IP Management Effectiveness at Universities: an Analysis of Italian Academic Patents.

Valerio Sterzi[①], Francesco Lissoni[①③*], Michele Pezzoni[②③]

[①] GREThA – UMR CNRS 5113, Université de Bordeaux
[②] GREDEM – UMR CNRS 7321, Université de Nice
[③] CRIOS-Università « L.Bocconi », Milan

[*] Corresponding author: francesco.lissoni@u-bordeaux.fr

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Abstract

Based on an extensive dataset of Italian academic inventions and number of consolidated patent quality measures, we show that, on average, universities are not as good as firms in managing their patent portfolios. This results is robust to the possible endogeneity due to the self-selection (highest-quality academic inventions end up being assigned and managed by business companies).

We propose two explanations for this result: first, university patenting is a recent phenomenon and universities lack of capabilities and experience in the IP management; second, acting as non-practice entities, universities not only are highly dependent on the private firms, but also have access to fewer strategies for maximizing the quality of their patent portfolio.

Keywords: University; Intellectual Property; Patent quality; Technology Transfer; Policy Evaluation.

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1. Introduction

Academic research contributes to innovation mostly indirectly, through education and fundamental research, but also directly, through inventive activity and transfer-to-industry efforts. Academic inventions can result from activities taking place at the sole initiative of the academic scientist and/or her university or in collaboration with industry, whether this takes the form of consulting, joint research or development partnership (Colyvas et al., 2002; Czarnitzki et al., 2009; Lissoni, 2010). They may also be jointly produced with fundamental research results, as it was the case with early laser technology, polypropylene, and recombinant DNA (Hughes, 2011; Martin, 2007; Townes, 1999) or as complements to it, a classic case being that of scientific instruments (Von Hippel, 2007).

These multiple origins of academic inventions explain the heterogeneity of their intellectual property (IP) regime (Lissoni et al., 2008; Thursby et al., 2009; Czarnitzki et al., 2011; Sterzi, 2013; survey by Geuna and Rossi, 2011). While some inventions may be left without IP protection, others are patented ("academic patents"), with their property rights assigned to one or more of the different actors of the inventive process: the scientist (academic inventor), the research sponsor (private and/or public), or the scientist's institution of affiliation (the department or, more often, the university). Further sources of heterogeneity are legal norms concerning the assignment of IP rights over public-funded research either to universities or their faculty, as well as the legislation affecting universities' autonomy when it comes to asset management and recruitment of IP experts.

Over the past 15 years, European universities have been both pressured into and given the means of taking a more aggressive stance towards IP appropriation, by reclaiming it either from their employees or from industry partners. This resulted from a general demand by policy-makers to make room for technology commercialization among the university's missions. A good illustration in this respect is the "Code of Practice" approved by the European Commission in April 2008, which explicitly recommends universities to create "coherent portfolios of intellectual property" (European Commission, 2008; Arundel et al. 2013). In a similar vein, the Italian Ministry of Education (MIUR) considered until recently university-owned patents as the sole indicator of universities' performance in technology transfer, thus ignoring those assigned to firms or other actors (ANVUR 2011).

While all of these policies are justified by the necessity to "better convert knowledge into socio-economic benefits" (in the words of the European Commission press release IP/08/55), little or no evidence exists to suggest that universities are better placed than other actors in deciding what academic inventions are worth patenting and/or in managing a patent portfolio (Mowery and Sampat, 2005). Nor we can assume any longer, as it was common until recently, that the relative paucity of university-owned academic patents in the Old Continent, compared to the US, implies a limited exploitation of academic inventions (Lissoni, 2012).

To investigate these issues we study the quality of academic patents in Italy, from 1997 to 2009. Based on a battery of indicators that make the consensus in the literature, we find that, on average, universities are not as good as firms in managing their IP patent portfolios. This results is robust to endogeneity due to quality-based self-selection (highest-quality academic inventions end up being assigned and managed by business companies).

We proposed two explanations for this result. First, university patenting is a recent phenomenon and universities still need to accumulate capabilities and experience in the IP management. Second, acting as non-practice entities, universities not only are highly dependent on the private firms, but also have access to fewer strategies for maximizing the quality of their patent portfolio. In particular, the increasing interest of universities in the commercialization of the scientific results could be not always accompanied by an analogous interest of the private sector and this condition would lower the incentives for university administrators and TTO managers in investing in activities supporting the commercialization of scientific results.

We do find evidence only for the latter hypothesis. This leads us to speculate that leaving IP over selected inventions in the firms' hands may be part of a more general strategy of some universities, one that should be judged positively by policy-makers.

The paper proceeds as follows. In section 2 we survey the literature on academic patenting, with a special emphasis on the assignment issue. We also discuss some methodological problems concerning the measurement of patent quality. In section 3 we present a conceptual framework and a reduced form model for relating the quality of the patent management to the identity of their assignees. Section 4 is dedicated to data presentation and descriptive evidence. Section 5 contains our econometric exercises and the discussion of their results. Section 6 concludes.

2. Background literature

2.1 Academic inventions and patents

We can broadly define as "academic" all inventions that originate from research performed by one or more academic scientists as part of their job, possibly in collaboration with non-academic ones. A cursory look at publications listed in the Social Science Index of the Web Of Science (SSH-WoS), from 1950 to 2014, would reveal only around 10 of them mentioning "academic invention(s/ing)" in either their title, abstract or keyword list, all of them published after 2003 (see Figure A1 in the Appendix). The alternative term "university invention(s/ing)" also appeared late in the literature, more or less at the same time of the appearance of the term "academic patent(s/ing)" (never used, bar one exception, before 2002), and much later than that of "university patent(s/ing)", which dominated the literature until 2000 and still is much in use.[1]

This terminology is revealing of the way the literature has evolved, which we can describe as a backward discovery of the inventive activity of academic scientists, starting from just one of its manifestations, namely the patents filed by universities in their own name ("university patents"). It was these patents that first attracted most of the attention, following the introduction, in the US, of the Bayh-Dole Act, which in 1980 shifted IP rights over public funded research results from government to universities.[2] A US-centred literature developed then around three main themes:

1. The "basic" nature of inventions stemming from academic research (from now on, "academic inventions"), compared to those originated by industrial research, and the need of IP protection in order to ensure their effective development and commercialization.
2. The individual scientists' incentives to disclose their inventions to their universities and/or to subsequently invest in their development.

[1] Neither term was used by publication listed in the Social Science Index of the Web Of Science before 1984.
[2] For a history of the Bayh-Dole Act, see Schacht (2011).

3. The quality of university patents, and its change over time.[3]

The classic argument in favour of granting IP protection to academic inventions rests on the assumption that the latter tend to be "proofs of concepts" and "prototypes" with high potential, but little immediate applicability (Jensen and Thursby, 2001; Thursby and Thursby, 2007). Stemming from fundamental research, academic inventions could not be effectively turned into viable technologies in the absence of substantial development efforts, which can only be repaid by exclusive IP rights.

This vision of academic inventions sits well with a linear view of the science-technology relationship. Scientific research comes first, it is publicly funded, and produces general results. The decision to patent comes after the results have been achieved, and it may require a system of incentives to be set in place in order to motivate academic inventors to get engaged in commercialization efforts. One key element of the patenting decision is assignment. Should the IP rights be assigned to the inventor or her employer (the university)? The general rule of law, in almost all countries with up-to-date IP legislation, assigns them to the latter, as long as the inventive activity has been paid for (through wages or ad hoc prizes).[4] However, while R&D workers in firms conduct their research under close monitoring by management, the same does not apply to academic scientists, who are then supposed to "disclose" their inventions to the university administration (most often, its technology transfer office - TTO).[5]

The "disclosure" step is fraught with principal-agent problems. First, the academic inventor may not be aware of the inventive potential of her research results; or she may not be willing to get distracted from research (Lacetera, 2009). Second, and most important, the academic inventor may wish to bypass the TTO and sell or license directly her invention to an industrial partner, so to avoid sharing her revenues with the principal. Carayol and Sterzi (2013) propose a theoretical treatment of the issue, which they validate with respect to a sample of UK academic patents. They suggest that the faculty with high quality inventions and with some patenting experience may signal their quality to the private sector and transfer their inventions directly. These results are compatible with Markman et al.'s (2008) earlier findings for a sample of US academic patents, as well as with evidence surveyed by Siegel et al. (2007).[6]

Despite being widely shared, this "linear view" of academic inventions met at first some criticism from within the US, and later on from European scholars. Colyvas et al. (2002) point out that several high-impact US academic patented inventions did not appear as embryonic proofs of

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[3] This research agenda was largely set by Henderson et al.'s (1998) seminal paper, to which we owe the take-off of the literature in the 2000s, well illustrated by figure 1. For a discussion of its results and main conclusions, see Mowery et al. (2002).

[4] To date, the only notable exceptions to this rule are to be found in Sweden and Italy, on which we come back below. It should be also pointed out that, in several European countries, tenured academics are considered civil servants, which means that some confusion exists on the identity of their employer, as far as IP issues are concerned: the State or its universities? With the increasing autonomy granted almost everywhere to universities, the doubt has been resolved in favour of the latter.

[5] The disclosure problem would present itself also in case of public agencies reclaiming the IP rights over the results of the research programme they have funded. This was actually a common practice in the US before the approval of the Bayh-Dole Act. As for Europe, a classic case was that of the National Research Development Corporation (later named British Technology Group, and finally privatized in 1992), a UK state agency officially in charge of reclaiming and administering all IP rights over public funded research results. As part of the worldwide trend towards the university-owned model, no country nowadays contemplates legal provisions of this kind (Arundel, 2013; OECD, 2013)

[6] Needless to say, principal-agent problems would present themselves with even greater force in case the inventors had to disclose not to their universities, but to an even more distant principal such as the State, either in its role of employer or research sponsor (see previous footnote).

concepts or prototypes, but as fully functional technologies, which needed not as much further development as envisaged by the linear view. Nor universities were the only owners of such patents, some of them having been filed by or sold to companies with the universities' consent, as a result of collaboration agreements or option contracts that pre-dated the discovery time. The possibility for academic research to produce immediately applicable results, while keeping its basic orientation, is coherent with non-linear visions of the science-technology relationship, such as the chain-linked model (Kline and Rosenberg, 1986) or the Pasteur's quadrant theory (Stokes, 1997). Both suggest that scientists have a non-financial interest in solving pressing technological problems faced by business firms, to the extent that this may lead to results of general interest. It is also compatible with the important role played in advanced countries by the rise of "scientific engineering" and its drive towards producing "useful knowledge" (Rosenberg and Steinmueller, 2013).

In this perspective, principal-agent problems concerning disclosure do not take centre stage. Rather, one could follow Aghion and Tirole (1994) and portray established firms and universities as parties of a research contract which assigns IP rights before the contract itself is executed (the invention has materialized). Aghion and Tirole suggest that for inventions to which academic research contributes marginally it will be optimal for both parties and society to assign IP rights to the firm, while the opposite holds when academic research contributes more decisively. In this second case, though, second-best contracts may end up being signed, which assign anyway the IP to firms, whenever the university faces substantial costs for fully appropriating the benefits of the invention, and it is cash- and credit-constrained. As for the correlation between the commercial relevance of the invention ("size of the innovation") and IP ownership, the authors stress that no general conclusion can be drawn.

European researchers have contributed to the non-linear view by proposing a set of research questions and empirical methodologies more suited to the institutional framework of their countries (surveys by Geuna and Rossi, 2011; Grimaldi et al., 2011; Lissoni, 2012). First, they observed that, until the early 2000s, the IP laws of Scandinavian and German-speaking countries exempted academics from any disclosure duty towards their universities, as they retained exclusive IP rights over their inventions (professor's privilege).[7] Second, even in countries that never contemplated the professor's privilege, universities did not enjoy the same degree of administrative autonomy of their US counterparts. This means that they could not manage their own financial assets, nor recruit IP managers on the labour market, let alone participating to spin-off firms or letting their faculty invest in them. This implies that they had little means and interest in investing in IP, very much like envisaged by Aghion's and Tirole's model recalled above. Under these conditions, it was all too natural for universities to leave most IP rights in their scientists' hands, or in the hands of their sponsoring firms[8]. From the methodological viewpoint, a new technique was proposed and quickly spread, which consisted in tracking academic patents by checking the inventors' names (rather than the assignees') and matching them to academic scientists' names, as derived from universities' rosters or bibliographic resources. In this way, it was revealed that European academic patenting, far from being a marginal phenomenon, is a sizeable one, which

[7] See Czarnitzki et al. (2011 and 2012), Damsgaard and Thursby, 2013; Greenbaum and Scott, 2010; Valentin and Jensen, 2007; von Proff et al., 2012

[8] In addition, their tenured faculty were considered civil servants, and/or legal provisions existed that created ambiguities over whether the State, instead of universities, was entitled to IP rights over public funded research. See Baldini et al., 2006; Della Malva et al., 2013

account for around 5% of several countries' patenting activity, with peaks of over 20% in biotechnology. [9]

This line of research also revealed that the university-ownership model is diffusing in Europe, too, due to three policy changes (Arundel et al., 2013; OECD, 2013):

1. The almost general abolition of the professor's privilege, now surviving only in Sweden and, with many limitations, Italy (where it was introduced only in 2001).
2. The increasing autonomy conceded to universities, which can now exert more control over their faculty's remuneration, time management, and activities, as well as invest and profit from IP.
3. A general drive to include university patents (as opposed to academic inventions at large) among the indicators used to assess universities' performance in technology transfer, with possible consequences for ranking and funding.

An all too natural question raised by these developments concerns their social welfare effects, namely whether the diffusion of the university-ownership model goes in the direction of increasing the number, quality, and exploitation of academic inventions, and at what cost for universities.

Notice that university-ownership of academic patents, as opposed to firm-ownership, is more common when inventors come from the life science faculty, as opposed to physical sciences and engineering (Thursby et al., 2009) and for patents in biotechnology as opposed to ICT and Chemicals (Lissoni, 2012). This suggests the possibility that the linear and non-linear views of the academic invention and patenting may capture some cross-sectional variation in how academic science affects invention.

2.2 The quality of academic patents

Collecting information on the quality of patents is costly, since this information is largely private and often valuable by itself (so that patent holders may not be willing to disclose it). It is then commonplace, for large patent samples, to rely on patent-based indicators. Among them, since Trajtenberg (1990), forward patent citations are the most used indicator, based on the idea that they reveal the existence of downstream R&D efforts. Several authors have found them to be highly correlated both with the perceived importance of the invention by the inventors themselves (Lanjouw and Schankerman, 2004; Harhoff et al. 1999; Harhoff and Reitzig 2004; Jaffe et al. 2000) and with the expected economic returns from the invention (Fischer and Leidinger, 2014). For a sample of agricultural (hybrid corn seeds) patents, Moser et al. (2014) have found evidence of a correlation between citations and the size of the inventive step, as measured by field trial data on yield increases.

Besides the intrinsic technological quality of the invention, however, forward citations may reflect the assignees' management choices. Hall et al. (2005) suggest that self-citations may positively correlate with the assignee's follow-on invention efforts, and Moser et al. (2014) provide evidence for it. In the case of university patents, these efforts are most likely to be undertaken by licensees

[9] See Callaert et al. (2013), Dornbusch et al. (2013), Iversen et al. (2007), Lawson (2013), Lawson and Sterzi (2014), Lissoni et al. (2008 and 2013), Martínez et al. (2013), Mejer (2012), Meyer (2003), Schoen and Buenstorf (2013), Thursby et al. (2009), Sterzi (2013). For Germany, Czarnitzki et al. (2011 and 2012), classify patents as academic whenever the inventors' name include reference to a professorial status.

and to affect not only self-citations, but citations in general (Sampat and Ziedonis, 2005; Mowery and Ziedonis, 2015).

Applications of citation-based measures to academic patents have concentrated on measuring either the quality of academic vs non-academic patents or the quality of academic patents according to their ownership (mostly, company vs university). Overall, results are quite mixed, as one may expect in a context in which institutional variables both carry a lot of weight and have undergone important changes over time.

Early research by Henderson et al. (1998) tested positively 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. The same authors also found a negative trend for such "citation premium", which has been confirmed by Rosell and Agrawal (2009) but not by Mowery et al. (2001, 2002). All of this research was limited to university-owned patents, and to the case of the US. As for other countries, Sapsalis et al. (2006) and Sapsalis and van Pottelsberghe (2007) find that the citations rate of patents owned by French-speaking Belgian universities not to differ substantially from that of a control sample of corporate patents. Bacchiocchi and Montobbio (2009) find evidence of a citation premium for university-owned patents over corporate ones, but only for US universities (as opposed to European and Japanese ones) and only in selected technologies.

Czarnitzki et al. (2007 and 2011) confirm the "citation premium" hypothesis for German academic patents, irrespectively of ownership. The citation premium, however, appears to be higher for academic patents owned by universities and public research organizations, compared to those owned by business companies, and to decline over time. The authors suggest a link between their findings and the abolition of the professor privilege in 2000, which in turn appears to be associated to an increase in academic patenting.

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 general than those assigned to universities, and suggest that this result depends on the company owned academic patents to result from consulting activities, rather than academic research. Lissoni and Montobbio (2015) examine the citation rates of academic patents in several European countries and find them to differ greatly across country, conditional on ownership. For instance, 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. For the UK, Sterzi (2013) finds that university-owned academic patents are less cited than company-owned ones, especially over the short run, and that ownership changes (from university to company) increase the citation rate.

Citation-based measures of patent quality have been found to be both noisy and possibly biased, for example by the patent examiners' preferences for specific prior art items or items of others (Cockburn et al., 2002; Lerner, 2002) or strategic citing by patent applicants (Lampe, 2012). We discuss and use alternative quality measures, such as the probability of opposition and the family size, in section 4 (survey by van Zeebroeck, 2011).

3. Quality and IP management of academic inventions: A conceptual model

3.1 Conceptual issues: technological patent value and IP management effectiveness

Effectively managing and optimizing the value of the patent portfolio is a major challenge for all organizations, one which requires well-structured IP management processes and organizational structures. These processes (Bader et al. 2012) consist of several tasks and phases, which go from (i) the *exploration phase*, in which firms collect ideas for new invention and check the relevant competitors through a comprehensive patent search, to continue with (ii) the *generation phase*, where ideas are realized through the development of new processes and products, (iii) the *protection phase*, during which firms might be interested in building patent fences around a core invention to foreclose patenting of substitutes by rivals, to end with (iv) the *optimization phase*, in which firms decide how to maximize revenues from their patents by considering alternative strategies, such as internal development, out-licensing, selling or donation opportunities[10]. If the first two phases concern the inventive steps, the last two are strictly related to IP management.

Most R&D performing firms control all four phases, namely both those concerning the inventive steps and those concerning the IP management. This is not the case for universities, whose administration, in general, do not interfere much with the faculty's choice of research topics, from which any inventive activity does ultimately depend. The faculty's choice, in turn, is dictated by the science and technology policies followed by public funders (including philanthropic institutions) and their call for projects, or by private sponsors (mostly firms) with whom the faculty entertain some direct relationships. So, the IP management for TTOs and universities in general is limited only to manage the patent procedure and maximize the revenues from it (phase iii and iv). And even in such phases, universities have a more limited set of choices than most R&D performing firms, bound as they are to their status of non-practice entities (NPEs), which limit the range of exploitation possibilities to licensing and selling (Koruna, 2001).

Our hypothesis is thus that universities are worse placed than firms in deciding what academic inventions are worth patenting and, moreover, in extracting surplus from them.

However, since the IP management is a chain of different processes which follow one another, measuring the quality of the patent portfolio management is not an easy task. Necessarily, the quality of the management step - *protection* and *optimization* phase - does depend on the quality of the invention - *exploration* and *generation* process. In other words, it is easier to protect and license the patent when the protected invention is of high quality.

Being the sum of several phases, the notion of patent quality is thus is a composite one, regardless of the indicators we might consider. In particular, it sums up two distinct concepts such as the quality of the *generation* and *exploration* phases, which are related to the contribution of the patented invention to the advancement of technology (its technological "importance", as in Henderson et al., 1998; or its inventive step, as in the legal jargon) and the quality of the *protection* and *optimization* phases, which are strictly connected to the applicant's will and ability to manage it successfully.

From an observational viewpoint, however, it may be hard to distinguish these two dimensions. As discussed above, classical measures for patent quality (such as forward citations) may capture both the inventive step and follow-on management efforts. Similarly, a patent may be withdrawn after publication either because of lack of inventive step or non-obviousness or for strategic reasons

[10] In their paper Bader and coauthors (2012) considered the declining phase as separated from the optimization phase.

(such as when it was filed only to kill novelty) or as a result of other management choices (such as when a cash-constrained university cannot find a licensee or a buyer to pay for a lengthy and costly examination procedure). Finally, a granted patent may not be renewed because the invention has turned out not to be working out (technically) as expected, or because of problems met at the commercialization level.

3.2 A model for patent management effectiveness

Depending both on the inventive and management step, we write the observed quality of a patented academic invention i (ω_i) as a function of its technological importance (v_i) and of the effectiveness of the IP management (q_i):

$$\omega_i = f(q_i, v_i) \qquad [1]$$

We then assume *[1]* to be an additive function of q_i and a measurement error, which contains the invention's technological importance v_i:

$$\omega_i = q_i + \epsilon_i(v_i) \qquad [2]$$

We want to verify whether the management effectiveness q_i depends, ceteris paribus, on whether the applicant is a firm (as with academic inventions not disclosed to the university, or not retained in the university's patent portfolio) or a university (as with academic inventions disclosed to and retained by a TTO). Hence, we propose to estimate the following model, where q_i is a linear function of the identity of its applicant (a university vs. a firm):

$$q_i = \alpha + \beta University_i + u_i \qquad [3]$$

However, since we do not observe directly q_i but only a proxy for it (ω_i), we must plug (2) in (3) and obtain:

$$\omega_i = \alpha + \beta University_i + \varepsilon_i \qquad [4]$$

where $\varepsilon_i = u_i + \epsilon_i(v_i)$

To the extent that the invention's technological importance v_i is correlated with the type of applicant ($University_i$) we have a problem of endogeneity.

To obtain a consistent estimation of the impact of first applicant's type, we first augment Equation [4] with proxies for the technological importance of the invention and other controls that might be correlated at the same time with the type of applicant and with the management of the patent. These controls (X_i) include some characteristics of the patent and the team of inventors which are related to the technological quality of the invention (see discussion in Section 4). So we propose to estimate first the following model:

$$\omega_i = \alpha + \beta University_i + \delta X_i + \varepsilon_i \qquad [5]$$

In addition, we test for endogeneity where, as exogenous source of variation in the type of applicant, we consider the inventor's *Age* at the time of the patent filing, which we assume to be correlated with the identity of the first applicant but not with the patent quality.

In particular, we assume senior professors to be less likely to disclose their inventions to their TTOs, or to be more likely to negotiate for the IP to be retained by their industrial partners (with no sharing with the university), for three reasons.

(i) Cohort: senior professors started and progressed in their careers at a time when Italian universities exerted little control on IP matters and left them largely in their own hands; so we assume them – *ceteris paribus* - to be more familiar in handling IP then younger colleagues, or to resent more the TTO's intervention;
(ii) Social capital: senior professor have more social capital than their younger colleagues, which extend outside the academic area into industry (they are their own broker with respect to commercial partners, with less need of TTO as an intermediary);
(iii) Status: senior professor are less prone to the pressures of the university in terms of patent disclosure, due to their higher status.

Based on this hypothesis, we expect *Age* to be a strong instrument.

4. Data and variables

4.1 Data

We exploit the APE-INV dataset collected by Lissoni et al. (2013), to whom we refer for full methodological details and in-depth descriptive statistics [11]. The dataset contains all patent applications at the European Patent Office (EPO) by inventors with an Italian address, from 1997 to 2009 (42784 inventors for 51054 patent applications).

Italy is a well researched case, for which one can assemble both a rich policy documentation and longitudinal data (Lissoni et al., 2008 and 2013). It is also an illustrative example of the trend towards a "university-owned model" of academic patenting, with the share of university-owned academic patents having passed from less than 10% in the 1990s to more than 40% at the end of the 2000s (Figure 1). This trend emerged in midst of contradictory institutional changes concerning

[11] See also the APE-INV project website: http://www.academicpatenting.eu. Non-anonymized data, can be provided upon request. Being focussed on trends, Lissoni et al. (2013) examined data only up to 2007, for truncation reasons.

the IP of academic inventions, ranging from the concession of university autonomy in the first half of the 1990s to the *impromptu* introduction of the professor's privilege, in 2001, at a time when other countries abolished it (Baldini et al., 2010; Baldini et al., 2006; Muscio et al., 2014). This was later modified, and largely de-potentiated in 2005, also by effect of universities being quite active in introducing disclosure-inducing IP statutes. An interesting feature of these statutes is the emphasis they place on the inventor's right to propose, jointly with disclosure, a potential licensee or buyer. This implies an acknowledgement, by TTOs, of their need to leverage existing collaborations between their faculty and industry. It also lowers the incentives of experienced faculty to circumvent disclosure.

[FIGURE 1 ABOUT HERE]

All information on patents come from the CRIOS-PatStat database, which contains applications filed at EPO since 1978, including those undergoing PCT procedure.[12]

Inventor names are disambiguated according to the procedure described by Pezzoni et al. (2014), and then matched to those of tenured faculty in service at Italian universities in one or more of the following years: 2000, 2005, and 2009. Inventor-faculty matches are validated on the basis of within-patent information (such as the identity of the assignees or the address of the inventor, when it points to a university department) plus e-mail and telephone surveys. In addition, based on an econometric exercise on non-respondents, a number of firm-owned patents are identified as academic ones, thus providing an "upper bound" estimate of the phenomenon of interest (the "lower bound" consisting just of the validated data, with all non-respondents treated as non-academic). In what follows we make use of the upper bound data.

Since we are interested in evaluating the quality management of the patent portfolio of universities, we restrict our sample only to granted patents. This leaves us with 1879 university-patent observations[13], for a total of 1400 academic inventors and 1532 patents[14]. In the econometric exercise we further restrict our sample to 1553 observations in which at least a university or a company are listed as assignee.

4.2 Variables

As (observable) main measure of patent quality - which encompasses both the IP management effectiveness and the technological importance of the invention - we use a dummy indicating whether the patent has been ever cited.

[12] The CRIOS-PatStat database is a derivative product of PatStat, the Worldwide Patent Statistical Database released twice a year by EPO. See Coffano and Tarasconi (2014) for details.

[13] In the analysis which follows when patents invented by inventors of different universities are counted more than once.

[14] The choice of professor-patent pairs as observations for our econometric analysis is due to the need to control for both the characteristics of the inventor and those of the patent. At the same time, though, each academic in our sample may have signed more than one patent, and each patent may have been signed by more than one professor.

Forward citations are often used as measure for patent quality as they suggest the presence of other researchers working in a similar field and are a signal of the rapid recognition of importance of the patent.

Since the distribution of citations is highly skewed[15], both in the case of university-owned and for company-owned academic patents (See Figure 2), our baseline results consider as dependent variable a dummy indicating whether a patent has ever been cited.

[FIGURE 2 ABOUT HERE]

However, for robustness checks, we also consider other proxy for the quality of a patented invention *i* (ω_i), namely:

- a binary variable indicating whether the patent has been opposed by a third part after the grant (*Dummy Opposition*);
- the number of patents in the family of the focal patent (*Family Size*).

Our variable of interest is the ownership status of academic patents, at the moment of first filing[16]. We therefore assign each patent to its DOCDB family, and identify the applicant(s) listed on the priority patent within the family[17]. That is, we make sure to consider as owner only the original patent applicant, and not any individual or organization to whom the patent may have been sold after the first filing.[18]

On this basis, we identify seven ownership categories, namely patents applied:

1. only by firms, or (very rarely) by firms and individual inventors (*Firm only*)
2. by individual inventors only (*Individuals only*)
3. only by Italian universities (*University only*)
4. jointly by universities and firms (*University & Firm*)
5. jointly by university and an heterogeneous set of applicants such as hospitals and public research organizations (*University & Others*)

[15] 31% of the patents have no citations and 90% have less than seven citations.

[16] Notice that we refer to the first applicant of the patent, and not generically to its assignee. This is because an academic patent whose application has been first filed by a university can be later sold to a company (the reverse is hard to believe), and we consider the sale to a company willing to commercialize the inventions, instead of holding it up, an indication of successful exploitation by the university.

[17] DOCDB families are produced by patent examiners at the EPO, on the basis of simple patent families. A simple family is defined as a set of patent applications all of which share the same priority date. In most cases, the family consists of applications for the same invention at different patent offices, with the first application date as the priority date, plus all the follow-up documentation (amendments, divisionals, publications of the granted patent etc). DOCDB families are a refinement of simple families, based upon the patent examiners' decision to exclude some irrelevant documents. Neither the EP-CRIOS database (nor the PatStat raw data it makes use of) include an ID for simple patent families, so we go for DOCDB. For a thourough discussion, see Martinez (2010).

[18] When priority patents are EPO ones, this required manually checking the information provided by PatStat, by comparing it to that provided by Espacenet, a popular patent search engine also run by EPO. This is because PatStat information on applicants and assignees is updated if and when the latter changes, so that current editions of PatStat do not necessarily report the original applicant.

6. by an academic spin-off (*Spin-off*) [19]
7. by other organizations (*Others*).

As anticipated above, for our econometric exercise we retain only the patents owned by *Firms only* and those owned or co-owned by the universities, which result by aggregating, under a generic *University* heading all patents in the following categories: *University & Firm, University & Others,* and *Spin-off* in the category "university-owned" patents. We discard patents by *Individuals only* and by *Others* from the analysis.

Table 1 shows the frequency and the average of citation-based quality scores for all the applicant categories and for the categories retained for the regression analysis.

[TABLE 1 ABOUT HERE]

Academic patents owned exclusively by firms (*Firm)* represent 61% of total observations and are of the highest quality, no matter the time horizon we consider for the citations. Patents assigned exclusively to universities (*University only)* represent 13.5% of the observations. Co-applications of universities with firms or other public research organizations represent more than 6%. Altogether, academic patents in which universities appear as first applicants, alone or with a co-applicant, are more than 20% of the cases. This in line with the literature discussed in section 2.

Finally, almost 10% are assigned to the academic inventors.

According to Equation [5] we include in the regression a set of variables that control for the technological importance of the invention, causing possible biases when omitted. Thus, in all models, we control for technological fields and priority year fixed effects. The latter, among other things, control for the fact that more recent patents receive on average less citations, by default.

As a first proxy for the technological quality of the invention we consider a variable (*Collaboration*) which tell us the number of universities involved in the patent. The idea is that the larger the number of universities participating in the inventive activity, the higher the investment and the technological importance of the outcome.

We also include the *Originality* of the patent, as in Thursby et al. (2009). This variable takes values between 0 and 1 and it is constructed by measuring the dispersion of the backward citations made by the focal patent across patent classes. The more a patent is original the closer the index is to 1. We expect that consulting-based academic patents are less original (Thursby et al. 2009) and, at the same time, of lower importance. *Originality* also controls for the fact that academic inventions originated and owned by universities may reflect discoveries very far from the market and for this reason more difficult to manage.

For the same reason, we may expect university-owned academic patents to be broader than company-owned ones, where breadth is measured by the number of *Claims* inserted in the focal patent application (in line with Lanjouw and Schankerman 2001; see also Townes', 1999, account

[19] In order to identify these patents we match the names of academic patent assignees with the names of companies listed in the TASTE database of Italian academic spin-offs, and with the names of spin-offs identified as academic in the RITA database (see, respectively: Bolzani et al., 2014; and Colombo and Piva, 2008).

of the drafting of the first laser patents). Again, since *claims* have been found to be positively correlated with observable measures of technological patent quality, we expect that their inclusion reduces (in absolute term) the impact of university patent ownership on IP management effectiveness.

Similarly, we expect that the patenting experience of the team of inventors might be correlated with both the technological importance of the invention and the observable measures of patent quality. The variable *Patenting Experience,* measured as a dummy which indicates if the team was composed of inventors with some previous (EPO) patenting experience. More experienced faculty may both produce more important inventions and have less need to rely on their TTO for handling IP.

As discussed in section 3.2, the age of the academic inventor at the time of the patent filing (*Age*) is used as instrument for university patent ownership. We calculated it by considering the professors' year of birth, as reported by publicly available ministerial records.

Table 2 reports the descriptive statistics.

[TABLE 2 ABOUT HERE]

5. Empirical analysis

5.1 Citation-based measures of patent quality

We first estimate equation *[5]* by adding one by one the controls described in Section 4.2. In particular, Table 3 presents the estimates for Probit models for IP management effectiveness as measured by the dummy indicating whether the academic patent has been ever cited. We control for heteroskedasticity with robust standard errors (we cluster standard errors at the professor's university level to account for possible dependence in the errors). Marginal effects only for university ownership are reported in the bottom of the table. Columns (1) - (4) show that, on average, university-owned academic patents are poorly managed if compared with company-owned ones. In marginal effects, academic patents managed by universities have about 10% less probability to receive at least one citation [20]. However, the difference in IP management effectiveness seems to decrease with the inclusion of controls for the technological importance of the invention, which suggests that in case of their omission we would suffer of endogeneity problem.

In particular, this would suggest that part of the negative effect of the university dummy is due the self-selection process, in which academic inventors seems to prefer on average leave their patent to the university when are of lower quality (Carayol and Sterzi, 2013).

To test whether our results still suffer of endogeneity, even after adding our controls for the technological importance of the patent, we estimate a bivariate probit model where the patent university ownership is instrumented by the age of the academic inventor(s)[21] at the time of the patent. This model allows the university ownership variable to be correlated with unobserved

[20] Marginal effects are evaluated at mean values.
[21] We consider the average in case a patent has been invented by more than one academic inventor.

factors that also affect the observable measure of patent quality, which it could be represented by the patent technological importance.

Were age correlated with the technological importance of the patent we should insert it in our main regression and lose it an instrument. However, we find no evidence or theory in the literature that suggests, at a conceptual level, the possibility of a correlation between the age of an academic inventor and the importance of her inventions, as proxied by patent citations. The closest topic we find in the literature are the empirical studies the life cycle effect in scientific productivity, as measured by scientific publications. As reported by Stephan (2010), the evidence in this sense is limited and contradictory, with some authors finding a non-monotonic effect (the number of publications first increases, then declines with age) and others a negative one. So, we checked whether Italian academic scientists in our sample exhibit any sign of growing less likely to become or stay inventive over the years, and found no evidence in this direction . Moreover, at the empirical level, age results not being significant (p-value of 0.990 for model presented in Column (5) of Table 3) when included as a regressor of IP management effectiveness.

To control for potential endogeneity of university ownership, we thus estimate the following model:

$$\begin{cases} Dummy\ Citation = 1[z_1\delta_1 + \alpha_1 University + u_1] \\ University = 1[z\delta_2 + v_2] \end{cases} \qquad [6]$$

where (u_1, v_2) are independent of $\mathbf{z}$ and distributed as bivariate normal with mean zero, unit variance and such that $\rho = corr(u_1, v_2)$. The vector $\mathbf{z}$ contains control variables (z_1) for Dummy Citation Equation and the age of the professor, used as instrument for university ownership. The exogeneity condition is stated in terms of the correlation coefficient ρ_1.[22]. Knapp and Seaks (1998) show that a likelihood-ratio test of whether the correlation coefficient of the residuals in the two equations is equal to zero can be used as a Hausman endogeneity test. If $\rho_1 = 0$ then the two error terms are not correlated and the simple probit estimation for the Dummy Citation Equation is consistent for $\delta_1$and α_1. On the contrary, $\rho_1 \neq 0$ implies that University is endogenous and that the estimated parameters of the non-instrumented version of the Citation Equation will be not consistent.

The bivariate probit (bi-probit) approach is more efficient than the commonly used two-steps procedure (Greene, 1993), because it allows to take into account the correlation between the disturbances of the citation and ownership equations. However, for comparison purposes, we present also the results of the two-steps procedure where the age of the academic inventor is used as instrument for patent ownership.

Results for the bivariate probit are shown in column (6) of table 3. According to the bi-probit estimates, as expected *Age* appears to be negatively correlated with university ownership. More interesting, the test for exogeneity of university ownership (Likelihood-ratio) suggests that the university ownership is exogenous: although the negative sign (-0.03) of the ρ coefficient might suggest that unmeasured factors that increase the probability of having a citation also decrease the

[22] See Brown et al.'s paper (2004) for an application of endogeneity tests.

university ownership, the associated p-value (0.89) suggests that this effect is far from being significant.

This results is also confirmed by the IV two-steps procedure, displayed in column (7). The Wald test of exogeneity is consistent with the Likelihood-ratio test for the bi-probit and does not reject the hypothesis of exogeneity of university ownership (p-value of 0.87). The coefficient for University ownership is of the same magnitude of the simple probit estimates (-0.347) but with larger standard errors.

[TABLE 3 ABOUT HERE]

As robustness check, in Appendix we show results for alternative models and different proxies for patent management effectiveness always based on citations. First, since the literature has found that early citations are more correlated with the economic value of the patents (Lanjouw and Schankerman, 2004; Sampat et al., 2003; Czarnitzki et al. 2012), Table A1 shows the estimated coefficients for probit models where the dependent variable is a dummy indicating whether the patent has been cited in the first three years after the priority date. Second, Tables A2 and A3 present result for OLS models in which the dependent variable is the logarithm of the total number of citations received and the of number of citations received in the first three years after the priority date respectively. Finally, Tables A4 and A5 present results based on negative binomial models. Results are always the same, showing that, controlling for the technological importance of the patent, university-owned academic patents are not managed as effectively as the firm-owned ones.

5.2 Alternative measures of patent quality

In this section we present further results, based upon alternative, non citation-based measures of patent management effectiveness. In particular, we consider oppositions and family size.

Patent oppositions are recently used as indicator of patent quality, based on the assumption that they signal the existence of a market for the patented invention (one that opponents want to contend to applicants) and thus are informative on its economic importance[23]. This, in turn, may depend, as for the patent citations, both on the technological importance of the invention and applicant's ability to exploit the invention, as perceived by the opponents.

[23] Opposition is a typical legal institute of EPO patents. After the patent office has decided in favour of granting the patent, and published its decisions, third parties have up to nine months opposing the decision on a legal ground. For example, they may argue that some prior art escaped the examiners' attention and that, if this is considered, the invention would be found to lack novelty or not to involve an inventive step. Since the cost of an opposition procedure can be substantial for the attacker (Harhoff et al.), opposition cases provide a signal of a patent's value on the market and of the ability of the applicant to exploit it successfully. For a full discussion, see: Harhoff et al. 1996 and 2002; Graham et al., 2002. For technical information on the opposition procedure: https://www.epo.org/about-us/jobs/examiners/what/opposition.html

Patent families are sets of patent document that share one or more priority date (see footnote 18). Given the costs required to file the invention in many offices, the size of patent families denotes a market potential for the patented technology and has been widely used as indicator of patent quality by many authors (Schmoch et al., 1988; Lanjouw and Schankerman, 2001; Harhoff et al., 2003). We still consider DOCDB families.

Table 4 shows results for patent oppositions, where the dependent variable is a dummy taking value 1 if the patent has been opposed. In our sample only 3% have been opposed. Our data also highlight that opposition rates slightly decrease in more recent years. Still, we find a strong difference between university and company-assigned patents. Academic patents applied by companies have been opposed in average in the 4.2% of the cases, while university-applied patents only in 0.3% of the cases. In particular, in some sectors we do not observe any opposition for university-applied patents: for this reason we aggregate the 30 technological classes used in the previous analysis to seven classes. With these limitations, opposition-based results are coherent with citations-based ones. Academic patents that are applied and managed by universities seem not to be managed as effectively. The estimated coefficient for *University* is negative in all Probit models (Columns 1-4), with the inclusion of controls for the technological importance of the patent reducing its magnitude, but not its significance.

When it comes to testing for exogeneity, we conclude once again that our models is not affected by endogeneity, whether we consider the Bivariate Probit model (Column 6) or the two-steps IV Probit (Column 7).

[TABLE 4 ABOUT HERE]

Finally, table 5 shows that the results of a number of log-linear OLS regressions, with the patent's family size as the dependent variable, and the usual battery of regressors; plus an IV regression, with the same dependent variable and *Age* as an instrument.

Once again, the estimated coefficient for *University* is negative in all OLS models (columns (1-5), also after controlling for the technological importance of the patent; and the exogeneity test confirms that our results are not affected by endogeneity.

[TABLE 5 ABOUT HERE]

5.3 Discussion

On the basis of the previous results we can conclude that Italian universities are not as good as private firms in managing their patent portfolios. Based on our conceptual model of the determinants of IP management effectiveness, as presented in Section 3, we can interpret our results in two ways.

The first, and simplest, explanation is that Italian universities lack of capabilities and experience in IP management. Italian universities have taken an active interest in the commercialization of the research only since the 1990s. Since then, it took them a long time first to establish some clear rules to assign IP rights over academic inventions, then to organize technology transfer formally, through the established of TTOs and clear procedures of evaluation, patent filing, and commercialization (Potì and Romagnosi, 2010; Lissoni et al. 2013). Many of them may be still on their way down the learning curve.

Alternatively, and more in accordance with our conceptual mode, we may stress that universities are NPEs, whose strategies are limited to licensing and selling their IP and, for this reason, they do strongly depend on the demand of the private sector. However, the increasing interest of Italian universities in the commercialization of their scientific results may not be reciprocated by the private sector. In most of the cases Italy is still experiencing a lack of venture capital activity[24] and the private sector has long suffered from underinvestment in R&D compared to the EU average (Action Institute, 2013). Moreover, investments in Italy are unevenly distributed at the regional level: overall, the R&D expenditures of the Northern Italian regions, together with the one of Toscana, Emilia Romagna and Lazio regions account for 75% of the all national expenditures. So, since licensing and selling IP assets involve ex-ante search, evaluation and negotiating costs, we can speculate that university administrators and TTO managers in universities characterized by an unfavorable local context have no resources nor incentives to invest in activities supporting the commercialization of scientific results.

The first hypothesis seems not be confirmed from the data. Figure 3 shows the effect of university ownership over time and does not support the idea that universities are doing a better job in recent years. Moreover, data on TTO seem to confirm this result. Table 6 (Columns (1-2)) shows that universities with a formal TTO (*TTO*) at the time of the patent or with an experienced TTO (*TTO Experience*) are not better than universities without a formal TTO in the patent portfolio management. So, although the presence of the TTO has been found by some authors to be positively correlated with the probability that the university retains the ownership of the invention (Della Malva et al., 2013), it seems not to have an impact on the quality in which the patent is managed, at least in Italy.

To test the second hypothesis we proxy the local demand by the percentage of R&D funded by the private sector in the region where the university of the academic inventors is located. The idea is that the more important the local demand is, the higher the incentive of the universities in investing resources and times in commercialization activities. The results shown in Table 6 (columns (3)-(6)) seem to support this hypothesis. The interaction between university ownership and the percentage of R&D performed by the private sector in the region of the university (*University*R&DSharePRIVATE*) is positive and significant suggesting that universities in regions with higher private R&D expenditure over GDP perform, on average, better than universities in regions where the private sector invest less.

[FIGURE 3 ABOUT HERE]

[TABLE 6 ABOUT HERE]

[24] The OECD Science Technology & Industry Scoreboard of 2007 ranked Italy in the 17th position in terms of availability of venture capital funds as a percentage of the GDP and in 2008

6. Conclusions

More than a quarter of century after the introduction of the Bayh-Dole Act in the US and almost 15 years after the abolition of the professor privilege in Germany, Austria and most Scandinavian countries, a trend is well underway which sees universities to increasingly engage in patent filing and direct commercialization efforts. Yet, the jury is still out on whether assigning patents to universities in first place (as opposed to inventors) and encouraging the latter to license their IP to business companies, instead of selling it, is socially optimal or not. Based on difference-in-difference analysis, Czarnitzki et al. (2015) question the results obtained by the abolition of the professor privilege, which they find to have diminished, rather than increased, German academics' patenting propensity. For the US, Kenney and Patton (2009 and 2011) argue that inventor ownership leads to faster and more effective commercialization of academic inventions. Finally, the literature we surveyed in section 2 finds, for several European countries, that university-owned academic patents are not better, and possibly worse, than firm-owned ones (the latter ending up in firms' hands thanks to stronger control exerted by the inventors). In particular, this last result might be explained either by the fact that academic patents of observed higher quality are self-selected into the firms' hands or by the fact that they are poorly managed by the universities. In fact, little or no evidence investigates whether universities are eventually better placed than other actors (firms) in deciding what academic inventions are worth patenting and/or in managing a patent portfolio.

In this paper, we investigate the quality of the IP management at the universities by considering granted patents invented by academic researchers in Italy from 1997 to 2009.

The results we obtained go in the direction of confirming that the best quality academic patents are those assigned to firms. In addition, we have proved that this does depend on Italian universities' mismanagement of patents in their portfolios.

Conditional on welfare optimization objectives (academic inventions ought to maximize innovation at large, and not just serve as self-financing tools for universities), our results suggest to consider with caution all policy mechanisms that push universities to retain title and directly manage their academic patents. Were self-selection to occur via lack of disclosure, our results would concur to evidence that experienced academic inventors can do without the brokerage services of TTOs, at least when it comes to find a market for public-funded inventions (they may still need them to find the right industrial partners for collaborative research). Were the early involvement hypothesis correct, we should judge positively the universities' (tacit or explicit) decision to let their inventors' business partners to take title of the results of collaboration, through the proper contractual arrangements.

This conclusion would change, however, if we shared the view of academic patents as important tools for universities' self-financing. In this case, universities should be encouraged to retain the best patents, and try to extract the maximum rent from them. However, there is considerable evidence that university-owned patent portfolios, even the large ones held by US universities, hardly generate enough revenues to cover their costs, and this despite some important blockbusters in pharmaceuticals and biotechnology (Cummings, 2013), and an increasingly aggressive pursuit of infringers, especially in ICT (Lemley, 2007; Love, 2015).

Still, Italian universities do appear, on average, to do worse than firms when it comes to managing their patent portfolios. These findings may be of interest for technology policy designers in a context where the technology transfer offices represent only one of the possible way to transfer technology to the private sector and where the financial returns for the universities usually concern a very small proportion of the university inventions.

In this respect, the recent decision by the Italian Agency for the Evaluation of Universities and Research (ANVUR) to consider all academic patents, whether owned by universities or not, as indicators of effective technology transfer may not go in the right direction.

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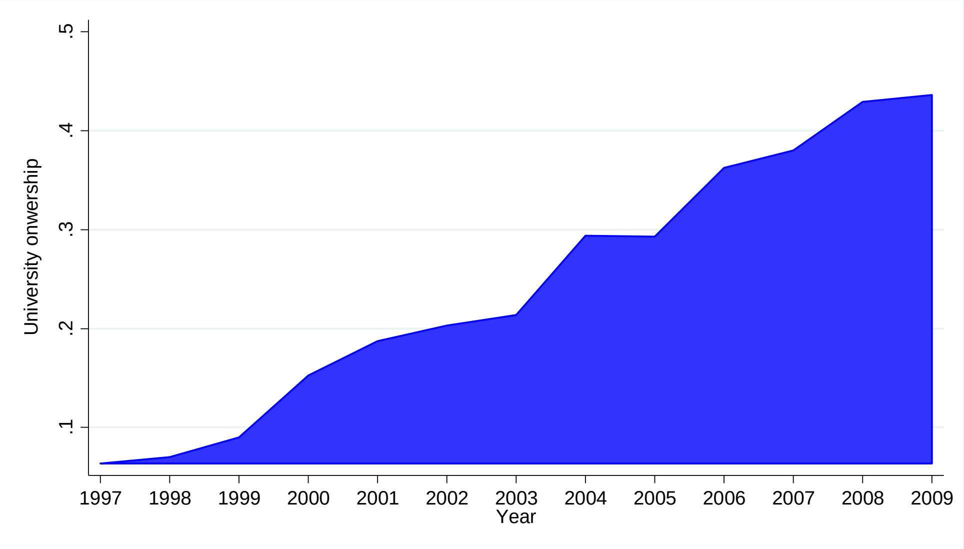
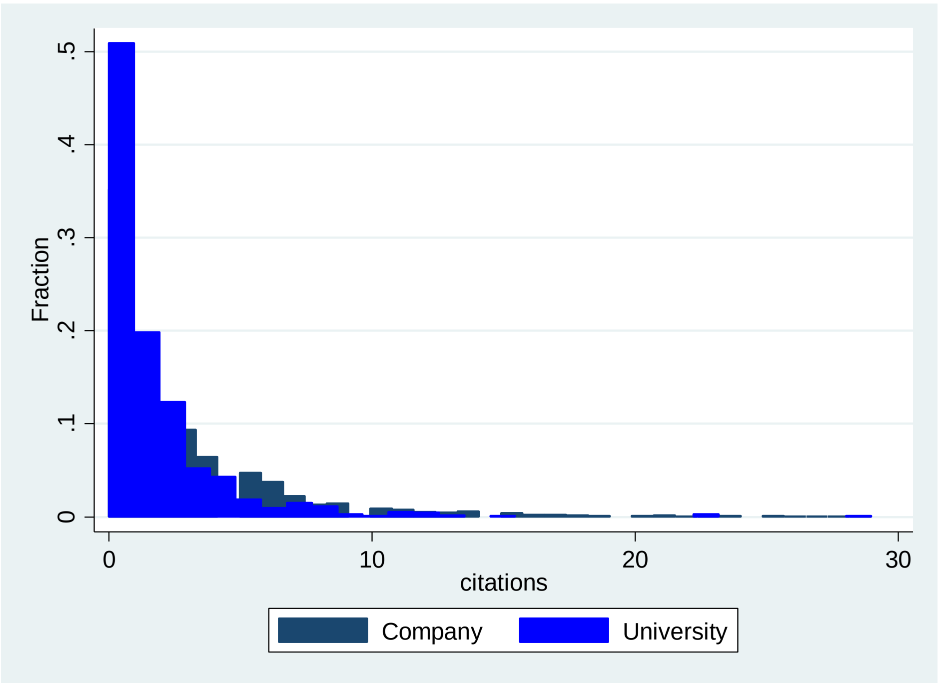
TABLES and FIGURES

FIGURE 1. OWNERSHIP OF ACADEMIC PATENTS: % OF ACADEMIC PATENTS ASSIGNED TO UNIVERSITIES



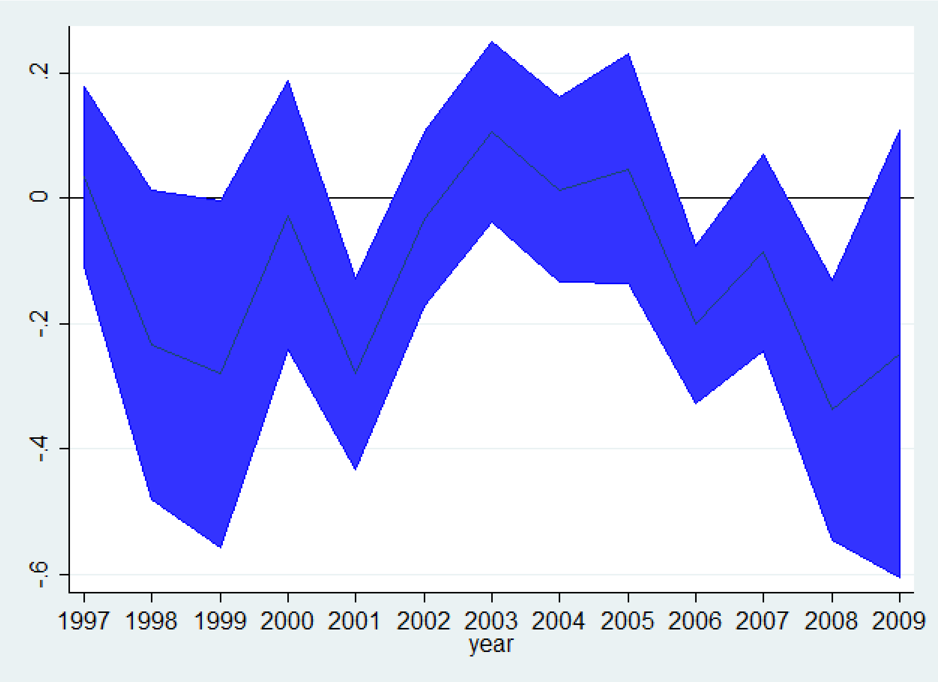
The y-axis shows the ratio of university-owned academic patents. Only granted patents are considered. University-owned patents are patents applied by universities alone, or in collaboration with firms, individuals and other public research organizations, or university's spin-offs.

FIGURE 2. CITATIONS DISTRIBUTION FOR TYPE OF APPLICANT



Granted patents only. EP-EP citations, without any time constraint, are considered. The two categories of applicants (company and university) are defined in Table 1.The "Company" category considers academic patents assigned to firms only. The "University" category stands for patents applied by universities alone, or in collaboration with firms, individuals and other public research organizations, or university's spin-offs.

FIGURE 3. IP MANAGEMENT AND UNIVERSITY OWNERSHIP OVER TIME



The y-axis shows the coefficients for university ownership for all the years considered in the analysis according to the model (4), Table 3. The coefficient is the interaction between university ownership and year. The dependent variable is the dummy for forward citations.

TABLE 1. CATEGORIES OF FIRST APPLICANT

First applicant	nr	% by type	% Citations>0	Citations	Citations (3yrs)
Firm or Firm and Individuals (1)	1149	61,15	76%	3,94	1,63
Individuals only (2)	181	9,63	64%	2,55	1,08
University only (3)	253	13,46	57%	2,07	0,91
University and Firm (4)	36	1,92	47%	1,97	0,86
University and Others (5)	81	4,31	54%	1,68	0,86
Spin-off (6)	34	1,81	59%	1,65	1,09
Others (7)	145	7,72	74%	3,41	1,17
Firm (1)	1149	61,15	76%	3,94	1,63
Dropped (7+2)	326	17,35	69%	2,93	1,12
University (3+4+5+6)	404	21,50	56%	1,95	0,91
All patents (1+2+3+4+5+6+7)	1879	100,00	6850,0%	3,11	1,3

Patents are counted more than once if invented by academic inventors in different universities.

TABLE 2. SUMMARY STATISTICS

	Firm-owned academic patents					University-owned academic patents					T-test for mean equality
	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max	
Dependent variables											
Dummy citation	1149	0.76	0.43	0	1	404	0.56	0.50	0	1	7.77
Dummy citation (3 yrs)	1149	0.60	0.49	0	1	404	0.43	0.50	0	1	5.84
Citations	1149	3.94	6.76	0	84	404	1.95	4.91	0	84	5.44
Citations (3 yrs)	1149	1.63	3.20	0	45	404	0.91	2.41	0	41	4.15
Dummy Opposition	1149	0.04	0.20	0	1	404	0.00	0.07	0	1	3.67
Family Size	1149	9.31	6.81	1	44	404	6.79	3.41	1	24	7.12
Regressors											
Collaboration	1149	1.56	1.00	1	5	404	1.76	0.99	1	5	-3.44
Originality	1149	0.58	0.30	0	0.93	404	0.50	0.33	0	0.92	4.67
Claims	1149	15.12	9.59	0	97	404	15.02	8.99	0	53	0.18
Patenting Experience	1149	0.85	0.36	0	1	404	0.67	0.47	0	1	7.71
Age	1149	50.90	9.22	30	75	404	48.95	6.92	32.5	69	3.89

Patent are counted more than once if invented by academic inventors in different universities. Firm-owned academic patents are assigned exclusively by firms as first applicants. University-owned academic patents are assigned to any type of organization but with at least one university involved. See Table 1 for the categories considered.

TABLE 3. BASELINE RESULTS FOR IP MANAGEMENT QUALITY (CITATIONS, DUMMY)

	(1)	(2)	(3)	(4)	(5)	(6)		(7)
	Probit	Probit	Probit	Probit	Probit	Bi-Probit		IV Probit
VARIABLES	Dummy Citations	Dummy Citations	Dummy Citations	Dummy Citations	Dummy Citations	Dummy Citations	Dummy University	Dummy Citations
University	-0.342***	-0.379***	-0.341***	-0.347***	-0.306***	-0.248		-0.472
	(0.0769)	(0.0815)	(0.0814)	(0.0813)	(0.0739)	(0.420)		(1.036)
Collaboration		0.146***	0.142***	0.145***	0.135***	0.131***	0.228***	0.146*
		(0.0408)	(0.0408)	(0.0413)	(0.0415)	(0.0508)	(0.0414)	(0.0802)
Originality			0.389***	0.338**	0.309**	0.320**	-0.743***	0.279
			(0.131)	(0.134)	(0.134)	(0.148)	(0.134)	(0.227)
Claims				0.0160***	0.0159***	0.0158***	0.00328	0.0160***
				(0.00481)	(0.00471)	(0.00441)	(0.00400)	(0.00432)
Patenting Experience					0.211**	0.222*	-0.699***	0.181
					(0.0823)	(0.121)	(0.101)	(0.211)
Age							-0.0230***	
							(0.00510)	
Constant	0.912***	0.731***	0.601***	0.432***	0.308*	0.296	0.0786	0.344
	(0.123)	(0.126)	(0.139)	(0.163)	(0.165)	(0.219)	(0.344)	(0.299)
Rho (e,u)						-0.03		
						(0.24)		
Likelihood-ratio test of ϱ(e,u)=0 (p-value)						0.89		
Wald test of exogeneity (p-value)								0.87
Marginal effect for University (dy/dx)	-0.11	-0.12	-0.11	-0.11	-0.10			
Correctly classified	74.82%	74.82%	74.37%	74.82%	74.31%			
Observations	1,553	1,553	1,553	1,553	1,553	1,553	1,553	1,553
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Field FE	YES	YES	YES	YES	YES	YES	YES	YES

Robust standard errors are clustered at the university level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The dependent variables is a dummy indicating whether the patent has been ever cited.

TABLE 4. RESULTS FOR IP MANAGEMENT QUALITY (OPPOSITIONS, DUMMY)

	(1)	(2)	(3)	(4)	(5)	(6)		(7)
	Probit	Probit	Probit	Probit	Probit	Bi-Probit		IV Probit
VARIABLES	Dummy Oppositions	Dummy Oppositions	Dummy Oppositions	Dummy Oppositions	Dummy Oppositions	Dummy Oppositions	Dummy University	Dummy Oppositions
University	-0.914***	-0.915***	-0.857***	-0.863***	-0.837**	-0.959		1.295
	(0.314)	(0.312)	(0.321)	(0.330)	(0.334)	(0.692)		(1.754)
Collaboration		0.00793	0.00359	0.0195	0.0136	0.0189	0.227***	-0.0897
		(0.0674)	(0.0681)	(0.0684)	(0.0676)	(0.0720)	(0.0430)	(0.109)
Originality			0.694**	0.588**	0.561**	0.543*	-0.743***	0.921**
			(0.274)	(0.265)	(0.266)	(0.306)	(0.134)	(0.428)
Claims				0.0139**	0.0140**	0.0141**	0.00330	0.0119*
				(0.00561)	(0.00570)	(0.00552)	(0.00402)	(0.00692)
Patenting Experience					0.218	0.191	-0.701***	0.635
					(0.255)	(0.256)	(0.101)	(0.406)
Age							-0.0229***	
							(0.00519)	
Constant	-2.572***	-2.585***	-3.028***	-3.159***	-3.324***		0.0800	-3.813***
	(0.339)	(0.378)	(0.520)	(0.522)	(0.589)		(0.334)	(0.685)
Rho (e,u)						0.0786		
						(0.442)		
Likelihood-ratio test of ϱ(e,u)=0 (p-value)						0.8589		
Wald test of exogeneity (p-value)								0.1967
Marginal effect for University (dy/dx)	-.0411	-.0412	-.03565	-.034688	-.03322			
Correctly classified	96.72%	96.72%	96.72%	96.72%	96.72%			
Observations	1,553	1,553	1,553	1,553	1,553	1,553	1,553	1,553
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Field FE	YES	YES	YES	YES	YES	YES	YES	YES

Robust standard errors are clustered at the university level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The dependent variables is a dummy indicating whether the patent has received at least one opposition.

TABLE 5. RESULTS FOR IP MANAGEMENT QUALITY (FAMILY SIZE, COUNT)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	IV
VARIABLES	ln(family size)	ln(family size)	ln(family size)	ln(family size)	ln(family size)	ln(family size)
University	-0.206***	-0.184***	-0.155***	-0.155***	-0.145***	0.225
	(0.0516)	(0.0514)	(0.0503)	(0.0506)	(0.0476)	(0.370)
Collaboration		-0.0776***	-0.0788***	-0.0780***	-0.0809***	-0.105***
		(0.0161)	(0.0164)	(0.0165)	(0.0162)	(0.0271)
Originality			0.257***	0.249***	0.241***	0.309***
			(0.0516)	(0.0532)	(0.0524)	(0.0816)
Claims				0.00211	0.00205	0.00187
				(0.00130)	(0.00132)	(0.00143)
Patenting Experience					0.0595	0.127*
					(0.0406)	(0.0772)
Constant	2.033***	2.136***	2.036***	2.012***	1.975***	1.893***
	(0.0521)	(0.0584)	(0.0570)	(0.0595)	(0.0616)	(0.103)
Wald test of exogeneity (p-value)						0.31
R2	0.397	0.408	0.421	0.421	0.423	0.375
Observations	1,553	1,553	1,553	1,553	1,553	1,553
Year FE	YES	YES	YES	YES	YES	YES
Field FE	YES	YES	YES	YES	YES	YES

Robust standard errors are clustered at the university level. *** p<0.01, ** p<0.05, * p<0.1. The dependent variables is the logarithm of the patent family size. The age of the academic inventor is used as instrument in the IV estimation.

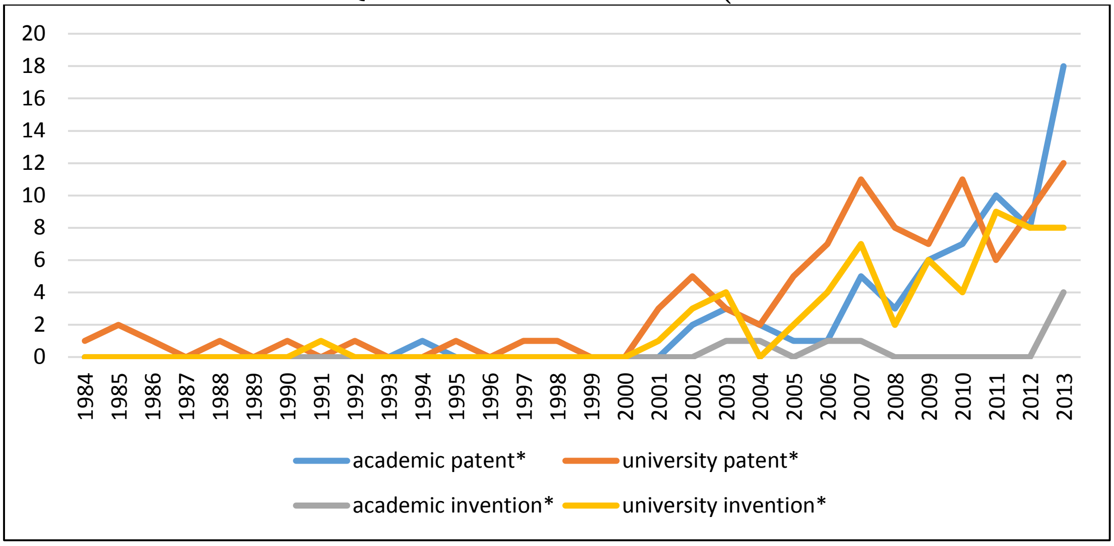
TABLE 6. TTO AND LOCAL DEMAND

VARIABLES	(1) Probit Dummy Citations	(2) Probit Dummy Citations	(3) Probit Dummy Citations	(4) Probit Dummy Citations	(5) Probit Dummy Citations	(6) Probit Dummy Citations
University	-0.309***	-0.279***	-0.634***	-0.329**	-0.777***	-0.834***
	(0.108)	(0.103)	(0.154)	(0.138)	(0.249)	(0.223)
University * TTO	0.00544					
	(0.149)					
University * TTO Experience		-0.00834				
		(0.0183)				
University*R&DSharePRIVATE			0.543**			0.640***
			(0.222)			(0.228)
University*R&DSharePAUNI				0.0381		0.233
				(0.147)		(0.169)
University*R&DShareTOTAL					0.390**	
					(0.197)	
Collaboration	0.135***	0.135***	0.144***	0.135***	0.144***	0.147***
	(0.0414)	(0.0415)	(0.0413)	(0.0415)	(0.0405)	(0.0413)
Originality	0.309**	0.309**	0.295**	0.310**	0.308**	0.298**
	(0.134)	(0.134)	(0.134)	(0.133)	(0.132)	(0.133)
Claims	0.0159***	0.0159***	0.0155***	0.0159***	0.0158***	0.0155***
	(0.00462)	(0.00472)	(0.00481)	(0.00470)	(0.00475)	(0.00480)
Patenting Experience	0.211***	0.215***	0.193**	0.212**	0.211***	0.197**
	(0.0816)	(0.0827)	(0.0842)	(0.0833)	(0.0814)	(0.0843)
Constant	0.308*	0.303*	0.312*	0.307*	0.299*	0.306*
	(0.168)	(0.170)	(0.167)	(0.166)	(0.165)	(0.167)
Observations	1,553	1,553	1,553	1,553	1,553	1,553
Year FE	YES	YES	YES	YES	YES	YES
Field FE	YES	YES	YES	YES	YES	YES

Robust standard errors are clustered at the university level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The dependent variables is a dummy indicating whether the patent has been ever cited. TTO is a dummy indicating whether the university had a formal technology transfer office at the time of the patent. TTO Experience is a continuous variable indicating the number of years since the establishment of the TTO in the university.

APPENDIX

FIGURE A1. KEYWORDS FREQUENCY IN THE LITERATURE (NR OF PUBLICATIONS PER YEAR)



Source: Own elaboration on SSH-WoS, 1950-2014 (Core collection – Scientific Articles)

TABLE A1. RESULTS FOR IP MANAGEMENT EFFECTIVENESS (3 YEARS CITATIONS, DUMMY)

	(1)	(2)	(3)	(4)	(5)	(6)		(7)
	Probit	Probit	Probit	Probit	Probit	Bi-Probit		IV Probit
VARIABLES	Dummy Citations	Dummy Citations	Dummy Citations	Dummy Citations	Dummy Citations	Dummy Citations	Dummy University	Dummy Citations
University	-0.355***	-0.398***	-0.363***	-0.369***	-0.338***	-0.637		-0.392
	(0.0869)	(0.0853)	(0.0820)	(0.0833)	(0.0801)	(0.465)		(0.936)
Collaboration		0.151***	0.149***	0.153***	0.144***	0.163***	0.227***	0.148**
		(0.0352)	(0.0350)	(0.0352)	(0.0345)	(0.0445)	(0.0413)	(0.0713)
Originality			0.340***	0.286***	0.263***	0.207	-0.736***	0.253
			(0.0897)	(0.0941)	(0.0985)	(0.150)	(0.134)	(0.207)
Claims				0.0164***	0.0162***	0.0163***	0.00323	0.0162***
				(0.00262)	(0.00265)	(0.00377)	(0.00401)	(0.00385)
Patenting Experience					0.172**	0.116	-0.705***	0.162
					(0.0862)	(0.123)	(0.101)	(0.192)
Age							-0.0234***	
							(0.00488)	
Constant	0.340**	0.148	0.0200	-0.159	-0.267*	-0.198	0.128	-0.255
	(0.169)	(0.174)	(0.179)	(0.175)	(0.160)	(0.203)	(0.333)	(0.268)
ϱ(e,u)								
						0.184		
Likelihood-ratio test of ϱ(e,u)=0 (p-value)						(0.286)		
Wald test of exogeneity (p-value)						0.5207		0.9539
Marginal effect for University (dy/dx)	-.140	-.1573	-.1431	-.1455	-.13358			
Correctly classified	62.72%	62.20%	60.53%	62.52%	62.72%			
Observations	1,553	1,553	1,553	1,553	1,553	1,553	1,553	1,553
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Field FE	YES	YES	YES	YES	YES	YES	YES	YES

Robust standard errors are clustered at the university level. *** p<0.01, ** p<0.05, * p<0.1. The dependent variables is a dummy indicating whether the patent has been cited in the first three years after the priority date.

TABLE A2. RESULTS FOR IP MANAGEMENT EFFECTIVENESS (CITATIONS, LOG)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	IV
VARIABLES	ln(cit+1)	ln(cit+1)	ln(cit+1)	ln(cit+1)	ln(cit+1)	ln(cit+1)
University	-0.197***	-0.206***	-0.178***	-0.179***	-0.168***	0.297
	(0.0393)	(0.0386)	(0.0370)	(0.0368)	(0.0358)	(0.494)
Collaboration		0.0297**	0.0286**	0.0318**	0.0286**	-0.00113
		(0.0139)	(0.0131)	(0.0128)	(0.0134)	(0.0370)
Originality			0.250***	0.217***	0.209***	0.294***
			(0.0373)	(0.0398)	(0.0410)	(0.107)
Claims				0.00895***	0.00889***	0.00866***
				(0.00140)	(0.00141)	(0.00201)
Patenting Experience					0.0652	0.150
					(0.0438)	(0.0992)
Constant	0.670***	0.631***	0.533***	0.432***	0.391***	0.288**
	(0.0713)	(0.0790)	(0.0777)	(0.0731)	(0.0645)	(0.142)
Wald test of exogeneity (p-value)						0.30
R2	0.108	0.109	0.121	0.136	0.137	0.065
Observations	1,553	1,553	1,553	1,553	1,553	1,553
Year FE	YES	YES	YES	YES	YES	YES
Field FE	YES	YES	YES	YES	YES	YES

Robust standard errors are clustered at the university level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The dependent variables is the logarithm of the number of citations plus one. The age of the academic inventor is used as instrument in the IV OLS.

TABLE A3. RESULTS FOR IP MANAGEMENT EFFECTIVENESS (3 YEARS CITATIONS, COUNTS)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	IV
VARIABLES	ln(cit3+1)	ln(cit3+1)	ln(cit3+1)	ln(cit3+1)	ln(cit3+1)	ln(cit3+1)
University	-0.227***	-0.236***	-0.195***	-0.197***	-0.179***	0.616
	(0.0475)	(0.0480)	(0.0467)	(0.0466)	(0.0424)	(0.585)
Collaboration		0.0313	0.0297	0.0343*	0.0293	-0.0215
		(0.0204)	(0.0197)	(0.0198)	(0.0206)	(0.0440)
Originality			0.363***	0.317***	0.303***	0.449***
			(0.0660)	(0.0699)	(0.0694)	(0.132)
Claims				0.0127***	0.0126***	0.0122***
				(0.00160)	(0.00161)	(0.00239)
Patenting Experience					0.101**	0.247**
					(0.0495)	(0.118)
Constant	1.409***	1.367***	1.225***	1.082***	1.019***	0.843***
	(0.0832)	(0.0910)	(0.0899)	(0.0880)	(0.0845)	(0.175)
Wald test of exogeneity (p-value)						0.14008
R2	0.268	0.269	0.283	0.300	0.301	0.183
Observations	1,553	1,553	1,553	1,553	1,553	1,553
Year FE	YES	YES	YES	YES	YES	YES
Field FE	YES	YES	YES	YES	YES	YES

Robust standard errors are clustered at the university level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The dependent variables is the logarithm of the number of citations in the first three years plus one. The age of the academic inventor is used as instrument in the IV OLS.

TABLE A4. RESULTS FOR IP MANAGEMENT EFFECTIVENESS (CITATIONS, COUNT)

	(1)	(2)	(3)	(4)	(5)
	NB	NB	NB	NB	NB
VARIABLES	Citations	Citations	Citations	Citations	Citations
University	-0.403***	-0.403***	-0.307***	-0.303***	-0.293***
	(0.0901)	(0.0909)	(0.0889)	(0.0922)	(0.0890)
Collaboration		-0.000586	-0.00125	0.00687	0.00485
		(0.0243)	(0.0228)	(0.0236)	(0.0244)
Originality			0.706***	0.603***	0.600***
			(0.114)	(0.126)	(0.126)
Claims				0.0202***	0.0203***
				(0.00255)	(0.00258)
Patenting Experience					0.0670
					(0.0755)
Constant	1.528***	1.529***	1.217***	0.954***	0.908***
	(0.116)	(0.119)	(0.123)	(0.125)	(0.130)
lnalpha	-0.00789	-0.00789	-0.0536	-0.101	-0.101
	(0.0637)	(0.0638)	(0.0676)	(0.0650)	(0.0650)
Observations	1,553	1,553	1,553	1,553	1,553
Year FE	YES	YES	YES	YES	YES
Field FE	YES	YES	YES	YES	YES

Robust standard errors are clustered at the university level. *** p<0.01, ** p<0.05, * p<0.1. The dependent variables is the number of citations received by the patent.

TABLE A4. RESULTS FOR IP MANAGEMENT EFFECTIVENESS (3 YEARS CITATIONS, COUNT)

	(1)	(2)	(3)	(4)	(5)
	NB	NB	NB	NB	NB
VARIABLES	Citations	Citations	Citations	Citations	Citations
University	-0.533***	-0.530***	-0.442***	-0.442***	-0.429***
	(0.103)	(0.102)	(0.0959)	(0.0976)	(0.0973)
Collaboration		-0.00809	-0.00773	0.00489	0.00170
		(0.0240)	(0.0226)	(0.0251)	(0.0259)
Originality			0.709***	0.634***	0.625***
			(0.0978)	(0.104)	(0.104)
Claims				0.0177***	0.0177***
				(0.00283)	(0.00289)
Patenting Experience					0.0951
					(0.0962)
Constant	0.252**	0.265*	-0.0533	-0.264*	-0.333**
	(0.121)	(0.140)	(0.142)	(0.151)	(0.147)
lnalpha	0.120	0.119	0.0739	0.0354	0.0346
	(0.105)	(0.106)	(0.107)	(0.108)	(0.107)
Observations	1,553	1,553	1,553	1,553	1,553
Year FE	YES	YES	YES	YES	YES
Field FE	YES	YES	YES	YES	YES

Robust standard errors are clustered at the university level. *** p<0.01, ** p<0.05, * p<0.1. The dependent variables is the number of citations received by the patent.