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THE OWNERSHIP OF ACADEMIC PATENTS AND THEIR IMPACT. 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:

This paper compares the value and impact of academic patents in five different European countries with different institutional frameworks: Denmark, France, Italy, the Netherlands, and Sweden. Ownership patterns of academic patents are found to: (i) differ greatly across country, due to a combination of legal norms on IP and institutional features of the university system; (ii) be strongly associated to academic patents' value, as measured by patent 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 to their ownership, while university-owned patents get fewer citations in both France and Italy. We propose an explanation of these results based on the different autonomy and experience in dealing with IP and technology transfer 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 Classifications: 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 research results. A lively debate is ongoing on the importance of patents as a vehicle for university-industry technology transfer (Jensen and Thursby 2001, Agrawal and Henderson 2002, Sampat et al. 2003), their potential as a source of licensing revenues for academic institutions (Siegel et al. 2007, Thursby and Thursby 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.

All of these issues are related to patent ownership. Going back in history, we never cease to find instances of academic scientists involved in the inventive process, and of patents filed 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 (see section 2 of this paper). The rise of the modern corporation, and of engineering as an academic discipline, brought about collaborations between academic scientists and business companies, with the latter often reclaiming control over IPRs. The growth of large, public-sponsored research programmes after Second World War saw many Western governments, through their ministries or funding agencies, in the position of patent-holders over academic inventions. In the US, not-for-profit patent brokers, such as WARF or the Research Corporation, also played an important role (Mowery and Sampat 2001).

It was only during the last quarter of 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 public 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 to 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. 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; for a survey, see 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 less cited than non-academic ones, as opposed to what found for the US. These results, however, depend upon the type of academic patent ownership and the inventor's country. In particular, academic patents are more highly cited than non-academic ones in the Netherlands, no matter who own them. In the four other countries considered, university-owned academic patents are always less cited than non-academic

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.

ones, while business-owned academic patents are less cited only in Sweden (the same applies to academic patents owned by public research organizations in France). These results can be explained by legal and institutional cross-country differences, albeit not entirely.

The paper is structured as follows. Section 2 discusses the literature on academic patenting, and provides information on national legislations. 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 inventors². 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 patents, as they resulted from US scholars' interest in evaluating the impact of Bayh-Dole Act³. As explained by Franzoni and Lissoni (2004), 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 them (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 survey 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 scientists being civil servants (that is, government's employees rather than university's), and their administrations being much less geared towards fund-raising and asset management⁴. As civil servants, most of the European tenured staff has no disclosure duty 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 administered 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 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

² As discussed in section 3, when searching for academic inventors we consider only the faculty, whether tenured, tenured-track or in otherwise stable positions. Where feasible, we exclude post-docs and PhD students. In addition in the empirical part of the paper all patents assigned to universities are classified as academic.

³ For a detailed description of the Bayh-Dole Act and its subsequent amendments, see Schacht (2011). For an economic analysis, see Grimaldi et al. (2011).

⁴ 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).

are influenced by CNRS (the National Centre for Scientific Research), which contributes to finance and staff the best university laboratories, and has a claim on resulting intellectual property⁵.

The studies by Meyer (2003), for Finland, and Balconi et al. (2004), for Italy, were the first to tackle these issues and to adopt the definition of academic patent reported above. 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 shows that over 60% of academic patents 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. 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.

2.2 The characteristics and value of academic patents

We expect academic patents to differ from non-academic ones for a number of reasons:

- 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 application across different disciplinary fields (Henderson et al. 1998).
- Academic scientists base their career on the reputation they may get by contributing to fundamental research, so they face a higher opportunity costs than corporate researcher when dedicating themselves to more applied research targets, such as those required to produce narrow inventions susceptible of immediate applicability (Lacetera 2009).
- 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).

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^{6 7}. 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 "generality" by the number of technological classes where these citations come from.

⁵ Besides CNRS, other French PROs intervene in the generation and management of academic patents. Those with the largest patent portfolio are: INSERM (Institut national de la santé et de la recherche médicale), INRA (Institut national de recherche agronomique), and CEA (Commissariat à l'énergie atomique et aux énergies alternatives).

⁶ Patent citations are used not only in the literature concerning academic patents, but, more generally, in all studies dealing with patent value (Trajtenberg 1990, Lanjouw and Schankerman 2004). Hall (2005) shows that patent citations are associated to 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. Patent citations are also used to track knowledge flows and their use has been validated by a survey of inventors (Jaffe et al. 2000). More generally, the use of patent citations corroborates substantial evidence on the type and nature of knowledge flows (Jaffe et al. 1993, Maurseth and Verspagen 2002).

⁷ 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 a focus patent, the latter by the number of organizations cited by the focus patent. Both premiums appear to be positive and significant, although the diffusion premium appear to have declined over time in the "core" technologies of academic patenting, namely pharmaceuticals and biotechnology. For a critical analysis of the use of citations to academic patents as indicators of the relevance of academic knowledge for industry, see Roach and Cohen (2011).

Early findings by Henderson et al. (1998), for US university-owned academic patents, confirmed these hypotheses. However, the authors also found a decline in both the generality and importance premiums of university 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 academic research turning more and more applied and oriented to inventions of immediate economic value⁸.

Subsequent studies, both in the US and in Europe, have long debated these conclusions, and provided conflicting evidence. In particular, 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). Sampat et al. (2003) explain the differences between their results and those of Henderson and associates with the presence, in the early study, of truncation bias problem⁹.

Moving to Europe (and EPO patent data) Sapsalis et al. (2006) and Sapsalis and van Pottelsberghe de la Potterie (2007) (Sapsalis and van Pottelsberghe de la Potterie 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 and PROs do not appear to be more cited than average¹⁰.

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

⁸ In this vein, Thursby and Thursby (2002) suggest, on the basis of survey data, that growth in university patenting and licensing may be explained by "universities becoming more entrepreneurial" at all levels, after the Bayh-Dole Act. 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.

⁹ Sampat and associates find that forward citations to US university patents tend to appear later than those to non-university ones, and that this tendency has increased over time. This change reflects is due in part to an increase in the examination time of university patents. Although the authors provide no explanations for either phenomenon, they stress the sensitivity of citation analysis to technical issues arising from the examination process and to unobserved factors affecting citation patterns.

¹⁰ Notice that Bacchiocchi and Montobbio (2009) use EPO data and control for the truncation bias. Early findings of truncation bias derived from studies on USPTO (US patent office) data. As explained by Breschi and Lissoni (2005), legal and procedural norms followed by IP lawyers and patent examiners when inserting 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, but 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.

turn appears to be associated to 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 patents¹¹.

Crespi et al. (2010) examine 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.

Thursby et al. (2009) 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.

On the theoretical side, Aghion and Tirole (1994) 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). Finally Damsgaard and Thursby (2012) point at the importance and complexity of different institutional regimes and their impact on academic, IP-based entrepreneurship. They compare the probability of successful commercialization and academic start up in two countries with different IP regimes for academic research, such as the US (university IP ownership) and Sweden (professor privilege). 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 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.

2.3 Our study: aims and relationship to the literature

From the preceding survey, 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 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, in several instances, include in the analysis all academic patents, irrespective of their ownership. Results concerning importance and generality are 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.

¹¹ Czarnitzki et al. (2009) examine opposition data (a form of pre-granting litigation typical of European patents), and find academic patents to be less likely to be opposed than a control groups of corporate ones.

(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 PatStat¹².

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 their 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.

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 Sweden¹³.

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). Second, 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. After these two steps, the share of professors matched to one or more inventors differed widely across countries, due to the unequal quality of the biographic information (for example, many Dutch professors came only with surname and initials) and to linguistic problems (Scandinavian surnames are far less varied than Latin ones, so any name-matching exercise will always return many positives, whether true or false).

¹² 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>).

¹³ In particular, academic ranks are certainly homogeneous across universities for France and Italy, being defined by law and recorded by the Ministry of Education: "maitre a conference" and "professeur" for France; and "ricercatore", "professore associato" and "professore ordinario" for Italy. They are all tenured positions, and can be considered as covering the spectrum from assistant to full professor. As for Sweden, the academic positions which go closer to this spectrum are four: professor, "lektorate", "docent" and "forsk lektorate"). Similar ones can be found in Denmark. However, individual universities' lists may include some idiosyncratic variations, reflecting either linguistic or organizational specificities, which were taken into account. In the case of the Netherlands, it was not possible to obtain consistent information on the academic rank, so it was simply taken care not to include students or technicians.

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 status¹⁴. 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 (and therefore presumably more likely to be still active and reachable).

The methodology just described is in principle susceptible to introduce both type-I measurement errors (false positives, which consist in identifying a professor as an inventor, when in fact the two are just homonyms) and type-II measurement errors (false negatives). Type-I errors would lead to an overestimation of academic patenting, a mistake the authors of the datasets wanted to avoid, since the original goal of their research programme was to prove that conventional wisdom tends to *underestimate* the phenomenon. As a result, special care was placed in trying to minimize type-I errors, at the cost of accepting an unknown amount of type-II errors. Type-II 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; and those who were not were more likely than their junior colleagues to have achieved high status in their universities, 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, 2001¹⁵.

Another limitation of the database is the non-identification of “PRO researchers' patents”, that 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), dated between 1995 and 2001¹⁶. 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 patents¹⁷. 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 importance of patents as a function of:

- the origin of the invention (academic vs. non-academic)

¹⁴ Interviewees were also asked to confirm that at the time of the invention they had already undertaken their academic careers; professors whose patents listed their university as applicant were not contacted, as they were assigned the inventor status by default.

¹⁵ 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.

¹⁶ We dated the patents with their priority year; when missing, we replaced it with the application year.

¹⁷ Equivalents are patent documents sharing the same priority dates. Most often they are patent applications to different patent offices, which protect the same invention in different countries. In the PatStat database, a set of equivalent patents is said to constitute a “simple” patent family (Martínez 2011). This means that the citations we consider in this paper are those listed on our patents, and those received by our patents and their families.

- 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)

We measure importance with the number of citations received by the patent over the first four years after its priority date (self-citations excluded). We expect the ownership type of academic patents to be associated to 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 those obtained with the Poisson model, whose estimated coefficients can be interpreted as semi-elasticities (Wooldridge 2003, p.574).

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_CIT_{4i}). 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 ;
- ✓ $GEN_BH_i = [FWD_CIT_i / (FWD_CIT_i - 1)] * (1 - \sum_j s_{ij}^2)$: 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 ($FWD_CIT_i = \sum_j FWD_CIT_{ij}$; $j=1, \dots, K$; 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 .
- ✓ $ORIG_BH_i = [BACK_CIT_i / (BACK_CIT_i - 1)] * (1 - \sum_j s_{ij}^2)$: originality index of patent i , controlling for the small sample bias (Hall, 2005). $BACK_CIT_{ij}$ is the total number of forward citations to patent i from the technological class j ($BACK_CIT_i = \sum_j BACK_CIT_{ij}$; $j=1, \dots, K$); 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
- ✓ $FOREIGN_CO-INV_i=1$ if there are at least two inventors from different countries in patent i , 0 otherwise;
- ✓ $CLAIMS_i$ is number of claims in the patent in patent i .

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 to 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:

- ✓ $BACK_CIT_i$ =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. Table 2 presents similar data, per year¹⁸. 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, relative to PROs, is minimal compared to that of other countries in our sample. We do not observe any significant time trend, neither at the aggregate nor at the country level (country data available on request).

Table 3 and Figure 1 report 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. The relatively low value for France in Pharmaceuticals and Biotechnology may be explained by the absence, in our data, of patents invented by researchers at CNRS and INSERM, the two largest PROs. The relatively higher value, in France and Italy, for Chemicals and Materials is due to the great importance that the Chemical industry used to have in the two countries (and still has in France). In general, both supply (of science) and demand (of inventions) factors contribute to explain the observed cross-country differences.

Table 4 shows the share of academic patents by ownership and country. In Europe company ownership of academic inventions 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

¹⁸ As we explained above, it is very likely that the number of type-II errors in the identification of academic patents is inversely related to the priority year. As a consequence no apparent time trend in the share of academic patents over total patents is worth commenting (and anyway is of no interest for this paper).

agencies, while 6.28% are co-owned by a combination of different types of assignees¹⁹. Table 4 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 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 the start-up is very small and/or created by an academic inventor for the sole purpose of serving as repository for his/her patents). 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. A summary look at the data suggest that indeed several companies, among those that own academic patents, may be very small, but also that the relevance of such companies, when measured in terms of number of patents, is not very high. Figure 2 illustrates the distribution of company-owned patents according to a 3-entry categorization of companies:

1. companies whose entire patent portfolio (100% of patents) is academic, all of which have no more than 20 patent in their portfolios;
2. companies with 20% to less than 100% of academic patents in their portfolios;
3. companies with less than 20% of academic patents in their portfolios, all of which have more than 5 patents in their portfolio, and in many cases over 100 patents

The first category is the closest one to that of individual patents (academic start ups or shell companies), the third one the farthest (large companies with some academic collaborations), with the second category being more heterogeneous. Figure 2 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.

The following tables, from 5 to 8, 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 5 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 5 also shows that, consistently with previous findings based on EPO data (e.g. Bacchiocchi, Montobbio 2009), citations to academic patents tend to appear sooner than citations 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 6 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

¹⁹ 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.

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 7 and 8 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, that is 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 9 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 4), 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 9. 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 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).

In column (2) we show how the importance of academic patents varies according to patents' ownership. We do so by replacing AC_INV with the dummies for the different applicant types. Negative coefficients persist for academic patents owned by companies, universities or PROs, but absolute values and especially significance levels vary considerably. In particular, the estimated coefficient for AC_INV_UNIVERSITY is not significantly different from zero, while that for AC_INV_PRO is significant only at 90% level. 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 their inventors get 27% more citations than non-academic, similarly owned patents. Columns (3) to (7) replicate the regression in column

(2), by country. They show that the importance of academic patents depends not only on the type of ownership, but also on countries.

The first important result is that in France, Italy and Denmark we find negative values for the estimated coefficient of AC_INV_UNIVERSITY. For Denmark however we have very few university-owned academic inventions (34). 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 4). 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, academic patents are far from performing this well.

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). In fact, estimated coefficients for AC_INV_COMPANY in all other countries are positive, albeit significant only in one case. In a similar way, the negative result for AC_INV_PRO we observe in column (2) is entirely explained by France, where 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).

Coming to academic patents held by individuals, the estimated coefficient of AC_INV_INDIVIDUAL is always positive, but with great variations in absolute values. Again, this suggests that individually-owned academic patents are more important than non-academic patents also owned by individuals. It cannot be claimed that they are more important than the either the other, differently-owned academic patents. 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).

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 it is much smaller country than the others, in which we may expect a higher share of patents with foreign co-inventors); and France and Italy, in which we do not find a significant association between originality and importance.

4.3 Discussion and limitations

Our most important results can be summarised as follows. Academic patents, in the five European countries considered, tend to be less important than non-academic ones. However, a great heterogeneity exists, by country and type of ownership. In general, company-owned academic patents perform as well than non-academic ones, with the only exception of Sweden. 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 2 lead us to exclude this explanation.

We also find that the Netherlands are the only country in which academic patents 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, which are home to the most centralized and least autonomous university systems and whose university-owned academic patents get fewer citations than non-academic ones.

Other explanations are however possible. In France and Italy, university-owned inventions could have a lower impact due to lower investments in research and research infrastructure, for which we did not control. Alternatively, university-owned patents could turn out to be less important due to differences in the orientation of research, towards objectives with less direct impact on innovation. Finally, it could be that, in the period considered, universities in some countries lacked the resources necessary to acquire experience in technology transfer and, as a result, they chose not to dedicate substantial efforts to commercialization. Since we do not control for the presence and experience of TTOs or for the university experience in patenting we cannot test properly this explanation; but we observe it not to be in contrast with our evidence on the Dutch case.

Finally it is important to underline that we cannot identify precisely the causal relation between the ownership of the patents and their citation rate. For example, a low citation rate of university-owned academic patents could be either due to a selection effect, by which companies or individual scientists keep for themselves the most valuable inventions, and leave the others to universities; or to universities' mismanagement of otherwise valuable inventions. Both explanations, however, have in common the presumption of some weaknesses on the university part, to the extent that its administration looks unable either to exploit a valuable patent portfolio or to resist filling it with leftovers by companies and professors.

5. Conclusions 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 similarly-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 introducing the professor privilege in that country.

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 conducive to select better the patents to be held in the university's portfolio or left to business companies, or to better manage university-owned patents. 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. Further research ought 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. Unreported data show that the former two are those, among 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 and the French ones, for whose (poor) performance we offer a mirror image explanation, based on the lack of autonomy and IP management experience of its academic institutions. The French case requires further analysis with respect to PROs, in order to collect evidence also on patents produced by their scientists.

A more general conclusion we can draw from our study is that 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.

References

- Aghion, P., and J. Tirole. 1994. The Management of Innovation. *The Quarterly Journal of Economics* **109**:1185-1209.
- Agrawal, A., and R. Henderson. 2002. Putting Patents in Context: Exploring Knowledge Transfer from MIT. *Management Science* **48**:44-60.
- Azoulay, P., W. Ding, and T. Stuart. 2007. The determinants of faculty patenting behavior: Demographics or opportunities? *Journal of Economic Behavior & Organization* **63**:599-623.
- Bacchiocchi, E., and F. Montobbio. 2009. Knowledge diffusion from university and public research. A comparison between US, Japan and Europe using patent citations. *The Journal of Technology Transfer* **34**:169-181.
- Balconi, M., S. Breschi, and F. Lissoni. 2004. Networks of inventors and the role of academia: an exploration of Italian patent data. *Research Policy* **33**:127-145.
- Baselli, S., and F. Pellicciari. 2007. Academic Patents and technology transfer in the Netherlands. An empirical analysis. *Università degli studi di Brescia*.
- Breschi, S., and F. Lissoni. 2005. Knowledge networks from patent data. *Handbook of quantitative science and technology research*:613-643.
- Breschi, S., F. Lissoni, and F. Montobbio. 2007. The scientific productivity of academic inventors: new evidence from Italian data. *Economics of Innovation and New Technology* **16**:101-118.
- Crespi, G. A., A. Geuna, Ö. Nomaler, and B. Verspagen. 2010. University IPRs and knowledge transfer: is university ownership more efficient? *Economics of Innovation and New Technology* **19**:627-648.
- Czarnitzki, D., Gl. W. nzel, and K. Hussinger. 2007. Patent and publication activities of German professors: an empirical assessment of their co-activity. *Research Evaluation* **16**:311-319.
- Czarnitzki, D., W. Glänzel, and K. Hussinger. 2009. Heterogeneity of patenting activity and its implications for scientific research. *Research Policy* **38**:26-34.
- Czarnitzki, D., K. Hussinger, and C. Schneider. 2011. Commercializing academic research: the quality of faculty patenting. *Industrial and Corporate Change* **20**:1403-1437.
- Czarnitzki, D., K. Hussinger, and C. Schneider. 2012. The nexus between science and industry: evidence from faculty inventions. *The Journal of Technology Transfer* (**forthcoming**).
- Damsgaard, E. F., and M. C. Thursby. 2012. University Entrepreneurship and Professor Privilege. *National Bureau of Economic Research Working Paper Series No. 17980*.
- Estermann, T., and T. Nokkala. 2009. University Autonomy in Europe - I. Brussels.
- Fabrizio, K. R. 2007. University patenting and the pace of industrial innovation. *Industrial and Corporate Change* **16**:505-534.
- Foray, D., and F. Lissoni. 2010. Chapter 6 - University Research and Public-Private Interaction. Pages 275-314 in B. H. Hall and N. Rosenberg, editors. *Handbook of the Economics of Innovation*. North-Holland.
- Franzoni, C., and F. Lissoni. 2009 Academic entrepreneurs: critical issues and lessons for Europe. In A. Varga, editor. *Universities, Knowledge Transfer And Regional Development: Geography, Entrepreneurship and Policy*. Edward Elgar, Cheltenham.
- Frietsch, R., U. Schmoch, B. v. Looy, J. P. Walsh, R. Devroede, M. Du Plessis, T. Jung, Y. Meny, P. Neuhäusler, B. Peeters, and T. Schubert. 2010. The value and indicator function of patents. Fraunhofer ISI, Karlsruhe.
- Grimaldi, R., M. Kenney, D. S. Siegel, and M. Wright. 2011. 30 years after Bayh-Dole: Reassessing academic entrepreneurship. *Research Policy* **40**:1045-1057.
- Hall, B. H. 2005. A Note on the Bias in Herfindahl-Type Measures Based on Count Data *Revue d'Économie Industrielle* **110**.
- Harhoff, D., F. Narin, F. M. Scherer, and K. Vopel. 1999. Citation Frequency and the Value of Patented Inventions. *Review of Economics and Statistics* **81**:511-515.
- Henderson, R., A. B. Jaffe, and M. Trajtenberg. 1998. Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965-1988. *Review of Economics and Statistics* **80**:119-127.

- Jaffe, A. B., and M. Trajtenberg. 2002. *Patents, Citations, and Innovations. A Window on the Knowledge Economy*. MIT Press, Cambridge MA.
- Jaffe, A. B., M. Trajtenberg, and M. S. Fogarty. 2000. The Meaning of Patent Citations: Report on the NBER/Case-Western Reserve Survey of Patentees. National Bureau of Economic Research Working Paper Series **No. 7631**.
- Jaffe, A. B., M. Trajtenberg, and R. Henderson. 1993. Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *The Quarterly Journal of Economics* **108**:577-598.
- Jensen, R., and M. Thursby. 2001. Proofs and Prototypes for Sale: The Licensing of University Inventions. *American Economic Review* **91**:240-259.
- Lacetera, N. 2009. Academic entrepreneurship. *Managerial and Decision Economics* **30**:443-464.
- Lach, S., and M. Schankerman. 2004. Royalty Sharing And Technology Licensing In Universities. *Journal of the European Economic Association* **2**:252-264.
- Lanjouw, J. O., and M. Schankerman. 2004. Patent Quality and Research Productivity: Measuring Innovation with Multiple Indicators*. *The Economic Journal* **114**:441-465.
- Lissoni, F. 2012. Academic Patenting in Europe: an Overview of Recent Research and New Perspectives. *World Patent Information* (**forthcoming**).
- Lissoni, F., P. Llerena, M. McKelvey, and B. Sanditov. 2008. Academic patenting in Europe: new evidence from the KEINS database. *Research Evaluation* **17**:87-102.
- Lissoni, F., P. Lotz, J. Schovsbo, and A. Treccani. 2009. Academic patenting and the professor's privilege: evidence on Denmark from the KEINS database. *Science and Public Policy* **36**:595-607.
- Lissoni, F., B. Sanditov, and G. Tarasconi. 2006. *The Keins Database on Academic Inventors: Methodology and Contents*. Università Bocconi, Milano.
- MacLeod, C. 2012. Reluctant Entrepreneurs: Patents and State Patronage in New Technosciences, circa 1870–1930. *Isis* **103**:328-339.
- Martínez, C. 2011. Patent families: When do different definitions really matter? *Scientometrics* **86**:39-63.
- Maurseth, P. B., and B. Verspagen. 2002. Knowledge Spillovers in Europe: A Patent Citations Analysis. *Scandinavian Journal of Economics* **104**:531-545.
- Meyer, M. 2003. Academic patents as an indicator of useful research? A new approach to measure academic inventiveness. *Research Evaluation* **12**:17-27.
- Mowery, D., and B. Sampat. 2005. The Bayh-Dole Act of 1980 and University-Industry Technology Transfer: A Model for Other OECD Governments? Pages 233-245 in A. N. Link and F. M. Scherer, editors. *Essays in Honor of Edwin Mansfield*. Springer US.
- Mowery, D. C., R. R. Nelson, B. N. Sampat, and A. A. Ziedonis. 2001. The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh–Dole act of 1980. *Research Policy* **30**:99-119.
- Mowery, D. C., R. R. Nelson, B. N. Sampat, and A. A. Ziedonis. 2004. *Ivory Tower and Industrial Innovation. University-Industry Technology Transfer Before and After the Bayh-Dole Act*. Stanford University Press, Palo Alto CA.
- Mowery, D. C., and B. N. Sampat. 2001. Patenting and Licensing University Inventions: Lessons from the History of the Research Corporation. *Industrial and Corporate Change* **10**:317-355.
- Mowery, D. C., B. N. Sampat, and A. A. Ziedonis. 2002. Learning to Patent: Institutional Experience, Learning, and the Characteristics of U. S. University Patents after the Bayh-Dole Act, 1981-1992. *Management Science* **48**:73-89.
- Mowery, D. C., and A. A. Ziedonis. 2002. Academic patent quality and quantity before and after the Bayh–Dole act in the United States. *Research Policy* **31**:399-418.
- Murmann, J. P. 2006. *Knowledge and Competitive Advantage. The Coevolution of Firms, Technology, and National Institutions*. Cambridge University Press.
- Murray, F., and S. Stern. 2007. Do formal intellectual property rights hinder the free flow of scientific knowledge?: An empirical test of the anti-commons hypothesis. *Journal of Economic Behavior & Organization* **63**:648-687.
- Nelson, R. R. 2004. The market economy, and the scientific commons. *Research Policy* **33**:455-471.

- Roach, M., and W. M. Cohen. 2011. Lens or Prism? A Comparative Assessment of Patent Citations as a Measure of Knowledge Flows from Public Research. Patent Statistics for Decision Makers Conference, U.S. Patent and Trademark Office, Alexandria VA
- Rosell, C., and A. Agrawal. 2009. Have university knowledge flows narrowed?: Evidence from patent data. *Research Policy* **38**:1-13.
- Sampat, B. N., D. C. Mowery, and A. A. Ziedonis. 2003. Changes in university patent quality after the Bayh-Dole act: a re-examination. *International Journal of Industrial Organization* **21**:1371-1390.
- Sapsalis, E., and B. van Pottelsberghe de la Potterie. 2007. The institutional sources of knowledge and the value of academic patents. *Economics of Innovation and New Technology* **16**:139-157.
- Sapsalis, E., B. van Pottelsberghe de la Potterie, and R. Navon. 2006. Academic versus industry patenting: An in-depth analysis of what determines patent value. *Research Policy* **35**:1631-1645.
- Schacht, W. H. 2011. *The Bayh-Dole Act: Selected Issues in Patent Policy and the Commercialization of Technology*. Washington DC.
- Siegel, D. S., R. Veugelers, and M. Wright. 2007. Technology transfer offices and commercialization of university intellectual property: performance and policy implications. *Oxford Review of Economic Policy* **23**:640-660.
- Thursby, J., A. W. Fuller, and M. Thursby. 2009. US faculty patenting: Inside and outside the university. *Research Policy* **38**:14-25.
- Thursby, J. G., and M. C. Thursby. 2002. Who Is Selling the Ivory Tower? Sources of Growth in University Licensing. *Management Science* **48**:90-104.
- Thursby, J. G., and M. C. Thursby. 2007. University licensing. *Oxford Review of Economic Policy* **23**:620-639.
- Trajtenberg, M. 1990. A Penny for Your Quotes: Patent Citations and the Value of Innovations. *The RAND Journal of Economics* **21**:172-187.
- Verspagen, B. 2006. University Research, Intellectual Property Rights And European Innovation Systems. *Journal of Economic Surveys* **20**:607-632.
- Wooldridge, J. 2003. *Introductory Econometrics: A Modern Approach* South-Western College Pub.

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	(9.,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 year

	Non-academic (i)		Academic (ii)		All (i)+(ii)	
	nr	% of All	Nr	% of All	nr	% of All
1995	11633	(95.9%)	495	(4.1%)	12128	(100%)
1996	13250	(95.2%)	659	(4.8%)	13909	(100%)
1997	14785	(95.2%)	735	(4.8%)	15520	(100%)
1998	15851	(95.2%)	789	(4.8%)	16640	(100%)
1999	17207	(94.9%)	924	(5.1%)	18131	(100%)
2000	18327	(94.8%)	1013	(5.2%)	19340	(100%)
2001	18716	(95.9%)	801	(4.1%)	19517	(100%)
Total	109769	(95.3%)	5419	(4,7%)	115185	(100%)

^aDenmark, France, Italy, the Netherlands, Sweden

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

Table 3. 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%)

^aDenmark, France, Italy, the Netherlands, Sweden

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

Table 4. Number and share of academic patents in selected European countries, by ownership and country 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 5. 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

*** : 90%, 95%, 99% significance

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 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 7. 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 8. 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 9. Summary statistics (regression variables)

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

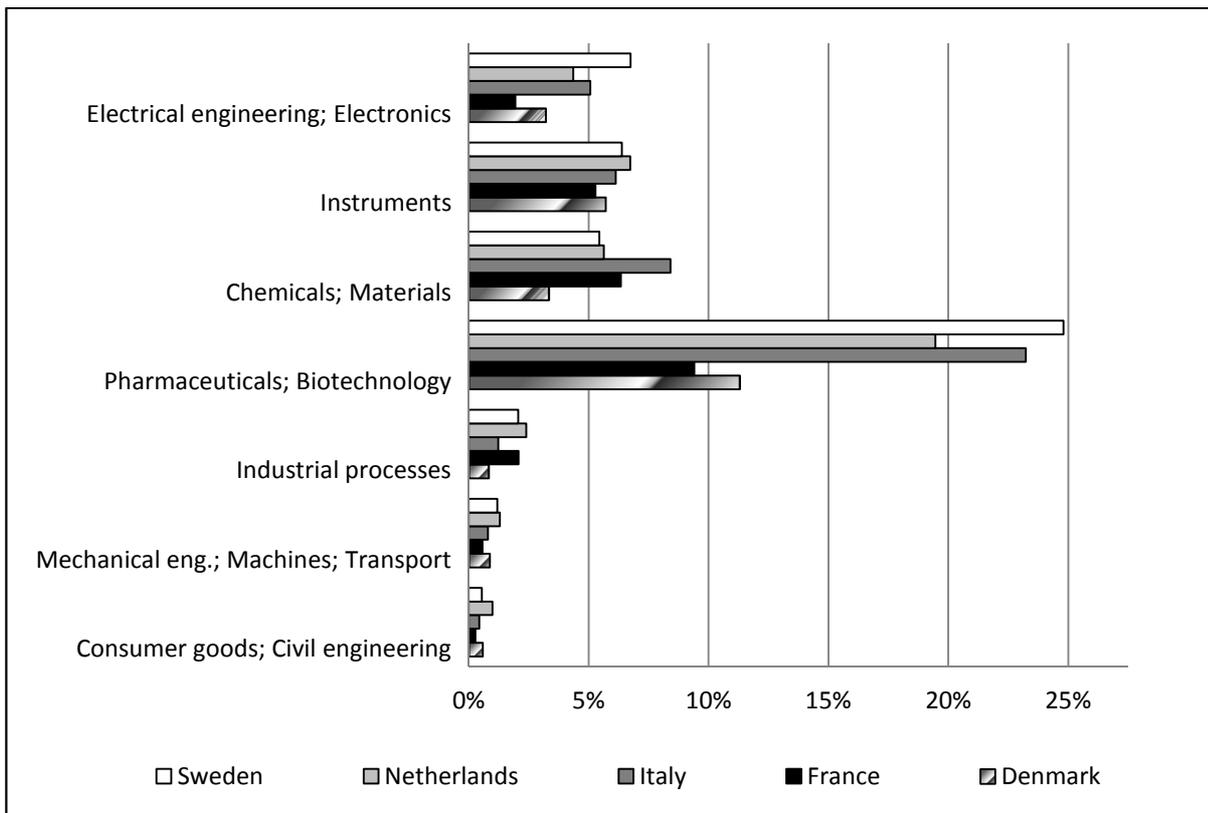
(3) Reported values for AVG_BACK_LAG are only for observations (patents) with at least 1 backward citation. For patents with zero backward citations, the AV_BLAG generates a missing value, which we replace with the mean value. A ZERO_BACK_CIT dummy (= zero backward citations) is introduced to control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

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

Table 10. Regression results (y=FWD_CIT4; Poisson regression)

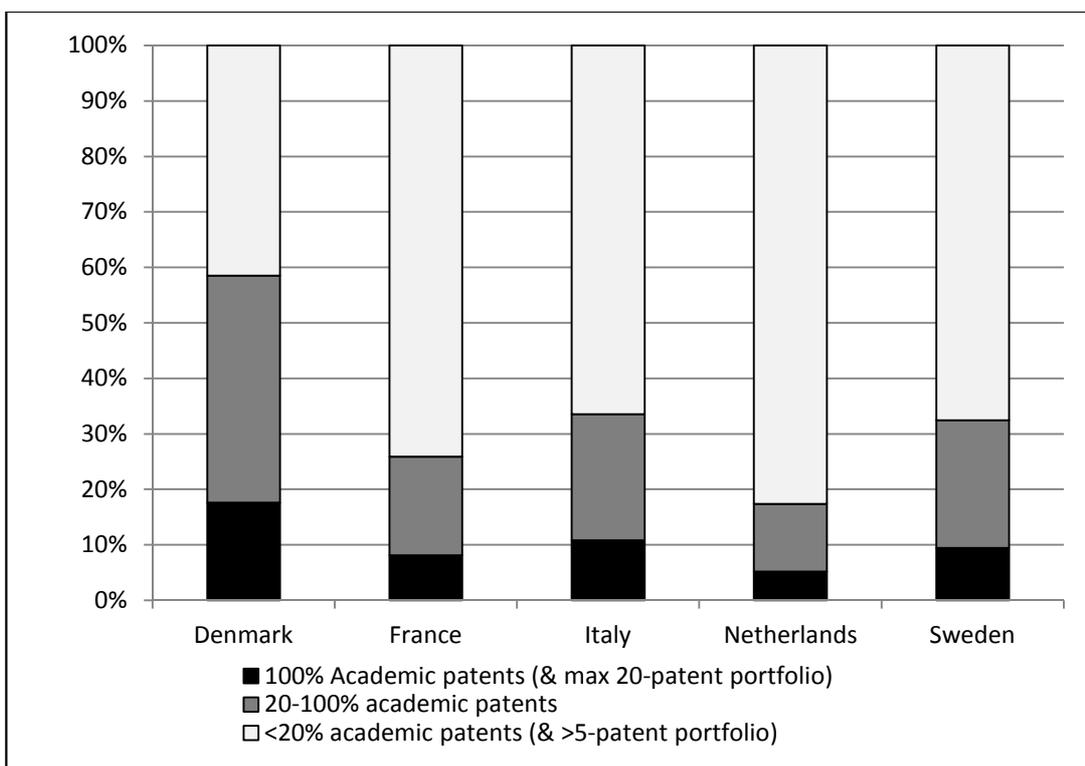
	(1) All countries	(2) All countries	(3) France	(4) Italy	(5) Netherlands	(6) Denmark	(7) Sweden
AC_INV	-0.050*** (0.016)						
AC_INV_COMPANY		-0.051*** (0.019)	0.016 (0.033)	0.018 (0.040)	0.16*** (0.042)	0.061 (0.075)	-0.41*** (0.041)
AC_INV_UNIVERSITY		-0.057 (0.038)	-0.15** (0.063)	-0.26** (0.10)	0.26*** (0.066)	-0.71*** (0.24)	-0.18 (0.11)
AC_INV_GOV		-0.088* (0.046)	-0.19*** (0.057)	0.050 (0.10)	0.058 (0.12)	-0.42 (0.41)	-0.48 (0.45)
AC_INV_INDIVIDUAL		0.27*** (0.059)	0.60*** (0.13)	0.073 (0.13)	0.60** (0.28)	0.48*** (0.14)	0.36*** (0.11)
INDIVIDUAL	-0.20*** (0.015)	-0.22*** (0.016)	-0.23*** (0.025)	-0.24*** (0.029)	-0.025 (0.044)	-0.23*** (0.068)	-0.45*** (0.044)
FOREIGN_CO-INV	0.20*** (0.0092)	0.19*** (0.0092)	0.23*** (0.014)	0.068*** (0.025)	0.12*** (0.024)	0.038 (0.035)	0.23*** (0.020)
CLAIMS	0.014*** (0.00023)	0.014*** (0.00023)	0.013*** (0.00040)	0.013*** (0.00075)	0.017*** (0.00068)	0.010*** (0.00060)	0.014*** (0.00050)
ORIG_BH	0.030*** (0.010)	0.030*** (0.010)	0.016 (0.016)	0.017 (0.024)	0.18*** (0.026)	0.20*** (0.041)	-0.060** (0.026)
AVG_BACK_LAG	-0.052*** (0.0011)	-0.052*** (0.0011)	-0.050*** (0.0017)	-0.041*** (0.0024)	-0.046*** (0.0030)	-0.036*** (0.0046)	-0.073*** (0.0029)
ZERO_BACK_CIT	-0.89*** (0.012)	-0.89*** (0.012)	-0.61*** (0.019)	-0.68*** (0.026)	-1.84*** (0.032)	-0.70*** (0.052)	-0.58*** (0.031)
BACK_CIT	0.045*** (0.00063)	0.045*** (0.00063)	0.043*** (0.0010)	0.053*** (0.0018)	0.044*** (0.0017)	0.027*** (0.0023)	0.053*** (0.0014)
Constant	-0.42*** (0.014)	-0.42*** (0.014)	-0.58*** (0.022)	-0.60*** (0.035)	-0.40*** (0.033)	-0.22*** (0.057)	0.012 (0.034)
Observations	115,185	115,069	48,944	24,608	20,754	5,673	15,090
Country dummies	Y	Y	N	N	N	N	N
Time dummies	Y	Y	Y	Y	Y	Y	Y
Tech. field dummies	Y	Y	Y	Y	Y	Y	Y
chi^2	33976	33961	9853	4004	9738	1557	9587
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

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 2. 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.