediate economic value.

Subsequent studies, both in the US and in Europe, have long debated these conclusions, and provided conflicting evidence. Mowery et al. (2001) find no sign of decline in the importance and generality of patents assigned to three of the largest US academic institutions (University of California, Stanford University, and Columbia University). Although they confirm that several smaller institutions have entered the patent arena with lower quality inventions, they find evidence of a rather quick learning process, which has allowed late comers to improve the quality of their patent applications over time (Mowery et al., 2002). Fabrizio (2007) finds similar results to those of Henderson et al. (1998), with reference not only to university-owned academic patents, but also to those assigned to business companies.

Moving to Europe, Sapsalis et al. (2006) and Sapsalis and van Pottelsberghe (2007) examine academic patents owned by six Belgian universities, and find their citations rate not to differ substantially from that of a control sample of corporate patents. In addition, they find the determinants of citation rates not to differ across the samples. Bacchiocchi and Montobbio (2009) compare US, Japanese, and European university-owned academic patents and find evidence of a citation premium over corporate ones. However these results are mainly driven by chemicals, pharmaceuticals, and mechanical technologies. In addition, the result is valid only for US universities, while patents owned by European and Japanese universities do not appear to be more cited than average[6].

Other studies on European academic patents have explored whether the type of ownership (public vs. private) is somewhat related to the quality of academic patents. In a series of papers on Germany, Czarnitzki et al. (2007 and 2011) identify academic patents by checking whether the patent document include information on the professorial status of the inventor (that is, whether the inventor’s name include the title of “Professor”). They confirm the "citation premium" hypothesis, irrespective of whether the academic patents are owned by universities, individuals, or companies. The citation premium, however, appears to be higher for academic patents owned by universities and PROs, compared to those owned by business companies, and declines over time. The trend derives from both the appearance of low-cited patents by scientists from universities with no patenting history, and a drop in the citation rates on academic patents by scientists in established institutions. The authors suggest a link between their findings and the abolition of the professor privilege in 2000, which in turn appears to be associated with an increase in academic patenting. Thus, results for Germany appear in line with those for the US, despite a radical difference in the ownership distribution of academic patents. Czarnitzki et al. (2012) also replicate Sampat et al.’s (2003) early findings, according to which university-owned academic patents exhibit longer citation lags than business-owned ones, a result explained by invoking the longer time it takes to inventions based on fundamental research to be fully understood and exploited.

These results are in accordance with those by Thursby et al. (2009), who examine a sample of 5811 patents on which US faculty are listed as inventors, 26% of which are assigned solely to firms. They show that such academic patents are less basic than those assigned to universities, which suggests that they result from consulting activities, rather than academic research. Moreover, faculty in the physical sciences and engineering are more likely to assign their patents to established firms than those in biological sciences.

[6] Notice that Bacchiocchi and Montobbio (2009) use EPO data and control for the truncation bias, while Mowery et al.’s (2001) evidence of truncation bias derived from studies on USPTO (US Patent & Trademark Office) data. Legal and procedural norms concerning citations in patent documents differ between the two offices. In addition, it should be noticed that, until 2001. US patents were published (thus becoming liable of being cited) if and only after being granted, that is after the examination process. US-based evidence of differences in forward citation lags between university and non-university patents could be then explained not by differences in the importance of patents, bur differences in the length of the examination process. The same does not apply to EPO patents, which have always been published 18 months after the filing date, irrespective of the length of the examination process.

Evidence on the UK, albeit less extensive, appears to go in the opposite direction (Sterzi, 2012): business-owned academic patents receive more citations than university-owned ones at an early stage, and no fewer citations as time goes by. In addition, academic patents whose knowledge base appears closer to science do not appear to enjoy a citation premium. This is in accordance with Crespi et al.'s (2010) examination of a sample of academic patents from PatVal database, which provide information on the financial value and applied (vs. fundamental) nature of the inventions, as derived from interviews to the inventors. The authors conclude that university-owned academic patents do not differ significantly, in any of the two dimensions, from company-owned academic patents.

2.3 Our study: aims and relationship to the literature

From the preceding discussion, it emerges a double divide between early evidence on the impact and value of academic patents, and more recent studies. The former was essentially focussed on the US and university-owned academic patents, and found clear evidence of academic patents' superior importance and generality (albeit possibly subject to a decline). The latter consider also the case of Europe and include in the analysis all academic patents, irrespective of their ownership; its results concerning patent value, as measured by citations, are quite mixed, and country-specific. This suggests the need for a cross-country comparison, in order to provide evidence on countries with different legal and institutional frameworks (the former concerning intellectual property, the latter the degree of university autonomy). Our exploratory study is a first attempt to compare the value and impact of academic patents in five different European countries with different institutional frameworks.

3. Data and methodology

3.1 Data

In this paper we merge three different datasets, which cover five European countries, and have been produced with the same methodology, although at different times. The earliest and most extensive of the three datasets covers France, Italy, and Sweden, and it is used and extensively described by Lissoni et al. (2006, 2008). The other two datasets cover respectively Denmark (Lissoni et al., 2009) and the Netherlands (on which no paper has been published so far; for a description, see Baselli and Pellicciari 2007). All datasets are primarily based on the EP-KITES database, which in turn is adapted (through cleaning and standardization of records, plus regular updating) from the EPO Worldwide Patent Statistical Database, also known as PatStat[7].

Presently, the EP-KITES database contains over 1,500,000 patent applications filed at the European Patent Office. Data relevant for this paper fall into three broad categories:

1. Patent data, such as the patent's publication, priority date, and technological class (IPC 12-digit).
2. Applicant data, including name, address, and type (company, individual, higher education institution, PRO, and governmental body)
3. Inventor data, such as name, surname, address and a unique code assigned to all inventors found to be same person.

[7] PatStat is the main resource provided by the European Patent Office for the statistical analysis of patents. For a description and rules of access: http://forums.epo.org/epo-worldwide-patent-statistical-database/topic621.html. As for the projects the database of academic patents, the two most important ones are KEINS (http://portale.unibocconi.it/wps/wcm/connect/Centro_KITES/Home/Research+Networks/KEINS/) and ESF-APE-INV (http://www.academicpatenting.eu).

All data refer to patent applications, and therefore include both granted and non-granted patents. For short, in the remainder of the paper we will refer to all of them as patents; we will also use the terms "assignee", "patent owner", and "applicant" as synonyms.

Parallel to the collection of the patent data, the authors of each country dataset proceeded to the collection of biographical information on academic scientists in the countries of interest. The collection effort was directed at medicine, the natural sciences and engineering and produced a national list of academic scientists for each country (for short, PROFLIST). The information contents and accuracy of the various PROFLISTs vary across nations, reflecting the source of the data: while the Italian and French PROFLISTs were derived from ministerial records, those for Denmark and Sweden were assembled from data provided by each university, while information for the Netherlands was derived almost entirely from academic websites. As a consequence, each PROFLIST comes with a different classification system for academic ranks, and it may or may not include non-tenured staff, also depending on national legislations on tenure. In principle, however, no PhD student, PostDoc or non-academic staff (such as laboratory technicians) has been included; for short, we will refer to all of the included scientists as “professors”. All the PROFLISTs refer to scientists on active duty in one or two year: 2000 and 2004 for Italy, 2001 and 2005 for Denmark, 2005 for France, the Netherlands, and Sweden.

The identification of academic inventors was pursued in three steps. First, inventors’ names and surnames were matched to professors’ names and surnames (allowing for some spelling variation). At this stage incongruous matches were eliminated semi-automatically, as in cases when the professor’s date of birth was too close to the priority date of the inventor’s patents; or when the professor’s discipline, if known, had nothing to do with the technological classification of the inventor’s patent. In the second step, a number of these matches were validated either through patent-related information (the assignee coincides with the professor’s university) or through web searching (CV collection etc.).

In the third step, the remaining matched professors were contacted by e-mail and/or phone, in order to ask for confirmation of their inventor status. Only professors who provided positive answers were retained in the database, while those who answered negatively, were unreachable, or never returned e-mails and calls were excluded. For France, the large number of observations forced the database creators to limit this step only to the professor-inventor pairs with at least one patent filed after 1993. At the end of this last step, a “pseudo” response rate could be calculated for each country, as C/P, where P is the number of professors matched to an inventor in the first step, and C is the number of professors whose inventor status was confirmed indirectly in the second step or directly in the third one. Values for C/P range from 57% for Denmark to 94% for Sweden, with France at 66%, the Netherlands at 82%, and Italy at 87%. Notice that low values of C/P may either depend on a low value for C, due to difficulties with reaching the professors (as in France, for example) or the imprecision of the name-matching, which results in a high P (as in Denmark, for example, due to the low number of different surnames in the country, which produced many redundant matches, and little information on the professors’ discipline, which prevented from filtering many of such matches). The methodology just described is in principle susceptible to introduce errors both of type I (false positives, which consist in wrongly identifying a professor as an inventor) and type-II (false negatives). Type-I errors would lead to an *over*estimation of academic patenting, a mistake the authors of the datasets wanted to avoid, so that we may presume our data to be quite affected by type-II errors. These errors are more likely to occur the more we go back in time, since many professors who may have signed a patent in remote years were retired at the time of the data collection, which made them hard to reach by e-mail or phone. In the present paper, we try to mitigate this problem by focussing only on patents (academic and non academic) with priority dates comprised between January 1, 1995 and December 31, 2001[8].

Another limitation of the database is the non-identification of "PRO researchers' patents", which is of patents signed by researchers at Public Research Organizations, who in many cases perform fundamental research of academic type. These patents are lumped together with the non-academic ones, a measurement error which is particularly severe for Italy and, even more, for France, due to the importance of PROs in both countries.

These operations left us with 115,185 EPO patent applications, signed by inventors with an address either in Denmark (DK), France (FR), Italy (IT), the Netherlands (NL), or Sweden (SE)[9]. Of these, 5416 are classified as academic patents (4.7%). All patents are assigned to a technological field, according to OST (2008) classification: (1) Electrical engineering; Electronics, (2) Instruments, (3) Chemicals; Materials, (4) Pharmaceuticals; Biotechnology, (5) Industrial processes, (6) Mechanical eng.; Machines; Transport, (7) Consumer goods; Civil engineering.

Finally we use patent citations to measure the impact of patented inventions. In particular, we collect citations from the PatStat database, updated to October 2009 and containing over 4.5 million citations. We selected all backward citations from EPO patents in our sample to other EPO patents or equivalents, and all citations received by EPO patents in our sample (or their equivalents) from other EPO patents. This figure includes all *self-citations*, that is all cases in which the citing and the cited patents share at least a common inventor or a common applicant (when necessary, we will remove them from the analysis).

3.2 Econometric Specification

We model the number of citations received by a patent as a function of:

- ✓ the origin of the invention (academic vs. non-academic)
- ✓ the ownership type of the patent; in particular, for all patents applications (whether academic or not) we can distinguish between those filed by individuals and those filed by organizations (the overwhelming majority of which are business companies); while for academic patents we can distinguish between those owned by universities, business companies, PROs or governmental organizations and individuals
- ✓ the inventor's country
- ✓ other characteristics of the patents, the most important being their priority date (at the year level), technological class, and scope (as measured by the number of novelty claims)

In our main regressions we consider only the citations received by the patent over the first four years after its priority date (self-citations excluded), but we run robustness checks with citations over six years[10]. We expect the ownership type of academic patents to be associated with the number of citations, but, as we discuss in the final section, we are cautious in interpreting as resulting from causation of the latter by the former. Being the dependent variable a count variable, we applied appropriate regression techniques, such as Poisson and Negative Binomial regression. The results we obtained are similar, despite some over-dispersion of citation counts. We report only

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[8] One further measure taken to correct Type-II error consisted in defining as "academic" all patents which had not been identified as such on the basis of the inventor's identity, and yet listed a university among the applicant. This data correction has been made only for the purposes of the present paper. This explains some differences between the estimates of the number of academic patents we report below, and those reported by the original publications from where the country data set have been taken.

[9] We dated the patents with their priority year; when missing, we replaced it with the application year.

[10] We have chosen a 4-years citation window to avoid bias due to truncation on the right-end side. Bacchiocchi and Montobbio (2009) show that for universities owned and PROs the citation lag distribution is shifted to the left relative to the companies. The second column of table 4 in this paper suggests that a similar result hold for all academic patents. At the same time Bacchiocchi and Montobbio (2010) show that likelihood that an EPO patent is cited becomes half of its estimated maximum after 6–7 years. This difference could create some biases in our results underestimating the citations of patents by companies; accordingly we have made all the regressions also with a 6-years citation window. Results do not change and are available from the authors.

those obtained with the Poisson model, whose estimated coefficients can be interpreted as semi-elasticities and their exponential transformation as factor changes (Wooldridge, 2003).

3.3 Variables

Our dependent variable is the number of citations received by each patent *i* over four years after the priority date, excluding self-citations (FWD_CIT4_i). In addition, we produce a set of descriptive statistics on the nature of academic patents, namely:

- ✓ $AVG\_FWD\_LAG_i$=Average citation lag of forward citations received by patent *i;*
- ✓ $GEN\_BH_i = [FWD\_CIT_i/(FWD\_CIT_i -1)]* (1-\sum_j s^2_{ij})$: generality index of patent *i*, controlling for the small sample bias (Hall, 2005). FWD_CIT_{iJ} is the total number of forward citations to patent *i* from the technological class *j* ($FWD\_CIT_i=\sum_j FWD\_CIT_{ij}$; j=1,…,K; where K is the number of technological classes); accordingly, $s_{ij}=FWD\_CIT_{ij}/FWD\_CIT_i$ is the share of forward citations from class *j* to patent *i.*
- ✓ $ORIG\_BH_i = [BACK\_CIT_i/(BACK\_CIT_i -1)]*(1-\sum_j s^2_{ij})$: originality index of patent *i*, controlling for the small sample bias (Hall, 2005). $BACK\_CIT_{iJ}$ is the total number of backward citations to patent *i* from the technological class *j* ($BACK\_CIT_i=\sum_j BACK\_CIT_{ij}$; j=1,…,K;); accordingly, $s_{ij}=BACK\_CIT_{ij}/BACK\_CIT_i$ is the share of forward citations from class *j* to patent *i.*

The explanatory variables come in three groups to which we add year and technology dummies.

Variables in the first group are dummies that identify academic patents and their ownership:

- ✓ AC_INV_i = 1 if the patent is an academic one, as defined above, 0 otherwise;
- ✓ $AC\_INV\_COMPANY_i$=1 if AC_INV_i=1 *and* the patent is company-owned, 0 otherwise;
- ✓ $AC\_INV\_INDIVIDUAL_i$=1 if AC_INV_i=1 *and* the patent is owned by an individual (most often, the inventor), 0 otherwise;
- ✓ $AC\_INV\_UNIVERSITY_i$=1 if AC_INV_i=1 *and* the patent is university-owned, 0 otherwise; note that all patents assigned to universities are classified as academic.
- ✓ $AC\_INV\_PRO_i$=1 if AC_INV_i=1 *and* the patent is owned by the government or public research institutions, 0 otherwise;

Notice that 6.28% of academic patents are characterized by multiple ownership so the last four variables are not mutually exclusive.

Variables in the second group describe some characteristics of the patent that are expected to be correlated with its value:

- ✓ $INDIVIDUAL_i$=1 if patent *i* is assigned to one or more of its inventors (neither to a company nor other organization), 0 otherwise; notice that this dummy is assigned irrespective of whether the patent is academic or not
- ✓ $FOREIGN\_CO\text{-}INV_i$=1 if there are at least two inventors from different countries in patent *i*, 0 otherwise;
- ✓ $CLAIMS_i$ is number of claims in patent *i* (this number can change when the patent is granted, following requests or suggestions by the examiner; we report the number of claims on the original application)

We expect CLAIMS to be positively related to the value of a patent as it measures its scope. FOREIGN_CO-INV is an indirect measure of the inventor team's quality, as we presume international teams to have been assembled for more ambitious research projects; therefore we also expect it to be positively associated with patent value. As for INDIVIDUAL, the literature suggests patents assigned to individuals to be of lower quality than those assigned to companies, as they may be the result on non-systematic, profit-oriented research activity, or less well managed when it comes to their exploitation (due to individual inventors' lack of resources compared to firms).

The third group of variables describes the patent in terms of *backward* citations[11]:

- ✓ $BACK\_CIT_i$=number of backward citations by patent *i;*
- ✓ $AVG\_BACK\_LAG_i$=Average citation lag of backward citations by patent *i;*
- ✓ $ORIG\_BH_i$ as described above

This last group of variables identifies important characteristics of the patent that may affect its probability of being cited, such as the level of cumulativeness and technological opportunities incorporated in the invention (BACK_CIT, ORIG_BH) and the speed of knowledge absorption (AVG_BACK_LAG) (Bacchiocchi and Montobbio, 2009).

4. Results

4.1 Descriptive Results

Table 1 reports the number and relative weight of academic and non-academic patents by country. Evidence is similar across all countries, with academic patents in between 3.7% and 6.2% of total patents by domestic inventors. Notice that the lowest figure refers to France, in which universities' weight in scientific research and technology transfer, is minimal compared to that of other countries in our sample, due to the presence of large PROs. We do not observe any significant time trend, neither at the aggregate nor at the country level (country data available on request).

Table 2 reports the number of patents in our sample per technological class. In all countries, as suggested by the literature, academic patents appear to be particularly numerous in Pharmaceuticals and Biotechnologies (with a peak of 25% share of all patents in the field, for Sweden), while their number is scarcely relevant for less science-based technologies such as Industrial Processes, Mechanical Engineering, and Consumer Goods.

Table 3 shows the share of academic patents by ownership and country. In Europe company ownership is extremely important. On aggregate, 62.74% of academic patents belong to companies, followed by 14.77% to universities, 5.08% to individuals, and 8.99% to PROs or governmental agencies, while 6.28% are co-owned by a combination of different types of assignees [12]. Table 3 also shows clearly that ownership patterns differ markedly across countries: company ownership is particularly low in France (52.29%) and high in Sweden (75.56%). Conversely, France is the country with the highest share of academic patents owned by PROs and governmental agencies (18.59%, which is double the cross-country average) while Sweden has, alongside with Denmark, the highest share of academic patents owned by individuals (16.61% and 11.58%). These figures reflect, respectively, the role of PROs in the French research system, and of the professor privilege in Scandinavian countries. Notice that the

[11] Since the dependent variable is based on forward citations we have decided to include in the regressions only the indexes based on backward citations. The backward measures that we included in the regressions include all the citations. This means that we kept in the calculation of the originality index the self-citations and all the citation lags in order to give the full picture of the origin of the inventions. Note that we use EPO patent citations that are selected mainly by patent examiners that - according to the EPO guidelines – have to include all technically relevant information within a minimum number of citations

[12] Of 340 co-owned academic patents 120 are co-owned by companies and PROs (mainly for France), followed by 104 co-owned by universities and PROs and 96 co-owned by companies and universities (36 from the Netherlands and 33 from France). For 116 academic patents we have no information about the applicant.

Netherlands, whose universities have greater autonomy than those in any other country in our sample, exhibit the highest share of university ownership (21.34%), and the lowest one for individual ownership (<1%).

One issue with our categorization of ownership types is that company ownership may in fact comprehend all patents held by academic start-ups, which to some extent would be better classified along with the individually-owned patents (especially if created by the academic inventor for the sole purpose of serving as repository of patents, in which case we call it a "shell company"). In particular, this should be true for Scandinavian countries, where academic inventors have more control of IPRs over their inventions, thanks to the professor privilege. Figure 1 investigates this issue by illustrating the distribution of company-owned patents according to a 3-entry categorization of companies:

1. companies with small patent portfolios (<21 patents), entirely dominated by academic patents (100% of patents) ;
2. companies with 20% to <100% of academic patents in their portfolios (with portfolios of any size);
3. companies with < 20% of academic patents in their portfolios, none of which is found to have less than 5 patents in the portfolio (many of which have indeed over 100 patents)

The first category of companies is the most likely to include academic start ups or shell companies, as opposed to the third one, which is likely to be composed only of large companies with some academic collaborations; the second category is more heterogeneous. Figure 1 shows that most patents fall in the third category, so that we can safely consider them held by companies whose creation was independent from the academic patent(s) they may own. The only exception is Denmark, where patents in the second category are as numerous. In any case, in all countries, patents in the first category represent a minimal share of company-owned academic patents, even in Scandinavian countries. Overall, this evidence confirms the reliability of our categorization of academic patents' owners.

The following tables, from 4 to 7, provide descriptive statistics on the characteristics of academic patents. In particular they compare the average values, for academic and non academic patents of: the number of four-year forward citations (FWD_CIT4, with self-citations excluded), the forward citation lag (AVG_FORWARD_LAG), and the indexes of generality and originality, corrected for small sample bias (GEN_BH and ORIG_BH, respectively).

Table 4 shows that academic patents are more important (more cited) than non-academic ones (the values of FWD_CIT4 are respectively 0.81 and 0.78). The difference, however, is not statistically significant and may be entirely explained by a composition effect, academic patents being concentrated in technological fields with a higher-than-average number of citations per patent. Table 4 also shows that, consistently with Bacchiocchi and Montobbio (2009), citations to academic patents tend to appear sooner, rather than later, than those to non academic ones (3.84 vs. 4.04 years). Also consistently with the literature, academic patents appear to be more general and more original than non-academic ones.

Table 5 compares the same indicators for academic patents with different types of ownerships. Company-owned and individually-owned academic patents appear to be the most cited, although none of the differences is significant. Citations to university-owned patents exhibit the shortest lag (and the difference with respect to company-owned is significant). Some differences also exist for generality (PRO-owned being the most general) and originality (individually-owned being the most original

Tables 6 and 7 compare indicators across countries and technologies, respectively. They report information in a more compact form than previous tables (mean ratios, instead of fully-fledged summary statistics). We notice that Sweden is the only country in which academic patents are less important than non-academic ones, and that in France importance is the same. As for originality and generality, Dutch academic patents do not appear to differ much from non-academic ones. As for technologies, academic patents appear to be the least important (relative to non academic) precisely in the field where they carry more weight, namely Pharma-Biotech, followed by another important field such as Electronics. On the contrary, academic patents appear to carry a significant advantage over non-academic ones only in Consumer goods & Civil engineering and Industrial process, two fields in which their presence is more limited. Differences with respect to other indicators are of less importance.

Table 8 reports summary statistics for all explanatory variables in our regression exercise. Ownership types for all patents (academic and non academic) is represented by one dummy: INDIVIDUAL, which takes value 1 whenever the patent is assigned to its inventor(s), and zero otherwise. This is because, for non academic patents, we do not have sufficient information to distinguish types of assignee, besides telling individuals apart from organizations of all types. However, our knowledge of the data suggest that, in the vast majority of cases, when INDIVIDUAL=0 the applicant is a company, with possibly a minor role played by PROs, especially in France. All patents assigned to universities are classified as academic. Dummies reporting information on academic patents' ownership type are not mutually exclusive, as there are several patents co-owned by different types of applicants (see again table 3), and we do not treat co-ownership with a dummy of its own.

Notice also that we can calculate ORIG_BH only for patents with at least two backward citations; similarly, we can calculate AVG_BACK_LAG only for patents with at least one citation. This would leave us with too many missing, a problem to which we put remedy as explained in the footnotes to table 8. In the tables, however, we report the number of non-missing observations we obtain before replacing missing ones with *ad hoc* values. Finally, we observe that the need of controlling for FOREIGN_CO-INV and CLAIMS is justified by summary calculations, which shows that academic patents have more foreign inventors (0.21% vs. 0.12%), and report more claims (18.26 vs. 13.81) than non-academic ones.

4.2 Regression results

Results from our regressions are reported in table 9 and 10. Column (1) reports the results from the basic model, in which academic patents are considered as one single category (AC_INV=1), irrespective of their property, and all countries are jointly considered (with country dummies as controls). We find that academic patents are significantly less important than non-academic ones, although the difference is modest: they get only 5% less citations in the first 4 years after priority, which is much less than the impact of some control dummies (most notably, INDIVIDUAL and FOREIGN_CO-INV, whose impact is about 20%, in absolute value). It is important to stress that we observe considerable heterogeneity across countries and fields. When replicating regression (1) for each country, the sign of AC_INV remains negative in all countries but the Netherlands and Denmark, and it is significantly different from zero only in Sweden (estimated coefficient equal to -0.32***; full results available on request). If we run regression (1) separately for each technological field, the negative sign for AC_INV remains significantly different from zero only in Electrical engineering&Electronics and Pharmaceuticals& Biotechnology (full results available on request).

In column (2) we show that the number of citations received of academic patents is affected by ownership. We do so by replacing AC_INV with the dummies for the different applicant types. The Wald test rejects the restriction that the coefficients are the same for all ownership types. Negative coefficients are observed for academic patents owned by companies, universities or PROs, but absolute values and especially significance levels vary considerably across countries and fields. As for the relationship between the dependent variable and AC_INV_INDIVIDUAL, this has to be understood by taking into account also the estimated coefficient for INDIVIDUAL: in the case of academic patents owned by individuals, in fact, both dummies take value 1. The estimated coefficient for INDIVIDUAL tells us that, in general, patents owned by their inventors get 22% less citations than average, while the estimated coefficient for AC_INV_INDIVIDUAL tells us that academic patents owned by individuals get 27% more citations than non-academic, individual-owned patents. Columns (3) to (7) replicate the regression in column (2), by country. The Wald tests reject the restriction that the coefficients are the same for all ownership types for all countries but Italy. Regressions by fields are displayed in table 10.

In Italy and Denmark we find negative values for the estimated coefficient of AC_INV_UNIVERSITY. In Italy university-ownership decreases the expected number of citations to an academic patent by a factor of 0.77, holding all other variables constant. In Denmark university-ownership decreases the expected number of citations by a factor of 0.49, holding all other variables constant[13].

The sign of AC_INV_UNIVERSITY is negative also in Sweden and France but not significantly different from zero. In Sweden, academic patents owned by companies get 41% less citations than non-academic ones and it appears clearly that it is this country that drives entirely the result for AC_INV_COMPANY we observe in column (2) of table 9. In fact, estimated coefficients for AC_INV_COMPANY in all other countries are positive, albeit not significant. In addition this result seems to be concentrated in particular in Electronics&Electrical Engineering (Table 10). Finally we observe in column (3) that in France PRO-owned academic patents get 19% less citations than non-academic ones (estimated coefficients for all other countries are not significantly different from zero, also due to the much lower number of observations with AC_INV_PRO=1, compared to France). Note that the importance of academic patents differs across fields. The negative sign is mainly due to patents in Industrial Processes, Consumer Goods and Civil Engineering, while the estimated coefficients are positive for Instruments, Electronics and Electrical Engineering.

In the Netherlands, all estimated coefficients for dummies related to academic patenting take a positive value, although they are significantly different from zero only in the cases of company- and university-owned patents (where we have a high number of observations) and individually-owned patents (with only few patents as shown in table 3). In particular, university-owned academic patents get 26% more citations than non-academic ones, while company-owned patents get 16% more. In all other countries, university-owned academic patents are far from performing this well. Note from Table 10 that the university-ownership affects patents' citations negatively especially in Pharmaceuticals & Biotechnology, where academic patents are most numerous (see table 2)[14].

Coming to academic patents held by individuals, the estimated coefficient of AC_INV_INDIVIDUAL is always positive. The exception is the Netherlands where the estimated coefficient for INDIVIDUAL is non significantly different from zero (whereas in all other countries we get the expected negative sign and similar values, albeit higher, in absolute terms, in Sweden). Notice however that, due to the little importance of this category of academic patents in the Netherlands, this result is due to 10 observations only.

We finally notice that the sign of all controls is the one expected and values are consistent across all columns. The only possible exceptions are Denmark, with a non-significant estimate for FOREIGN_CO-INV (but this is a much smaller country than the others, in which we may expect a higher share of patents with foreign co-inventors) and France, Italy and Sweden, in which we do not find a significant association between originality and the dependent variable.

4.3 Discussion and limitations

[13] These results do not change substantially including in the regressions only the academic invented patents.

[14] The significant result for Consumer Goods and Civil Engineering should not be taken into account because there are only two university-owned academic patents in this field. Both of them have with zero citations in the regression sample. The result disappears using a 6 year citation window because one of the two patents gets its first citation.

Our most important results can be summarised as follows. Academic patents, in the five European countries considered, tend to be less valuable or as valuable as non-academic ones. However, a great heterogeneity exists, by country and type of ownership. In general, company-owned academic patents' value appears to be closer to that of non-academic ones. On the other hand, university-owned academic patents in Italy and Denmark, along with PRO-owned ones in France, appear to be clearly less valuable than business-owned ones, whether academic or not. In contrast, the Netherlands are the only country in which academic patents clearly outperform non-academic ones, whether owned by universities or companies. It is also the country that hosts the most autonomous among the five university systems considered, the one in which academic institutions exert the strongest control over their faculty's IPRs, and have accumulated the largest experience in handling IPR matters, witness the high share of university-owned academic patents. Accordingly, we tend to explain the Dutch performance with the superior autonomy of their universities. Such explanation appears to be appealing especially when we compare the Netherlands to France and Italy. Both of these countries have a centralized academic system, in which universities gained autonomy only recently and still have limited administrative and financial means to select and manage effectively their patent portfolios (as described by Della Malva, 2013, and Lissoni et al., 2012).

We observe an anomalous result for Sweden, the only country in which business-owned academic patents perform worse than any other category. We have no explanation for this anomaly. We considered the possibility that, due to the professor privilege, Swedish company-owned academic patents may be in fact, by and large, individually-owned patents (see discussion in section 3). However, the data we presented in Figure 1 lead us to exclude this explanation.

A more important limitation of our work, however, is that the explanations of our findings we suggested above are, at least in part, speculative. With the data presently at our disposal we cannot identify all the causal links between nature (academic vs. non-academic) and ownership of patents, as discussed in section 2.2. In particular, we cannot establish with certainty whether a lower citation rates of university-owned academic patents compared to business-owned ones is due to their intrinsic quality (which in turn depends on the quality of the underlying research), or to lower commercialization abilities of universities compared to companies. Nor we can test the existence of a selection effect, according to which business companies would pick and buy from universities the best academic patents, and leave them with the least valuable ones.

5. Policy implications and further research

This paper has explored the impact and value of academic patents in several European countries, as measured by patent citations. Inventions based upon academic research are considered an important driver of innovation activities and academic patents are often regarded by policy makers as a crucial tool of technology transfer. However, little attention has been paid so far to their ownership structure and how it is related to the effectiveness of technology transfer. This paper provides the first empirical analysis of the issue by comparing academic patents across five European countries and types of ownership.

Among the most debated IP reforms of the last few years there are those concerning the professor privilege, which was abolished in Denmark and introduced in Italy more or less at the same time and with similar motivations (in both case, the new ownership rules were meant to establish a new incentive system, better suited to promote the commercialization of academic inventions). Albeit our data stop before these policy changes occurred, we can feed the debate by observing that individually-owned academic patents are more important than individually-owned non academic ones, but not necessarily more important than other, differently owned academic patents. The main exception is Italy, where individually-owned academic patents fare worse, so that many doubts can be raised on the opportunity of having introduced the professor privilege in that country, and on the usefulness of the professor privilege in general.

A much more striking result is the superior performance of Dutch academic patents, which we attribute not to any legal rule concerning academic IP, but to the autonomy of Dutch universities and their superior experience in handling IP matters. This may be either allow them to better select the patents to be held in their portfolios or to better manage them. More radically, it could simply be that Dutch universities carry on better research projects, at least if measured in terms of their technology transfer potential, but there is no literature to suggest this. Further research needs also to be undertaken in order to verify to what extent these results may depend from the behaviour of three universities only, namely those Delft, Leiden and Eindhoven. In fact, unreported data show that the former two are the Dutch universities with the largest share of university-owned academic patents, which amounts to the largest experience in handling IP: the results we get for the Netherlands as whole could be then entirely explained by these two institutions' performance. As for Eindhoven, this is the most prolific Dutch university in terms of number of academic patents, but also the one with the highest share of company-owned patents, due to its *de facto* integration in the R&D system of Phillips (which sponsors much of its research and retains the related IP). Again, the results we get for company-owned academic patents in the Netherlands may be entirely explained by this single case.

In contrast with the Dutch case, we have the Italian one, for whose (poor) performance we offer a mirror image explanation, based on the lack of autonomy and IP management experience of its academic institutions. Very recent results on ownership trends of Italian academic patents, by Lissoni et al. (2012), support this explanation.

A more general conclusion we can draw form our study is that the evidence on the phenomenon of academic produced by US scholars can be hardly extended to Europe, and certainly cannot provide much policy guidance. The institutional features of US and European universities differ considerably, as it differs the experience accumulated over the years in handling IP matters. Much more within-Europe comparative work ought to be done, from which more useful lessons can be learned. In order to do so, we plan to update our database, which currently stops in 2001, and to widen the number of countries considered.

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TABLES AND FIGURES

Table 1. Academic vs. non-academic patents in selected European countries, 1995-2001

	Non-academic (i)		Academic (ii)		All (i)+(ii)	
	nr	*% of All*	Nr	*% of All*	nr	*% of All*
Denmark	5407	*(95.2%)*	271	*(4.8%)*	5678	*(100%)*
France	47160	*(96.3%)*	1813	*(3.7%)*	48973	*(100%)*
Italy	23483	*(95.3%)*	1157	*(4.7%)*	24640	*(100%)*
Netherlands	19534	*(94.0%)*	1142	*(6.0%)*	20776	*(100%)*
Sweden	14185	*(93.8%)*	933	*(6.2%)*	15118	*(100%)*
Total	109769	*(95.3%)*	5416	*(4.7%)*	115185	*(100%)*

Source: Lissoni et al. (2008, 2009); Baselli and Pellicciari (2007) and EP-KITES database.

Table 2. Academic vs. non-academic patents in selected European countries[a], 1995-2001; by technology

	Non-academic (i)		Academic (ii)		All (i)+(ii)	
	nr	*% of All*	Nr	*% of All*	*nr*	*% of All*
Electrical engineering; Electronics	27966	*(96.1%)*	1146	*(3.9%)*	29112	*(100%)*
Instruments	14114	*(93.5%)*	979	*(6.5%)*	15093	*(100%)*
Chemicals; Materials	12680	*(93.2%)*	920	*(6.8%)*	13600	*(100%)*
Pharmaceuticals; Biotechnology	9208	*(83.4%)*	1829	*(16.6%)*	11037	*(100%)*
Industrial processes	16843	*(98.0%)*	338	*(2.0%)*	17181	*(100%)*
Mechanical eng.; Machines; Transport	17736	*(99.2%)*	150	*(0.8%)*	17886	*(100%)*
Consumer goods; Civil engineering	11222	*(99.5%)*	54	*(0.5%)*	11276	*(100%)*
Total	109796	*(95.6%)*	5416	*(4.7%)*	115185	*(100%)*

[a] Denmark, France, Italy, the Netherlands, Sweden

Source: Lissoni et al. (2008, 2009); Baselli and Pellicciari (2007) and EP-KITES database.

Table 3. Nr and share of academic patents in selected European countries, by ownership 1995-2001

	Company-owned	University-owned	Individually-owned	PRO- or Gov't-owned	Co-owned	Missing info	Total
Denmark	170	34	45	9	8	5	271
%	*62.73*	*12.55*	*16.61*	*3.32*	*2.95*	*1 .85*	*100.00*
France	948	287	38	337	174	29	1,813
%	*52.29*	*15.83*	*2.10*	*18.59*	*9.6*	*1.60*	*100.00*
Italy	762	146	74	77	66	22	1,157
%	*65.86*	*12.62*	*6.40*	*6.66*	*5.7*	*1.77*	*100.00*
Netherlands	813	265	10	60	72	22	1,242
%	*65.46*	*21.34*	*0.81*	*4.83*	*5.80*	*1.77*	*100.00*
Sweden	705	68	108	4	20	28	933
%	*75.56*	*7.29*	*11.58*	*0.43*	*2.14*	*3.00*	*100.00*
Total	*3,398*	*800*	*275*	*487*	*340*	*116*	*5,416*
%	*62.74*	*14.77*	*5.08*	*8.99*	*6.28*	*2.14*	*100.00*

Source: Lissoni et al. (2008, 2009); Baselli and Pellicciari (2007) and EP-KITES database.

Table 4. Importance, forward citation lag, generality and originality of academic vs. non-academic patents; selected European countries[a], by type of patents (academic vs. non academic patents)

	Importance (FWD_CIT4)	Avg fwd citation lag (AVG_FWD_LAG)	Generality (GEN_BH)	Originality (ORIG_BH)
Academic				
Mean (St. Dev.)	0.81 (1.66)	3.84 (1.96)	0.38 (0.40)	0.36 (0.39)
N. of obs.	5416	2552	1419	2877
Min ; Max	0 ; 31	-2 ; 12	0 ; 1	0 ; 1
Non academic				
Mean (St. Dev.)	0.78 (1.72)	4.04(2.04)	0.30 (0.39)	0.31 (0.37)
N. of obs.	109769	52360	28426	61792
Min ; Max	0 ; 104	-2 ; 13	0 ; 1	0 ; 1
t value mean difference	1.3	-4.8***	7.5 ***	7.1 ***

[a] Denmark, France, Italy, the Netherlands, Sweden

*,**,*** : 10%, 5%, 1% significance

Source: elaborations on Lissoni et al. (2008, 2009); Baselli and Pellicciari (2007) and EP-KITES database.

Table 5. Importance, forward citation lag, generality and originality of academic patents; selected European countries[a], by type of ownership

	Importance (FWD_CIT4)	Avg fwd citation lag (AVG_FWD_LAG)	Generality (GEN_BH)	Originality (ORIG_BH)
Company-owned				
Mean (St. Dev.)	0.84 (1.71)	3.87 (1.90)	0.35 (0.39)	0.34 (0.38)
N. of obs.	3398	1617	923	1888
Min ; Max	0,31	-2,11	0,1	0,1
University-owned				
Mean (St. Dev.)	0.76 (1.71)	3.53 (1.90)***	0.41 (0.41)*	0.39 (0.41)**
N. of obs.	800	362	191	369
Min ; Max	0,31	-1,11	0,1	0,1
Individually-owned				
Mean (St. Dev.)	0.87 (1.33)	4.12 (2.10)*	0.40 (0.38)	0.44 (0.42) ***
N. of obs.	275	156	81	143
Min ; Max	0,8	0,11	0,1	0,1
PRO & Gov't-owned				
Mean (St. Dev.)	0.72 (1.46)	4.04 (2.13)	0.47 (0.42)***	0.38 (0.41)
N. of obs.	487	232	124	252
Min ; Max	0,16	-1,12	0,1	0,1
Co-owned				
Mean (St. Dev.)	0.78 (1.53)	3.74 (2.12)	0.39 (0.40)	0.35 (0.40)
N. of obs.	340	150	88	171
Min ; Max	0,10	-1,11	0,1	0,1
Missing inf.				
Mean (St. Dev.)	0.59 (1.78)	3.23 (2.02)	0.27 (0.40)	0.42 (0.40)
N. of obs.	116	35	12	54
Min ; Max	0,15	-2,8	0,1	0,1

[a] Denmark, France, Italy, the Netherlands, Sweden

*,**,*** : 90%, 95%, 99% significant t-test of mean value (v Company-owned)

Source: elaborations on Lissoni et al. (2008, 2009); Baselli and Pellicciari (2007) and EP-KITES database.

Table 6. Importance, forward citation lag, generality and originality of academic vs. non-academic patents in selected European countries: mean ratios, by country

	Importance (FWD_CIT4)	Avg fwd citation lag (AVG_FWD_LAG)	Generality (GEN_BH)	Originality (ORIG_BH)
Denmark	1.16	0.88	1.14	1.28
France	1.03	0.93	1.22	1.14
Italy	1.17	0.88	1.44	1.23
Netherlands	1.17	0.88	1.07	1.05
Sweden	0.80	0.91	1.33	1.27

Source: elaborations on Lissoni et al. (2008, 2009); Baselli and Pellicciari (2007) and EP-KITES database.

Table 7. Importance, forward citation lag, generality and originality of academic vs. non-academic patents in European countries[a]: mean ratios, by technology

	Importance (FWD_CIT4)	Avg fwd citation lag (AVG_FWD_LAG)	Generality (GEN_BH)	Originality (ORIG_BH)
Electrical engineering; Electronics	0.91	1.04	1.07	1.13
Instruments	1.02	0.92	1.08	1.08
Chemicals; Materials	1.06	0.97	1.08	1.17
Pharmaceuticals; Biotechnology	0.83	0.90	1.13	1.00
Industrial processes	1.16	1.00	1.64	1.40
Mechanical eng.; Machines; Transport	0.97	1.06	1.54	1.33
Consumer goods; Civil engineering	1.34	0.87	1.13	0.78

[a] Denmark, France, Italy, the Netherlands, Sweden

Source: elaborations on Lissoni et al. (2008, 2009); Baselli and Pellicciari (2007) and EP-KITES database.

Table 8. Summary statistics (regression variables)

		Nr of obs [1]	Mean	Std. Dev.	Min	Max
FWD_CIT4	*Nr of citations in 4 years after priority (self-citations excluded)*	115185	0.78	1.72	0	104
AC_INV	*=1 for academic patents*	115185	0.05	0.21	0	1
AC_INV_COMPANY	*=1 for acad. patents owned by a company*	115069	0.03	0.18	0	1
AC_INV_INDIVIDUAL	*=1 for acad. patents owned by the inventor(s)*	115069	<0.01	0.05	0	1
AC_INV_UNIVERSITY	*=1 for acad. patents owned by a university*	115069	0.01	0.09	0	1
AC_INV_PRO	*=1 for acad. patents owned by a PRO or governmental body*	115069	0.01	0.08	0	1
INDIVIDUAL	*=1 for patents owned by the inventor(s)*	115185	0.08	0.27	0	1
FOREIGN_CO-INV	*=1 if co-inventors include ≥1 foreign inventor*	115185	0.13	0.34	0	1
CLAIMS	*nr of claims*	114776	14.02	10.17	1	263
ORIG_BH [2]	*originality index, adjusted*	64669	0.31	0.38	0	1
AVG_BACK_LAG [3]	*avg lag of backward citations*	88351	6.53	3.69	-2	25
BACK_CIT	*nr of backward citations*	115185	2.55	3.15	0	78
ZERO_BACK_CIT [2] [3]	*=1 if zero backward citations*	115185	0.44	0.5	0	1

(1) Each patent is counted more than once if its inventors come from more than one of the five countries considered

(2) Reported values for ORIG_BH are only for observations (patents) with more than 1 backward citation. For patents with 1 backward citation, the ORIG_BH formula generates a missing value, which we replace with 0 (zero originality). For patents with zero backward citations, the ORIG_BH also generates a missing value, which we replace with the mean value. A ZERO_BACK_CIT dummy (= zero backward citations) is introduced to control for this correction.

(3) Reported values for AVG_BACK_LAG are only for observations (patents) with at least 1 backward citation. For patents with zero backward citations, the AV_BLAG generates a missing value, which we replace with the mean value. A ZERO_BACK_CIT dummy (= zero backward citations) is introduced to control for this correction.

(4) When appropriate, regressions also include time and technology dummies, not reported here

Table 9. Regression results (y=FWD_CIT4; QML-Poisson regression)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	All countries	**All countries**	**France**	**Italy**	**Netherlands**	**Denmark**	**Sweden**
AC_INV	-0.05*						
	(0.029)						
AC_INV_COMPANY		-0.05	0.02	0.02	0.16*	0.06	-0.41***
		(0.034)	(0.056)	(0.061)	(0.098)	(0.15)	(0.069)
AC_INV_INDIVIDUAL		0.27***	0.60***	0.073	0.60*	0.48**	0.36**
		(0.092)	(0.22)	(0.16)	(0.36)	(0.23)	(0.16)
AC_INV_UNIVERSITY		-0.06	-0.15	-0.26*	0.26**	-0.71***	-0.18
		(0.067)	(0.099)	(0.15)	(0.13)	(0.23)	(0.17)
AC_INV_PRO		-0.09	-0.19**	0.050	0.058	-0.42	-0.48
		(0.077)	(0.097)	(0.18)	(0.21)	(0.35)	(0.70)
FOREIGN_CO-INV	0.20***	0.19***	0.23***	0.068	0.12***	0.038	0.23***
	(0.019)	(0.019)	(0.031)	(0.042)	(0.045)	(0.057)	(0.047)
CLAIMS	0.01***	0.01***	0.01***	0.01***	0.02***	0.01***	0.01***
	(0.0006)	(0.0006)	(0.0008)	(0.0012)	(0.0016)	(0.0012)	(0.0011)
BACK_CIT	0.05***	0.05***	0.04***	0.05***	0.04***	0.03***	0.05***
	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.005)	(0.004)
ORIG_BH	0.03*	0.03*	0.02	0.02	0.18***	0.20***	-0.06
	(0.018)	(0.018)	(0.026)	(0.038)	(0.047)	(0.068)	(0.049)
AVG_BACK_LAG	-0.05***	-0.05***	-0.05***	-0.04***	-0.05***	-0.04***	-0.07***
	(0.002)	(0.002)	(0.002)	(0.004)	(0.005)	(0.007)	(0.005)
BCIT_ZERO	-0.89***	-0.89***	-0.61***	-0.68***	-1.84***	-0.70***	-0.58***
	(0.025)	(0.025)	(0.042)	(0.037)	(0.061)	(0.084)	(0.056)
INDIVIDUAL	-0.20***	-0.22***	-0.23***	-0.24***	-0.025	-0.23**	-0.45***
	(0.023)	(0.024)	(0.040)	(0.039)	(0.069)	(0.10)	(0.075)
CONSTANT	-0.42***	-0.42***	-0.58***	-0.60***	-0.40***	-0.22**	0.012
	(0.024)	(0.024)	(0.036)	(0.054)	(0.059)	(0.092)	(0.058)
Observations	*115,185*	*115,069*	*48,944*	*24,608*	*20,754*	*5,673*	*15,090*
Time dummies	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*
Tech. Field dummies	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*
Chi^2	*7869*	*7908*	*2782*	*1594*	*1965*	*6356*	*1920*
Significance	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Pseudo-r-sq.	*0.100*	*0.100*	*0.069*	*0.064*	*0.18*	*0.086*	*0.16*
Wald test , chi2(3)[§]		*18.41 (0.00)*	*12,69 (0.005)*	*3.37 (0.49)*	*10.77 (0.02)*	*15.89 (0.03)*	*41.25 (0.00)*

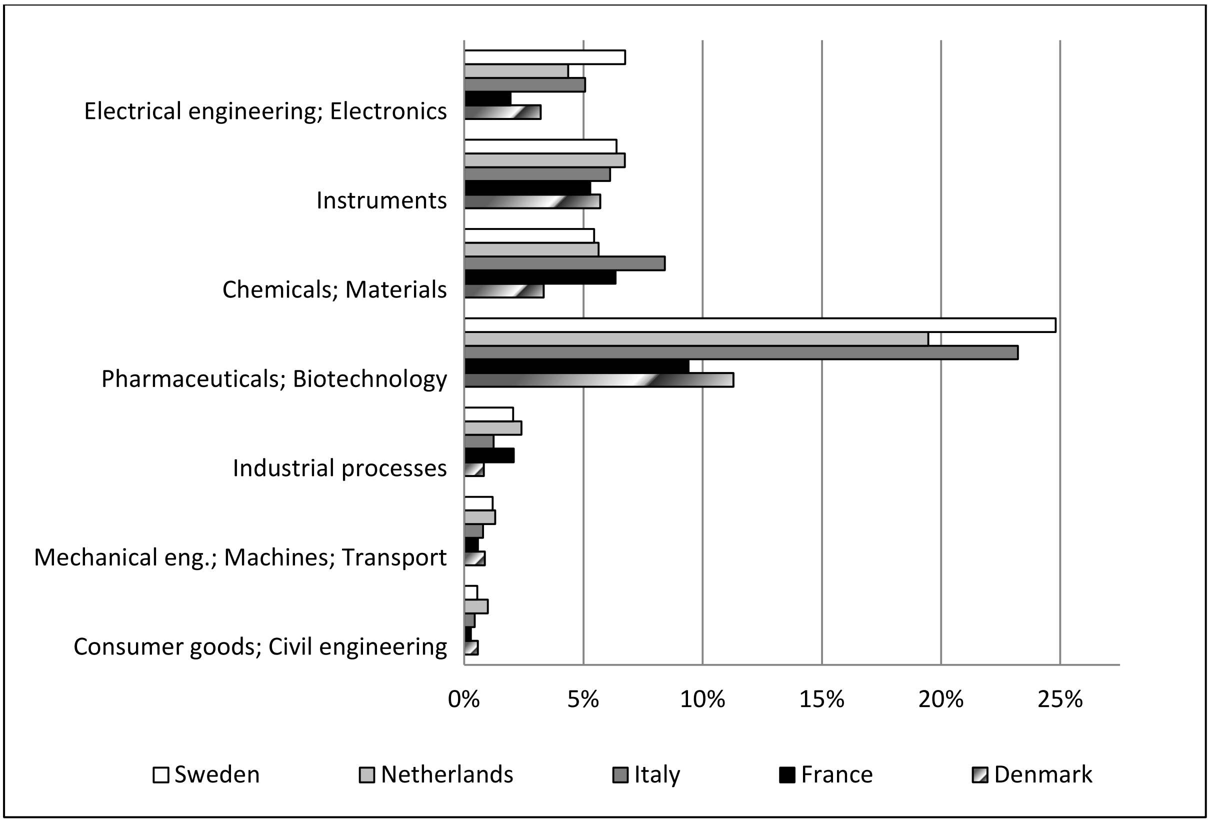
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
[§] *It tests the Hypothesis: AC_INV_COMPANY = AC_INV_INDIVIDUAL = AC_INV_UNIV = AC_INV_PRO (P value in parenthesis)*

Table 10. Regression results (y=FWD_CIT4; QML-Poisson regression) by field (control variables not displayed)

	(1) Electrical engineering; Electronics	(2) Instruments	(3) Chemicals; Materials	(4) Pharmaceuticals; Biotechnology	(5) Industrial processes	(6) Mechanical eng.; Machines; Transport	(7) Consumer goods; Civil engineering
AC_INV_COMPANY	-0.24***	0.020	0.10	-0.083	0.21*	-0.087	0.11
	(0.087)	(0.070)	(0.070)	(0.059)	(0.11)	(0.13)	(0.27)
AC_INV_INDIVIDUAL	-0.32	0.28*	0.28	0.11	0.70**	0.30	0.73**
	(0.34)	(0.16)	(0.32)	(0.17)	(0.31)	(0.24)	(0.34)
AC_INV_UNIVERSITY	-0.021	0.021	0.23	-0.20**	0.14	0.018	-13.3***
	(0.17)	(0.14)	(0.27)	(0.087)	(0.19)	(0.28)	(0.71)
AC_INV_PRO	0.44*	-0.31*	-0.25	-0.12	-0.62**	-0.41	-13.4***
	(0.24)	(0.17)	(0.19)	(0.10)	(0.31)	(0.67)	(0.53)
Observations	*29,100*	*15,073*	*13,582*	*10,979*	*17,174*	*17,885*	*11,276*
Time dummies	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*
Tech. field dummies	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*
chi^2	*3451*	*1180*	*1027*	*658*	*1154*	*879*	*1811*
significance	*0*	*0*	*0*	*0*	*0*	*0*	*0*
pseudo-R-sq.	*0.16*	*0.094*	*0.091*	*0.083*	*0.062*	*0.052*	*0.071*

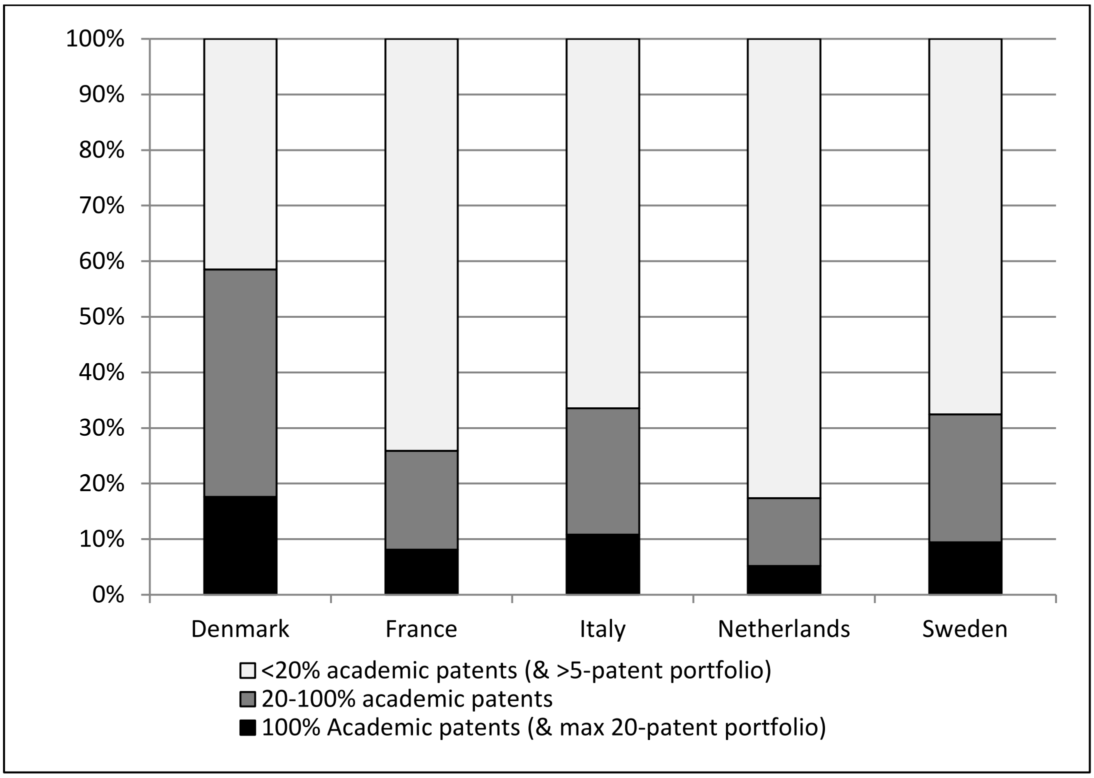
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 1. Share of academic vs. non-academic patents in selected European countries, 1995-2001; by technology and country



Source: Lissoni et al. (2008, 2009); Baselli and Pellicciari (2007) and EP-KITES database.

Figure 1. Distribution of company-owned academic patents, by weight on companies' patent portfolio and size of portfolio



Source: elaborations on Lissoni et al. (2008, 2009); Baselli and Pellicciari (2007) and EP-KITES database.