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The impact of the abolishment of the professor's privilege on European university-owned patents

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L'impact de la suppression du « Professor's privilege » sur la qualité des brevets universitaires en Europe

Résumé

Les régimes de propriété intellectuelle régissant les inventions universitaires étaient très diversifiés en Europe à la fin des années '90. Plusieurs pays européens ont maintenu le « *Professor's privilege* », qui accordait aux enseignant-chercheurs d'université le droit d'être titulaires de brevets. Les années 2000 ont été marquées par la convergence vers un système plus homogène, dans lequel les administrations universitaires ont pris le contrôle de la gestion de la propriété intellectuelle. Nous étudions l'impact de la réforme et constatons un déclin de l'importance technologique et de la valeur des brevets détenus et gérés par des universités dans les pays qui abolissent le privilège du professeur. Au contraire, en différenciant les brevets académiques par type de propriété, nous constatons que l'importance technologique des brevets académiques détenus par des entreprises a plutôt augmenté. Notre étude produit de nouveaux résultats qui peuvent alerter les législateurs sur les éventuelles imprévues du modèle attribuant la propriété intellectuelle aux universités (« university ownership model »).

Mots-clés: Brevets universitaires ; qualité des brevets; gestion des brevets; valeur du brevet; transfert de technologie

The impact of the abolishment of the professor's privilege on European university-owned patents

Abstract

Intellectual property regimes governing university inventions were quite diverse in Europe at the end of the 1990s. Several European countries maintained the so-called professor's privilege, an exception to employment law whereby university researchers were allowed to retain the ownership of academic inventions. The 2000s were characterised by convergence towards a more homogeneous system, in which university administrations took control of IP management. We investigate the impact of the reform and we observe a decline in the technological importance and the value of the patents owned and managed by universities in the countries abolishing the professor's privilege. On the contrary, by differentiating the academic patents by type of ownership, we find that the technological importance of academic patents owned by companies has instead increased. Our study produces some new results that may alert policymakers to the possible unintended consequences of the university ownership model.

Keywords: University-owned patents; academic-invented patents; patent quality; patent management; patent value; technology transfer

JEL: I23 ; L26 ; 031 ; 033 ; 034

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1. INTRODUCTION[1]

University research is nowadays widely recognised to be an engine for the economic growth of national and regional economies. Firms can benefit from such research indirectly or directly in many ways. Indirectly, they can profit from the spillovers generated by university research and the networks built upon university-industry collaboration. Directly, they can hire university graduates and researchers to undertake business projects in-house or via contract research or consulting; they undertake projects jointly with university researchers and they can also exploit university research results by acquiring or licensing university-owned patents.

Analysts often claim that one of the key reforms facilitating the technological success of university research commercialisation in United States is the Bayh-Dole Act, introduced in 1980. Since this reform, American universities have the right to own patents on inventions funded by federal public funds and to provide exclusive licenses to third parties. Many other countries have adopted initiatives to emulate the success of the US model and as a result universities have gradually taken a more aggressive stance towards intellectual property (IP) appropriation.

Focusing on Europe, this paper exploits the heterogeneity characterising university IP regimes within and across European countries, to investigate whether major shifts towards the institutional ownership of university inventions, and specifically the abolishment of the professor's privilege in some of them, have affected the technological importance of the inventions disclosed to university administrations and the effective exploitation of their value, relative to patents unaffected by such changes.

Changes to the IP regime in universities are expected to impact on the incentive structure of two types of agents involved in the production and commercialisation of academic research, namely researchers and university administrators. Following Arqué-Castells et al. (2016), Hvide and Jones

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(2018) and Sterzi et al. (2019) we consider the commercialisation of university-owned patents to be the result of the effort of academic researchers and the investment of university administrations in facilitating the protection and exploitation of inventions resulting from university research. That is to say, the effectiveness of commercialisation is taken to be the result of the combination of the technological importance (quality) of the invention and the effectiveness of IP management in exploiting the invention.

To our knowledge, we are the first to address the question of the impact of the abolishment of the professor's privilege on the technological importance and the efficiency of the management of university-owned patents. Using a multidimensional approach to the measurement of the quality and value of inventions, our findings are in line with previous results for individual countries regarding university patenting activity and entrepreneurship (Hvide and Jones 2018 for Norway, Czarnitzki et al. 2015 for Germany, Ejermo and Toivanen 2018 for Finland). We observe a relative decline in the average technological importance and effective exploitation of the value of university-owned patents in the countries abolishing the professor's privilege.

Moreover, we also provide new evidence of a shift of ownership of the academic-invented patents of lower quality from companies to universities. When we consider in the analysis also patents invented by academics but applied for by companies, we observe a rise in the average technological importance of company-owned patents.

The paper is organised as follows. The next section describes the principal laws governing IP ownership in universities in different countries, and the changes some of them have experienced in recent years. The related literature is discussed in Section 3. The background and the principal hypotheses guiding our empirical analysis are presented in Section 4. Section 5 introduces our empirical strategy and offers some descriptive statistics of the novel international database with information on university and company-owned patents we have constructed for the project. The principal results of the econometric analysis are offered in Section 6. Section 7 provides additional evidence including in the analysis academic-invented patents owned by companies for a selection of countries. Section 8 concludes.

2. UNIVERSITY IP REGIMES

The emphasis on the linear model of innovation and technology transfer[2] and the pressure on universities and their technology transfer offices (TTOs) to file patents on faculty inventions (hoping to obtain millions in royalty fees by licensing them to industry) is usually traced back to the Bayh-Dole Act, enacted in 1980 in the United States. International emulations of the Act began to proliferate in the following years, notably in Europe (Mowery and Sampat 2005).[3]

2.1 The Bayh-Dole Act

Supporters of the Bayh-Dole Act believed that university contributions to innovation were limited by difficulties in patenting the outputs of federally funded research and in licensing the patents exclusively to industry, although such arguments generally lacked empirical evidence (Mowery and Sampat 2005). In fact, it has been claimed that the debate was mainly ideological. As argued in Eisenberg (1996, p.1664), the passing of the Bayh-Dole Act meant that the US Congress endorsed a new vision of how best to exploit publicly sponsored research results: "In this new vision, public ownership of research results was equivalent to "dead-hand" control, and the public domain was a treacherous quicksand pit in which discoveries sink beyond reach of the private sector. If the results of federally-sponsored research were to be rescued from oblivion and successfully developed into commercial products, they would have to be patented and offered up for private appropriation." The Act permitted universities to file patents on the results of government-sponsored research and to provide exclusive licences to third parties, and enabled the government to retain march-in rights in their regard.[4] As summarised by Loise and Stevens (2010), the Act stated that inventions produced with federal funding could be owned by the institutions in receipt of such funds. These institutions should also: i) grant licences rather than transfer ownership; ii) disclose the government's interest in patent applications and notify the government before abandoning any patent applications;

[2] According to the linear model of technology transfer, the process begins with a discovery by the university researcher (laboratory) and follows a linear path from disclosure to the university administration (possibly to the TTO) overseeing the patenting process and, finally, to licences to an existing firm for further development and commercialisation (see Bradley *et al.* 2013 for reviews of the literature on technology transfer).

[3] The influence of the Act has also extended to other parts of the world, in addition to Europe, both in developed countries such as Japan (Takenaka 2005) and in emerging countries such as Malaysia, South Africa or the Philippines (Zuniga 2011).

[4] These march-in rights have not been exercised at the time of writing.

iii) share the income received with the inventors (how much to share was left up to individual institutions); iv) use any residual income retained by the institution for research and education; v) grant a royalty-free non-exclusive licence to the US government for its own use; vi) require licensees to manufacture products in the US that were to be sold in the US; vii) give preference to small businesses. Moreover, according to Henderson et al (1998), the 1984 approval of Public Law 98-620 expanded the rights of universities still further by removing certain restrictions contained in the Bayh-Dole Act regarding the kinds of inventions that universities could own and the rights of universities to assign their property rights to other parties. In addition to universities, the Act gave permission to small businesses to retain the ownership of patents of government-sponsored research, and in 1984 this provision was extended to large enterprises (Eisenberg 1996). For the top US research universities with patenting experience, the change introduced by the Act simply accelerated and facilitated the way things were already done: "First, it replaced a web of Institutional Patent Agreements (IPAs) that had been negotiated between individual universities and federal agencies with a uniform policy. Second, the Act's provisions expressed Congressional support for the negotiation of exclusive licenses between universities and industrial firms for the results of federally funded research" (Mowery and Sampat 2005, p.119). For the remaining universities it represented a more radical change, as it made patents a potential source of additional revenue. New TTOs were created and new patent policies and incentives for academics established.

The expansion of university patenting had begun prior to 1980, from when on it increased more markedly due to a combination of factors, in which the Bayh-Dole Act was just one among many. Other factors included the increasing importance of the biotechnology and software sectors, which were emerging at that time, the rise of industry applications based on biomedical research and a general trend towards strengthening the intellectual property rights in the United States. The latter included the establishment of the US Court of Appeals for the Federal Circuit and was reflected in several pro-patent decisions expanding the patent subject matter to cover more inventions in biotechnology and software (Martínez and Guellec 2004). Nevertheless, the changes brought about by the Bayh-Dole Act were mainly seen outside the United States as a way of increasing the attractiveness of European university inventions to industry and raise university revenues in a context of increasing funding constraints (with block grant funding being replaced by project funding).

2.2 Changes to IP regimes in Europe

The legislation governing patent ownership of publicly funded inventions was quite heterogeneous in Europe in the 1980s and 1990s but began to converge to more homogenous IP regimes in the early 2000s.[5] Five European countries (Denmark in 2000, Germany and Austria in 2002, Norway in 2003 and Finland in 2007) abolished the professor's privilege regarding IP ownership, allowing university researchers to retain the ownership of inventions developed at universities. New IP regulations were enacted to grant universities the right to own and manage university inventions, following the US model. At the same time, countries which had never established the professor's privilege gradually strengthened institutional ownership controls and made commercialisation and technology transfer one of their principal missions, a stance reflected in a number of laws, policy changes, university statutes and guidelines. The apparent outliers were Italy and Sweden. Italy introduced the professor's privilege in 2001, but the measure was counterbalanced by other legal changes granting universities tighter control over their faculties' activities regarding inventions, rendering the professor's privilege ineffective. A change introduced in 2005, narrowing this privilege to results fully funded by intramural university resources, reduced the influence of the professor's privilege in Italy still further. In contrast, Sweden maintained and maintains today the professor's privilege. Table 1 describes the IP regimes and the principal policy and legal changes affecting university patenting in recent decades in a selection of European countries.

3. RELATED LITERATURE

Several econometric studies have analysed the impact of changes to IP regimes derived from the abolishment of the professor's privilege in a number of European countries.

For Norway, Hvide and Jones (2018) find a decline of approximately 50% in the aggregate rate of new venture creation and patenting by university researchers following the reform, as well as a decline in the quality of university start-ups and patents. They do so by using multiple difference-in-

[5] Damsgaard and Thursby (2013), Greenbaum and Scott (2010), Grimaldi *et al.* (2011), Kenney and Patton (2011), Mowery and Sampat (2005), Schacht (2012), Valentin and Jensen (2007), von Proff *et al.* (2012).

difference regressions to compare patents and start-ups by university researchers and researchers working outside universities (public research institutes, companies, etc.).[6]

Table 1. Changes in IP regimes for university patenting in Europe

Policy and legal changes	Country	Change	Trend
Abolishment of the professor's privilege, to increase scientists' incentives to disclose inventions to university managers	Denmark	2000	Universities assign a share of the patent licensing revenue to the inventor and pay all the costs associated with the patent application
	Germany	2002	
	Austria	2002	
	Norway	2003	
	Finland	2007	
Stronger enforcement of institutional ownership system already in place	United Kingdom	1977	Harmonisation, measures to encourage intellectual property awareness, commercialisation and creation of technology transfer offices
	Spain	1986	
	France	1999	
	Switzerland	1991	
	Belgium	1997	
	Portugal	1998	
Mixed changes: Introduction of professor's privilege (from institutional ownership to inventor ownership) + Introduction of managerial and financial autonomy for universities	Italy	2001	Only applies to inventions fully funded by the university employing the inventor since 2005
Continuation of the professor's privilege	Sweden	1949	Recurrent national debate about IP regimes. The conclusion is always that there is no need for legislative change

Source: Based on information from Geuna and Rossi (2011) for most countries; Chardonnens (2010) for Switzerland; Della Malva *et al.* (2013) for France; Lissoni *et al.* (2013) for Italy; Martinez *et al.* (2013) for Spain; Mejer (2013) for Belgium (the change applied in 1997 in the Flemish region and in 1998 in the French); for Portugal, Arqué-Castells *et al.* (2016). See also Martinez and Sterzi (2019).

For Denmark, Valentin and Jensen (2007) take advantage of the fact that Sweden has maintained the professor's privilege, whereas Denmark abolished it in 2000; they perform difference-in-difference regressions to compare biotech patenting involving Danish and Swedish domestic academic inventors.[7] They find significant reductions in contributions from Danish researchers, combined with a simultaneous substitutive increase of non-Danish ones and a moderate increase in academic

[6] Two previous descriptive studies, using data from Norway, find less drastic decreases. Iversen *et al.* (2007) distinguish between patents with inventors affiliated to Norwegian universities and patents with inventors affiliated to public research institutes and filed between 1998 and 2003. They observe a decrease in 2003, but argue that this is temporary and attribute it to a lack of experience and uncertainty in face of the change. They further note that "the conception of 'professor privilege' patents as predominantly single-inventor patents held by the researcher himself tends to be inaccurate in most sectors. Individual public sector research inventor patents are in fact relatively limited." Using a larger sample, Spilling *et al.* (2015) show that the share of patent filings having inventors affiliated to the Norwegian public sector fell slightly (about 1%) between 1999-2003 and 2004-2008, but they warn against attributing it to the policy change, as the overall economic context changed greatly during this period in Norway.

[7] Valentin and Jensen (2007) use data from the Scanbit Database from the Research Centre on Biotech Business at Copenhagen Business School, which includes patent information and other indicators of pharmaceutical discovery by firms dedicated to biotechnology in Denmark, Sweden and Norway.

inventions channeled into university-owned patents following the policy change. They argue that the reduction in Danish academic patenting can be attributed, at least in part, to the reform. In their own words, "the larger part of the inventive potential of academia, previously mobilized into company-owned patents, seems to have been rendered inactive as a result of the reform" (Valentin and Jensen 2007, p.251). They claim that the ex-ante allocation of intellectual property rights to universities required by the reform harmed exploratory collaborative research, for which the results are still uncertain at the time when contracts must be signed and the allocation of potential future outputs must be discussed.

Two studies provide diverse results for Germany.[8] On the one hand, Von Proff *et al.* (2012) find no impact of the abolishment of the professor's privilege on the number of patents with academic inventors. Instead, they observe an increase in university-owned patents, leading them to conclude that the reform has principally caused a shift in ownership rights to universities. On the other hand, Czarnitzki *et al.* (2015) use patents with inventors from Public Research Organisations (PROs) as a control group in a difference-in-difference estimation of the impact of the change on patents with inventors from universities, by consolidating German and EPO filings at the family level, and excluding patents filed by researchers with dual affiliation, PRO and university. They find that academic-invented patents decreased following the change, in line with Hvide and Jones (2018) for Norway. When they distinguish between different types of university researchers they find that patenting by researchers with previous connections to industry fell after the change and patenting by researchers without such connections rose; consequently, they conclude that the latter benefited more from the institutionalisation of technology transfer, as the absence of support from their universities made patenting relatively more costly. Also on Germany, but focused on entrepreneurship, Cunningham et al. (2019) find that the policy change also had an initial positive effect on the number of start-ups measured by business registrations, although the effect declined over time.

For Finland, where the professor's privilege was abolished more recently (in 2007), Ejermo and Toivanen (2018) estimate the effect of the policy change on the number of patents with inventors from universities, compared to those with inventors from research institutes and firms. They find a

[8] In descriptive analyses for Germany, Schmoch (2007) observes no evidence of a change in the numbers of academic-invented patents before and after the abolishment of the privilege, while Dornbusch *et al.* (2012) point to a different trend in patent filings made at EPO and the German Patent Office by German academics. However, EPO filings, which are likely to be considered of a higher expected value by applicants, increased after the change, whereas filings to the German patent office decreased.

decrease in patenting of almost 30% after the change became effective, and an even sharper fall three years earlier, following the announcement of the forthcoming policy change.[9]

Finally, and for Italy, Lissoni et al. (2013) and Sterzi et al. (2019) find that the 2001 introduction of the professor's privilege was irrelevant to the ownership of academic patents. However, as highlighted by these authors, the change was anticipated and followed by several national legislative changes that granted universities full managerial and financial autonomy regarding patents. This autonomy allowed Italian universities to exert a degree of control over their faculties' inventions and render the professor's privilege virtually ineffective.

4. THEORETICAL ARGUMENTS

The abolishment of the professor's privilege in several European countries in the early 2000s led to a shift in the allocation of rights, modifying incentives for the two types of agents involved in the inventive and commercialisation activity of universities. Individual researchers (or teams) are the source of new ideas, and university TTO managers or, more generally, university administrators, have the tasks of commercialising university knowledge and managing their intellectual property rights. In what follows we present theoretical arguments in support of the empirical strategy described later.

4.1 The value of university-owned patents: a combination of technological importance and effective exploitation

Both individual inventors and TTO managers contribute to the value of university-owned patents. In line with Bessen (2008), we distinguish the technological importance of inventions from the ability to exploit them. In greater detail, we follow Sterzi et al. (2019), considering patent value to be the result of two components (determined at different points in time, before and after the patent filing), namely the technological importance of the invention and the exploitation process. Technological importance is an attribute of the invention which emerges during research. The exploitation process begins when the patent application is filed and depends on the commercialisation resources and experience of the university TTO managers.

[9] As we will see later, we exclude Finland from our econometric analysis because it abolished the professor's privilege in 2007, some years later than the other IP reform countries we consider.

4.2 The effect of IP reforms on incentives to university researchers and TTO managers

IP reforms may affect the incentives of university researchers at the origin of the invention and of TTO managers, who decide whether to file a patent at their universities. Hvide and Jones (2018) argue that the abolishment of the professor's privilege in Norway could be interpreted as an increase in the expected tax rate for the faculty. Prior to the reform, researchers were able to perceive 100% of the revenue from patent royalties; following the reform, they were required to share such revenue with the university administration. In terms of expectations, academic inventors see their predicted income reduced and may therefore have fewer incentives to produce high quality inventions (Lach and Shankerman 2008).[10] Nevertheless, this argument is incomplete if it is not taken into account that abolishment means that universities are not only expected to receive a share of the potential income from commercialisation but are also required to invest in the process of innovation and lower the cost of protection and exploitation for researchers. If this is the case, as Hvide and Jones (2018) also highlight, strengthening the university share of income might also lead researchers to invest more. This occurs when, in the case of complementary investments, the university's investment which follows the new IP regime increases the marginal product of the researcher's investment (Macho-Stadler *et al.* 2010).[11]

On the other hand, IP reforms can also affect the institutional evaluation and career prospects of TTO managers. Since university patent counts and rankings are often part of the evaluation indicators used by funding agencies, TTO managers may obtain rewards or promotions based on the number of initial patent filings, before the technological importance of the patents is revealed, leading to a possible decrease in the average quality of the patents filed.

4.3 The effect of IP reforms on the effectiveness of IP exploitation and resulting value of university-owned patents

Given the double-edged composition of patent value and the expected effect of IP reforms on the incentives of university researchers and TTO managers, there are several forces at play that make it difficult to determine the expected sign of the effect of reforms on patent value.

Firstly, and conditional on technological importance, the exploitation process should improve following the abolishment of the professor's privilege, as university administrators and TTOs then

[10] We may also expect changes to the IP regime to have little or no effect on researchers' inventive efforts. This would be the case if university researchers abide by Mertonian norms of science rather than financial rewards (Stephan 1996, Evans and Leighton 1989, Hamilton 2000, Shane *et al.* 2003).

[11] From this point of view, the abolition of the professor's privilege may also induce inventors to begin patenting.

receive a greater share of revenue when ownership is institutional. However, average patent value may decrease if the increase in the effectiveness of IP exploitation does not compensate for a reduction of technological importance overall, eventually deriving from lower incentives for university researchers.

Secondly, it may be that universities reduce the average investment per patent (and, in turn, the average effectiveness of the IP exploitation) when the increase in the number of patents filed by universities is unaccompanied by an increase in (public) investment. In such a case, TTO managers would manage more patents than before with the same resources (as they would add to their portfolio those that were managed directly by faculty or simply undisclosed), consequently dividing the time and budget available among a greater number of patents.

Thirdly, it may be also possible that the IP reform does attract mainly inexperienced universities in the patenting field, which had never been in the IP business and lack the IP management to exploit effectively the academic inventions.

5. EMPIRICAL MODEL AND VARIABLES

5.1 Estimation

We estimate the consequences of abolishment on the technological importance and overall value of university-owned patents. We therefore propose a model in which the unit of analysis is the patent, and we use its priority filing year to distinguish between patents filed before or after the change to the IP regime. Our approach is similar to Rosell and Agrawal (2009), in which the authors study the change in the concentration of knowledge flows over time of university-owned patents by employing a difference-in-difference estimation to compare university and corporate patents in two periods.

In the group of countries characterised by abolishment we consider Denmark, Germany, Austria and Norway. This is our *treated* group of countries. In the group of countries that are not characterised by abolishment (our *control* group) we include the United Kingdom, Spain, France, Switzerland, Belgium, Sweden and Portugal.

The year of abolition of the professor's privilege is different among the countries included in the *treated* group. As Table 1 shows, the year of change in the IP regime for Denmark is 2000, for Germany and Austria it is 2002 and for Norway it is 2003. We thus identified two periods for each country. The first extends from 1990 to the year before the change in the IP regime; the second period spans its respective IP regime change year to 2008.

We define *university patents* as those in which a university appears as the priority applicant in the European patent family (see Section 5.2 for further information). We classify patents according to the owner at the priority date, with the aim of identifying the institution where the decision to file the patent was made and the first decisive steps of IP management were taken.

In our econometric approach, we compare university patents in *treated* countries (before and after the policy change), with corporate patents in the *treated* countries and with university patents in the *control* group of countries. Thus, we consider four classes of patents, which are defined in two categories: i) university versus company patents, and ii) patents applied for by institutions of countries which abolished the professor's privilege versus patents applied for by institutions in countries without such a change in IP law. The change in IP policy only applies to one category, the treated group of patents is composed by university-owned patents in the group of countries that experienced the abolishment of the professor's privilege.

We thus estimate the following general model:

$$y_p = \beta_0 + \beta_1 Post_t + \beta_2 University_p + \beta_3 Treat_p + \beta_4 Post_t Treat_p + \beta_5 Post_t University_p + \beta_6 Treat_p University_p + \beta_7 Post_t Treat_p University_p + X_p \gamma + \varepsilon_p \quad (1).$$

In our framework, the dependent variable y_p may represent both the technological importance of the invention, which we call for the sake of simplicity *Invention Quality* (IQ), and the *Patent Value* (PV), since we expect the change in the IP regime to impact upon both. $Post_t$ identifies patents issued in the year of the IP reform and subsequent years. For the countries in the control group the policy change (which does not affect them) has been identified as occurring in 2002, so that the variable takes the value of one in 2002 and subsequent years. $University_p$ identifies patents originally applied for by universities. $Treat_p$ is a dummy that takes a value of one if *p* is assigned to applicants with addresses in countries affected by abolishment (*treated* group of countries). ε_p is a mean zero random error. X_p is a set of covariates that control for patent characteristics which may affect the dependent variables. In particular, depending on the models, we control for technological dummies, year dummies, common trend and country-specific trend. Finally, ε_p is a mean zero random error. The variables are presented in Section 5.3.

Potentially, this model can account for unobserved trends in the dependent variable in both groups of countries (*treated* and *control* groups) and for both types of patents (university and company).

The effect of the policy is captured by β_7. This parameter measures, in countries abolishing the professor's privilege, its effect on the IQ and PV of university patents.

We estimate two versions of equation 1. Firstly, we investigate the impact of abolishment on the quality (IQ) of university researchers' inventions retained and successively applied by their universities. In order to do so, we simply replace y_p with IQ_p and estimate the following model:

$$IQ_p = \beta_0 + \beta_1 Post_t + \beta_2 University_p + \beta_3 Treat_p + \beta_4 Post_t Treat_p + \beta_5 Post_t University_p + \beta_6 Treat_p University_p + \beta_7 Post_t Treat_p University_p + X_p \gamma + \varepsilon_p \quad \text{(2a)}$$

Secondly, we investigate the impact of abolishment on patent value (PV). To measure the impact of the change in the IP regime on the management of patent quality, we estimate the following equation:

$$PV_p = \beta_0 + \beta_1 Post_t + \beta_2 University_p + \beta_3 Treat_p + \beta_4 Post_t Treat_p + \beta_5 Post_t University_p + \beta_6 Treat_p University_p + \beta_7 Post_t Treat_p University_p + X_p \gamma + \varepsilon_p \quad \text{(2b)}$$

Building upon Hvide and Jones (2018) and Arqué-Castells et al. (2016), and following Sterzi et al. (2019), we assume that the patent value (PV) is a function of two components: the *technological importance* of the invention or invention quality (IQ) - which is related to researchers' ability and effort in conducting applied research - and the IP *exploitation effectiveness*, which is related to the ability of patent holders to commercialise and exploit inventions. By inserting IQ in the list of control variables (X) we are speculating that a residual part of the patent value is principally explained by the exploitation effectiveness of IP, and thus the parameter β_7 captures the impact of abolishment on the average IP management in universities.

5.2 Data

We focus on EPO-granted patents with priority filing years between 1990 and 2008 from the EPO Worldwide Patent Statistics Database, PATSTAT (April 2016 version). [12] We rely on the so-called DOCDB families, a type of families available in PATSTAT, where only direct priority links and relations added by EPO examinersare considered to define the patent family (Martinez 2011). To distinguish university-owned patents[13] from other types of patents we examine all the members of the DOCDB family of the sampled EPO patents, in order to distinguish EPO patent filings with priorities filed by universities from EPO patent filings with priorities filed by companies.

We begin with a sample of EPO patents with priority applicants from the thirteen European countries presented in Table 1 and priority applications filed either at the EPO or at their national patent offices, but in the empirical model we restrict the sample to eleven countries, excluding Italy and Finland. We exclude Italy because the country experienced both the introduction of the professor's privilege and an increased autonomy of universities in the 2000s. We also exclude Finland because it abolished the professor's privilege in 2007, and for which we do not have enough years for studying the impact of the IP reform.

5.3 Variables and descriptive statistics

We assign each patent to a country, based on the address reported by the applicant. We thereby define two groups of countries in our sample: countries abolishing the professor's privilege in the early 2000s and countries that did not experience such a change in the IP regime. In the former group we consider Denmark, Germany, Austria and Norway. In the latter group we include the UK, Spain, France, Switzerland, Belgium, Sweden, and Portugal.

We omit 3,074 patents with co-applicants both in countries that had experienced abolishment and in countries that had not experienced it. Table 2 reports the total number of patents and the number of university patents in the selected countries. What does emerge from Table 2 is that, as expected, the

[12] We do not consider in the analysis patents filed after 2008 in order to have enough years of observation for collecting data on forward citations that we use to proxy the technological importance of the inventions.

[13] We use the terms 'university-owned patents' or 'university patents' to refer to patent applications originally owned by universities at the time of the priority filing. Patents are thus classified by first ownership. Alternatively, patents can be classified by the affiliation of inventors, and distinguish between patents invented by academics but owned by companies and patents invented by academics and owned by universities, the latter are the university-owned patents we focus for the most part of the present paper, but for completeness, we also include an analysis of academic-invented patents, comparing company-owned and university-owned in Section 7 later.

average percentage of university-owned patents over the total number of patents filed is high for those countries that had already implement the university-ownership model (the "Other" countries, with the exclusion of Sweden).

Table 2. Patents and university patenting in a selection of European countries (Priority years: 1990-2008)

	Number of patents (a)	Number of university-ownedpatents, lower bound (b)	Number of university-ownedpatents, higher bound (c)	(b)/(a)	(c)/(a)
Countries abolishing the professor's privilege					
Denmark	6655	67	88	1.0%	1.3%
Germany	192495	842	1138	0.4%	0.6%
Austria	8183	51	63	0.6%	0.8%
Norway	2496	9	12	0.4%	0.5%
Other countries					
United Kingdom	35421	1767	1991	5.0%	5.6%
Spain	4395	209	229	4.8%	5.2%
France	69668	354	882	0.5%	1.3%
Switzerland	30993	235	297	0.8%	1.0%
Belgium	7806	472	574	6.0%	7.4%
Sweden	20524	31	43	0.2%	0.2%
Portugal	244	22	31	9.0%	12.7%

Two definitions of university patents are considered: (b) EPO patents with 'university' as the only type of priority applicant in the DOCDB family; and (c) EPO patents having at least one 'university' among the priority applicants in the DOCDB family. A patent may be counted more than once in case of co-applicants residing in more than one country.

For the classification of applicants we rely on KUL-Eurostat applicant harmonization (Callaert *et al* 2011) and use their institutional sector allocation (university, company, private-non-profit, hospital, etc.).[14] The tabulation of patents by applicant type is given in Table 3.

[14] As included in Table tls906_person of PATSTAT April 2016.

Table 3. Breakdown of patents by applicant type

Applicant type	# of patents	*Percent*
1. Company	**359682**	***95.3***
2. Company-other	1204	*0.3*
3. Other	11108	*2.9*
4. University	**4047**	***1.1***
5. University-company	579	*0.2*
6. University-company-other	132	*0.0*
7. University-other	504	*0.1*
Total	377256	*100.00*

The category 'Other' refers to the following cases: hospital, government non-profit, company government non-profit, company university, and company hospital. Individual patents are excluded. EPO-granted patents with priority dates 1990-2008.

We further select patents having either only university applicants or company applicants (categories #1 and #4 in Table 3).[15] A patent is thus defined as a 'university patent' if it has only university applicants in its priority filing (university-owned). Likewise, a patent is defined as a 'company patent' if it has only company applicants in its priority filing (company-owned).

The final sample is thus composed of 363,729 patents, either *university* patents (4,047 patents, corresponding to 1.11% of the sample) or *company* patents (359,682 patents, 98.89%). Our units of analysis are thus EPO patents deriving from inventions owned by universities at the priority filing from a selection of eleven European countries. If one of our patents was originally owned by a European university when filed at a national patent office, and was acquired by a company during the priority year so that by the time of the EPO filing the university was not among its applicants, we take such change of ownership as evidence of a successful technology transfer.

[15] University-company co-applications (categories #5 and #6) are excluded from the analysis as they represent only a small share of patents with at least one university as applicant and the origin and management of the inventions is unclear. However, they represent an increasing share of patents in all countries and the results do not change when co-applications are include.

Figure 1. University patenting intensity in countries with IP regime changes (treated) and without (other countries): All Sectors vs Pharma and Biotechnology

Figure a. All Sectors

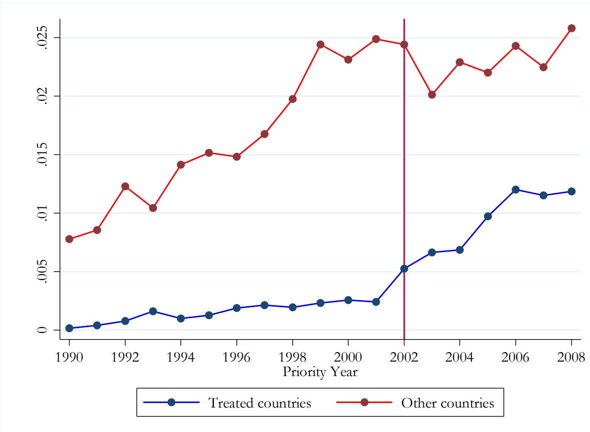
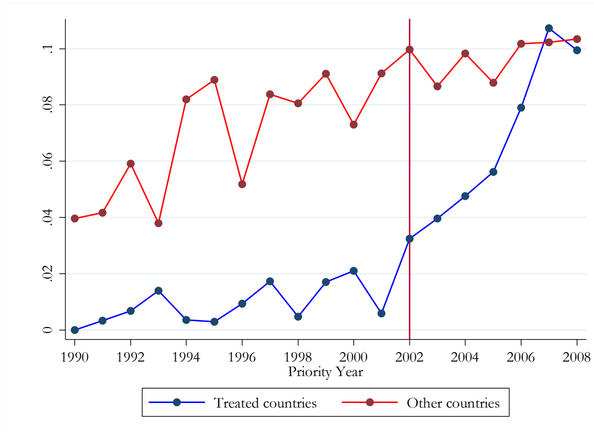


Figure b. Pharma and Biotechnology



Countries in the treated group are Denmark, Germany, Austria and Norway. Countries in the control group are the UK, Spain, France, Switzerland, Belgium, Sweden and Portugal. University-granted patents are defined as EPO patents having only university applicants in the priority patent document. Company-granted patents are defined as EPO patents having only company applicants in the priority patent document. The shares of the figures are the ratio between the number of university patents and the sum of university and company patents.

Figure 1 reports the percentage of university patents over total patent activity (defined here as the sum of the categories of university patents and of company patents) for the two groups of countries; the *Treated* group is composed of countries that experienced abolishment and the *Control* group comprises the remaining countries. The figure illustrates how countries in the former group saw the contribution of university patents increase gradually between 1990 and 2008, in response to the institutional and policy changes described in section 2; this is particularly true for pharmaceuticals and biotechnology, sectors in which university patenting has traditionally played an important role. This pattern can be explained both by an increasing patenting activity of universities and, at the same time, by a trend towards strengthened control over ownership of patents invented at universities and formerly assigned to individuals or companies.

5.3.1 Dependent variables

In equation (2a) the dependent variable is the technological importance, or quality, of the invention (IQ). As the principal indicator of technological importance, scholars use forward citations, since they relate first and foremost to the inventive step and the non-obviousness of the invention (for a recent survey, see Jaffe and De Rassenfosse, 2017). This measurement captures both the capacity to generate spillovers and to contribute to the advancement of scientific and technological knowledge. However, forward citations are also often used by scholars as a proxy for the economic value of the invention. Harhoff et al. (1999) find forward citations to be strongly correlated with the payment of renewal fees and, for this reason, they may also be related to patent management. To mitigate this problem and help to interpret forward citations as a proxy for technological importance, we exclude early citations[16], received in the years immediately following publication, as they may be more strongly affected by the commercialisation activity of the applicant than citations made later in time (Lanjouw and Schankerman, 2004). Long-term citations are more likely to be more dependent on the quality of the underlying technology. Moreover, Sampat et al. (2003), Czarnitzki et al. (2012) and Sterzi (2013) find that citations to university patents tend to occur later than citations of other patents. In the empirical analysis, our dependent variable (*Long-term Citations*) therefore excludes from the computation the citations received in the first three years since the first application. Data on citations is taken from the OECD citations database (Webb et al. 2005, OECD database version 2017).

We further refine this measurement by examining the origin of the citations to exclude those originating in other university patents, in order to track the knowledge transfer across institutional boundaries and focus on those originating in companies (*Long-term Citations from Companies*), as university patents are more relevant when they are used and put into practice by companies.[17]

Regarding Patent Value (PV), the dependent variable in Equation (2b), we define it broadly as the overall revenue generated by the patent, which results from the combination of the characteristics of the invention and the effectiveness of the exploitation of the patent protecting it. As we have no

[16] However, the inclusion of early citations does not change the main results of the paper. The estimated reduction in the number of citations post reform is 29%, with respect 33% (See Section 6.2) when only long term citations are included. Results are available upon request.

[17] As an alternative measure of the technological importance of the invention we use *Patent Originality*. This variable is taken from the OECD Patent Quality Dataset (Squicciarini *et al.* 2013, database version 2017) and refers "to the breadth of the technology fields on which a patent relies" (Squicciarini *et al.* 2013). This indicator, proposed by Henderson *et al.* (1998) and refined by Hall *et al.* (2005), is based on the dispersion of the technological classifications of the backward citations and varies between zero and one, with higher values for more original patents. We acknowledge that the concept of patent originality is closer to technological diversity than to technological importance (Jaffe and De Rassenfosse, 2017). Our data do however corroborate this intuition; the correlation between the two indicators is only 10%. Consequently, the results of using patent originality as the dependent variable are quite different from those shown in Table 7. Firstly, university patents do not differ from company patents in terms of originality. The dummy *University* is positive but not significantly different from zero in almost all the models. Secondly, we observe no difference between university patents in countries abolishing the professor's privilege and the control group, neither before nor after the reform.

data for such revenue, we rely principally upon one proxy widely used in the literature: *Patent Renewals*, defined as the number of years of validity of the patent since the date of filing at the EPO. The number of renewals is taken from the OECD Patent Quality Dataset (Squicciarini *et al.* 2013, database version 2017). Since maintaining patent protection over time is costly, we may assume that the value of patents covers at least the costs related to their renewal and that, conditional on technology-specific differences in knowledge obsolescence, more valuable patents are expected to be renewed for longer.

As an alternative proxy for patent value we also use *Family Size*, defined as the number of patent offices at which a given invention has been protected (Martinez 2011), which is also taken from the OECD Patent Quality Dataset (Squicciarini *et al.* 2013, database version 2017). Since extending patent protection to several countries is costly (in terms of application and examination fees), patents granted in more than one country are expected to be those of higher value, and in the case of university patents those that are extended internationally are more likely to have been commercialized (Martinez and Bares, 2018).

5.3.2 Independent variables

The variable $Post_t$ identifies patents issued in the year of the IP reform and subsequent years.[18] In some models we also replace this variable with year dummies that capture time-specific fixed effects for all the groups of patents (in the treated and control groups). $University_p$ identifies patents originally applied for only by universities. The reference group is formed by patents applied for only by companies. $Treat_p$ is a dummy that takes a value of one if the patent p is assigned to applicants with addresses in countries affected by the end of the professor's privilege. In the group of countries abolishing the professor's privilege we include Denmark, Germany, Austria and Norway. In the list of countries with no IP reform in the period considered we include the UK, Spain, France, Switzerland, Belgium, Sweden, and Portugal. As stated above, we omit from the analysis patents that have been (co)applied for by institutions residing in countries in both the *treated* and *control* groups.

[18] The dummy POST takes the value one in year 2002 and following years for all the countries in the data (treated and controls), with the exception of Denmark (for which the "post" variable identifies the IP regime change in 2000) and Norway (2003).

5.3.3 Control variables

Together with the principal independent variables, which emerge from the empirical strategy described in Section 5.1 and aim to quantify the impact of abolition, we control for the following variables, in addition to technology fields, priority year and priority country:

- *Backward citations*: references to patented prior art are sometimes used as a complementary proxy for patent value (Harhoff *et al.*, 2003; Harhoff and Reitzig, 2004), but they also signal the incremental nature of the underlying technology (Lanjouw and Schankerman, 2001). They are an expression of the possible invalidity of the patent, since patents citing many other patents are more likely to be highly controversial, challenged and found invalid (Hovenkamp *et al.* 2013). The number of backward citations is taken from the OECD Patent Quality Dataset (Squicciarini *et al.* 2013, database version 2017).

- *Number of applicants*: the number of (co)applicants listed in the priority document of the patent family controls for the fact that patents co-applied for by more than one organization may be of higher value or may be better exploited. Since we have excluded patents co-applied for by different types of applicant, having more than one applicant in the group of university patents means having more than one university as the priority applicant.

- *Team size*: refers to the number of inventors listed in the priority document of the patent family and controls for the fact that patents applied for by larger teams may be of higher value or may be better exploited.

Country-fixed effects do control for time invariant unobserved differences among countries in the treated and control groups. In addition, country-specific trend are intended to capture the country-specific dynamic of specialisation and industry composition.

Table 4 provide descriptive statistics of the main variables.

Table 4. Descriptive statistics

	# Obs.	Mean	Std. Dev.	Min	Max
Dependent variables					
Long-term citations	363 729	3.07	5.09	0	230
Long-term citations (from companies)	363 729	2.01	3.20	0	112
Renewals	363 729	11.07	4.15	1	20
Family size	363 729	6.55	4.57	1	56
Independent variables					
Post	363 729	0.41	0.49	0	1
University	363 729	0.01	0.10	0	1
Treated	363 729	0.56	0.50	0	1
Control variables					
Backward citations	363 729	4.03	2.15	0	36
Number of applicants	363 729	1.03	0.18	1	8
Team size	363 729	2.39	1.65	1	31

Among the control variables, not shown in this table, we include dummies for application year, country of the applicant and technological field (Schmoch (2010) 35-Sector classification). Patents granted by the EPO with priority dates 1990-2008.

6. RESULTS

In the following sections we present the principal results of the paper regarding the impact of abolishment on the *Technological Importance* and on the overall *Patent Value* of university inventions. The coefficient of greatest interest is the interaction *Post*Treat*University,* whereby we estimate β_7 in equation (2a) from the invention quality regressions and β_7 in equation (2b) from the patent value regressions, respectively. We firstly present the results based on the aggregate analysis; this averages values at the sector and year level (Section 6.1). We then provide evidence based on patent level (Section 6.2 and 6.3).

6.1 Aggregate results

Table 5 presents an aggregate analysis examining the change in our preferred measurements of technological importance and patent value: *Long-term Citations* and *Renewals*. In this analysis averages are constructed per technology field, country and year. The regressions implement the econometric model (2a) and (2b).[19]

The *Post*Treat*University* coefficients show that the reductions in the average technological importance and patent value are statistically significant when controlling for changes in the dependent variables for university patents in the control group and for company patents in the treated group.

Interestingly, concerning technological importance (Column 1), these results also show a premium for university patents. These are on average more technologically relevant than company patents (they receive on average 1.2 more long-term citations than company patents, as shown by the coefficient of *University*). We observe no differences between university patents in the treatment group and the control group before the change in the IP regime (the coefficient for *Treat*University* is positive, but not significant).

As regards renewals (Columns 2 and 3), we observe that even though university patents are on average of greater technological importance, they are renewed less often than patents applied for by companies (*University* coefficient). As with technological importance, we observe no difference between company and university patents before the change to the IP regime (*Treat*University* coefficient); but following abolishment university patents are renewed even less often than company patents, as shown by the negative and significant coefficients of *Post*Treat*University*. These results also hold true when controlling for the technological importance of inventions, measured by long-term citations (Column 3).

[19] Given that there are 35 technology fields, we should have 35*18*11=6930 observations, but we miss data points because not all countries, fields and years have patents granted at EPO.

Table 5. IQ and PV models: aggregate level analysis. OLS estimates

	(1) Long-term citations	(2) Renewals	(3) Renewals
Post	-1.745***	-3.773***	-3.550***
	(0.108)	(0.0785)	(0.137)
University	1.207***	-0.869***	-1.023***
	(0.146)	(0.219)	(0.224)
Treat	-1.033***	0.0163	0.148**
	(0.0972)	(0.0461)	(0.0652)
Post*Treat	0.605***	0.00279	-0.0744
	(0.110)	(0.0836)	(0.0858)
Post*University	-0.502**	0.422	0.486*
	(0.175)	(0.237)	(0.235)
Treat*University	2.074	0.581	0.316
	(1.281)	(0.383)	(0.392)
Post*Treat*University	**-2.338***	**-0.924****	**-0.626***
	(1.097)	(0.317)	(0.324)
Long-term citations			0.128*
			(0.0644)
Constant	4.236***	10.93***	10.39***
	(0.431)	(1.660)	(1.661)
Technological field dummies	Yes	Yes	Yes
R2	0.161	0.485	0.514
Observations	2,140	2,140	2,140

Errors clustered at the country level in parentheses. The dependent variable is the average of the long-term citations in column (1) and the mean of renewals in column (2). EPO- granted patents with priority dates 1990-2008.

6.2 Patent level results: invention quality (IQ)

Table 6 presents results from the regression at the patent level, based on econometric model 2a. The dependent variable is the number of long-term citations (*Long-term Citations*) as a proxy of the technological importance of the invention (IQ). We use count models (Poisson pseudo-maximum likelihood estimation, PPML) with standard errors clustered at the country level.

Column (1) in Table 6 presents a simplified analysis of the invention quality model. Column (2) adds fixed effects for technological fields; column (3) augments the model by considering the number of backward citations and the number of (co)applicants as controls; column (4) adds a trend to control for the changes in the dependent variables affecting all patents in the analysis; column (5) includes yearly fixed effects and column (6) adds country fixed effects. Finally, our preferred specification is that shown in column (7), where we control for several country-trend fixed effects. We observe little variation in the *Post*Treat*University* coefficient. In all models the triple interaction coefficient is negative and significant.

The variable *University* is positive and significant in all the models. In line with the results for the aggregate case, university patents receive on average more citations than company patents in the long term (the coefficient for university is always positive and significant). In particular, in column (7), the coefficient for *University* is 0.158, corresponding to an incidence ratio of 1.17. Comparing university patents to company patents, while holding the other variables constant in the model, these are expected to have a rate 1.17 times greater for long-term citations.

Table 6. IQ model: Abolishment of the professor's privilege and long-term citations. PPML estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post	-0.481***	-0.489***	-0.533***	-0.290***			-0.297***
	(0.0515)	(0.0384)	(0.0328)	(0.0334)			(0.0269)
University	0.441***	0.178**	0.195***	0.227***	0.209***	0.144***	0.158***
	(0.0888)	(0.0755)	(0.0735)	(0.0722)	(0.0726)	(0.0528)	(0.0518)
Treat	-0.267*	-0.209	-0.244*	-0.239*	-0.245*	0.132***	0.137**
	(0.146)	(0.130)	(0.132)	(0.133)	(0.132)	(0.0482)	(0.0621)
Post*Treat	0.0796	0.102*	0.112**	0.106**	0.106*	0.0518	0.0841***
	(0.0697)	(0.0574)	(0.0526)	(0.0526)	(0.0541)	(0.0431)	(0.0270)
Post*University	-0.0888	-0.0946	-0.111	-0.140*	-0.109	-0.0954	-0.128**
	(0.0877)	(0.0765)	(0.0762)	(0.0793)	(0.0754)	(0.0649)	(0.0615)
Treat*University	0.207*	0.198*	0.170	0.175	0.170	0.305**	0.315**
	(0.118)	(0.119)	(0.115)	(0.117)	(0.116)	(0.129)	(0.131)
Post*Treat*University	**-0.390*** **	**-0.413*** **	**-0.322*** **	**-0.313*** **	**-0.260*** **	**-0.330*** **	**-0.393*** **
	(0.0965)	(0.0851)	(0.0865)	(0.0885)	(0.0848)	(0.0958)	(0.120)
Backward citations			0.0587***	0.0603***	0.0601***	0.0581***	0.0585***
			(0.00220)	(0.00221)	(0.00191)	(0.000977)	(0.00101)
Number of applicants			0.266***	0.257***	0.263***	0.250***	0.247***
			(0.0265)	(0.0225)	(0.0262)	(0.0171)	(0.0165)
Team size			0.0820***	0.0845***	0.0835***	0.0866***	0.0873***
			(0.00445)	(0.00453)	(0.00446)	(0.00351)	(0.00339)
Trend				-0.0273***			
				(0.00248)			
Constant	1.415***	1.054***	0.392***	54.79***	-0.587***	-0.701***	0.157***
	(0.138)	(0.131)	(0.150)	(5.025)	(0.139)	(0.0559)	(0.0551)
Technological field dummies	NO	YES	YES	YES	YES	YES	YES
Year dummies	NO	NO	NO	NO	YES	YES	NO
Country dummies	NO	NO	NO	NO	NO	YES	YES
Country*Trend	NO	NO	NO	NO	NO	NO	YES
Observations	363,729	363,729	363,729	363,729	363,729	363,729	363,729

Standard errors clustered at the country level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The variable *Post* has, as expected, a negative sign. At least in part, this reflects the fact that more recent patents have had less time for citation. However, the interaction term *Post*University* appears to suggest that, on average and in both groups of countries, university patents are of lower technological importance in the most recent years: the coefficient of *Post*University* is negative and significant in our preferred specification (eq.7) although it is not significant in almost all other models. In addition, university patents in the treated group of countries appear to be of higher technological value than those in the control group *before* abolishment (at least for models which control for country-specific fixed effects): the coefficient of *Treat*University* is positive and (weakly) significant, suggesting that university patents in the group of countries that experienced abolishment were of greater technological importance before the IP reform, with respect to university patents in countries in the control group in the same years. However, following the reform, we observe a reduction in the number of long-term citations (the *Post*Treat*University* coefficient is always negative and significant, showing an approximate 33% (*exp*(-0.393)-1) decline in citations received according to the estimates in model 7). This suggests that the increase in the number of patents observed in the group of countries that abolished the professor's privilege has been at the expense of technological quality. Results considering only long-term citations made by companies, as an alternative measurement of invention quality, are in line with these and available in Table A1 in the Appendix.

6.3 Patent level results: the Patent Value (PV)

Table 7 considers regression evidence at the patent level, where the dependent variable is the number of renewals, taken as a proxy of the patent value (Equation 2b).

As for the IQ model, we control for different observable patent characteristics which, if omitted, may affect the results. In particular, we control for the *invention quality* (*IQ*) of the invention, as proxied by *Long-term Citations*. By inserting *IQ* into the list of control variables (Columns 2-8) we speculate that the residual part of patent value is mainly explained by the effectiveness of the IP exploitation. The results change only marginally when adding controls and fixed effects to the model. Our preferred model is Column 8, where we control for technological field dummies, country dummies and country-trend fixed effects.

Column 8 shows that university patents are on average renewed least often. The coefficient for *University* is -0.0264, corresponding to an incidence ratio of 0.97, meaning that university patents receive 3% fewer renewals than company patents, if the other variables in the model are held constant. We observe no difference between the two groups of countries in the years before the IP reform (the dummy *Treat*University* is not significant). However, in countries experiencing abolishment we observe a further fall in the number of expected renewals following the IP reform (the dummy *Post*Treat*University* is always negative and significant). In particular, the effect of the reform on Patent Value is also negative when we control for *Technological Importance*, meaning that TTO managers and university administrators in countries which have witnessed abolishment have not only seen a reduction in the average technological importance of the invention disclosed by the faculty, but have also diminished the effectiveness of the average IP exploitation. For robustness, we also applied matching techniques (Propensity Score Matching) to further control for the characteristics of the patents used in the analysis. The analysis, presented in Appendix 2, shows results which are in line with those presented in Table 7.

Table 7. PV model: Abolishment of the professor's privilege and renewals. PPML estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post	-0.349***	-0.334***	-0.339***	-0.340***	-0.204***			-0.200***
	(0.00288)	(0.00416)	(0.00464)	(0.00474)	(0.00685)			(0.0107)
University	-0.0348**	-0.0571***	-0.0652***	-0.0650***	-0.0470***	-0.0558***	-0.0383***	-0.0264**
	(0.0151)	(0.0154)	(0.0131)	(0.0130)	(0.0142)	(0.0134)	(0.0110)	(0.0128)
Treat	-0.0118	-0.00214	-0.000248	-0.00141	0.00171	-0.00159	-0.0507**	-0.0210
	(0.0107)	(0.0101)	(0.00958)	(0.00962)	(0.0106)	(0.00965)	(0.0249)	(0.0325)
Post*Treat	0.0142***	0.00878*	0.0109**	0.0114**	0.00743	0.00508	0.00601*	-0.00359
	(0.00463)	(0.00528)	(0.00541)	(0.00546)	(0.00610)	(0.00344)	(0.00345)	(0.0127)
Post*University	0.00760	0.0202***	0.0224***	0.0220**	0.00594	0.0197**	0.0169*	-0.00441
	(0.00675)	(0.00769)	(0.00854)	(0.00872)	(0.00808)	(0.00796)	(0.00871)	(0.00873)
Treat*University	0.0321	0.0243	0.0249	0.0246	0.0296	0.0233	0.00679	0.00978
	(0.0243)	(0.0294)	(0.0278)	(0.0275)	(0.0277)	(0.0279)	(0.0258)	(0.0251)
Post*Treat*University	**-0.104*** **	**-0.0896*** **	**-0.0965*** **	**-0.0949*** **	**-0.0925*** **	**-0.0535** **	**-0.0516** **	**-0.0832*** **
	(0.0119)	(0.0140)	(0.0146)	(0.0147)	(0.0157)	(0.0241)	(0.0238)	(0.0138)
Long-term citations		0.00901***	0.00911***	0.00897***	0.00863***	0.00784***	0.00780***	0.00853***
		(0.000916)	(0.000978)	(0.000943)	(0.000931)	(0.000835)	(0.000874)	(0.000999)
Backward citations				0.00149***	0.00241***	0.00249***	0.00259***	0.00264***
				(0.000525)	(0.000458)	(0.000358)	(0.000337)	(0.000420)
Number of applicants				0.00563	0.00117	0.00971**	0.0112***	0.00358
				(0.00578)	(0.00706)	(0.00386)	(0.00410)	(0.00694)
Team size				0.00293***	0.00464***	0.00432***	0.00430***	0.00469***
				(0.000875)	(0.000686)	(0.000674)	(0.000727)	(0.000735)
Trend					-0.0152***			
					(0.000779)			
Constant	2.538***	2.499***	2.506***	2.490***	32.80***	2.462***	2.488***	2.432***
	(0.0104)	(0.0109)	(0.0123)	(0.0145)	(1.558)	(0.0102)	(0.0135)	(0.0270)
Technological field Dummies	NO	NO	YES	YES	YES	YES	YES	YES
Year dummies	NO	NO	NO	NO	NO	YES	YES	NO
Country dummies	NO	NO	NO	NO	NO	NO	YES	YES
Country*Trend	NO	NO	NO	NO	NO	NO	NO	YES
Observations	363,729	363,729	363,729	363,729	363,729	363,729	363,729	363,729

Standard errors clustered at the country level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Results for family size (Table A3 in the Appendix) are very similar to those based on renewals; in all the models we observe a negative coefficient for the triple interaction "*Post*Treat*University*" which captures the impact of the policy on the patent value of university patents in the treated countries.

Before concluding, however, it is worth mentioning that these negative results appear to be driven by Germany. The average effect of the abolishment of the professors' privilege on the patent value conditional on invention quality for other countries (Austria, Norway, Denmark) is positive, when we exclude Germany from the regressions.[20] This may reflect that on average IP exploitation in German universities has been particularly inefficient, which is probably related to the much larger number of university patents entering the system, and the fact that these were likely to be managed by universities which did not have extensive patenting experience. This is in line with Cunningham *et al.* (2019) who argue that the abolishment of the professor's privilege was not sufficient to trigger the desired effects on regional entrepreneurship and business innovation, which are two aspects indirectly related to effective university IP exploitation via licensing, transfer and cooperations with business that would lead to keeping the university patent active (renewed) for longer.

7. THE OWNERSHIP OF ACADEMIC PATENTS

Throughout the paper we have focused on university-owned patents and defined them as those in which a university appears as the priority applicant in the European patent family protecting the invention. Academic inventions owned by companies have thus been confounded with other company-owned patents, as our interest has mainly lied on whether the abolishment of the professor's privilege had affected the quality and effective exploitation of university-owned patents.

We may thus question whether the abolishment of the professor's privilege have also had an impact on academic inventions in general, regardless of their owner. First of all, these IP reforms might have made more difficult for professors and companies to retain the property of academic inventions, leading to a transformation of the ownership structure of academic-invented patents. Secondly, IP reforms may have also had an impact on the technological quality of academic inventions that remained outside the control of universities.

To address these issues, we have collected data on academic patents on two countries that experienced the professor's privilege abolishment (Austria and Germany) and compared it with data

[20] Results available upon request.

on academic patents from two countries included in the group of controls in previous sections (France and Spain). For our collection of patents invented by university professors in Germany and Austria we rely on a method used by other scholars before (Czarnitzki *et al.*, 2015). We identify patents invented by university professors by searching for the title 'Prof. Dr.' in the text field of the inventors' names in EPO granted patents from PATSTAT.[21] Since the German language convention to include titles next to names also applies to Austria, we apply the same method to both countries. This method has some limitations however, as shown by von Proff *et al.* (2013). One limitation is that researchers below the professor rank are excluded when this method is used, leading to underestimations, another is that titles may not be used consistently across patent applications.[22]

As regards academic patenting data on countries not affected by the policy change, we focus on Spain and France. For Spain we use the data described in Maraut and Martinez (2014), where the benchmark used to identify academic inventors is the list of authors with affiliations to Spanish public universities listed in scientific articles published in journals indexed in Elsevier's Scopus database and published in the years 2003-2008. For France we rely on a newly built dataset on academic invented patents which matches academic staff lists to inventor names, where university employees are those active between 2005 and 2012 (Carayol and Carpentier 2019).[23]

Table 8, Figure 2 and Figure 3 show the main statistics and trend related to academic patenting activities and patent quality in these countries.

What is evident from Figure 2 is that the allocation of rights over academic inventions has significantly changed in the years following the abolishment of the professor's privilege.

Moreover, if the abolishment of the professor's privilege has gradually led to a shift of IP rights over academic inventions to universities, what Figure 3 suggests is that the average technological quality

[21] A better method to identify academic patents relies on matching inventors and academic staff lists, but that is fraught with problems and requires an enormous effort beyond the scope of this paper (e.g. difficulty in obtaining staff lists, problems of homonymy, imperfect disambiguation strategies, lack of large scale golden standards to estimate precision and recall rates and overall reliability of resulting datasets). To our knowledge, there have only been two important paneuropean collective efforts in the past to gather data on academic patenting based on matching academic staff lists. The first one, excluding Germany, is the KEINS project in the early 2000s (Lissoni et al. 2007). The second one is the APE-INV project in the late 2000s (Lissoni 2012), to which the authors of this paper have made significant contributions, with studies of academic patenting in the UK, Italy and Spain. German data is available in the APE-INV public datasets but the time range available is limited to 2006-2007 and thus not useful for our purposes (Schoen et al. 2014). Austria is also included, but for a different time period 1997-2009 (Back et al. 2019). With the aim to keep a sample as homogenous as possible in the data sampling and identification strategy, we use the "Prof.Dr." title technique for both Germany and Austria for this new section whose main purpose is to provide some robustness tests.

[22] Another limitation put forward by von Proff et al (2013) is that top-level R&D employees of R&D intensive firms may hold honorary professorships at universities, but that is a limitation that could also affect other methods to identify academic patents, such as those based on matching names of university professors to names of academic inventors.

[23] We thank Nicolas Carayol and Elodie Carpentier for the data.

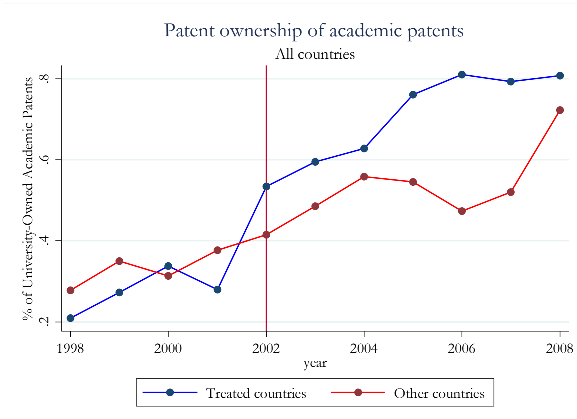
of academic inventions in those countries has not been immune to that change. The average technological importance of university-owned academic patents was much higher than that of company-owned academic invented patents before the policy change in the treated countries (and much higher than university-owned patents in the control group – see Figure 3b), but converged after the passage of the law. On the contrary, we do not observe the same strong reduction in the average technological importance before and after the professor's privilege abolishment for the group of patents applied by France and Spain which did not experienced the IP reform.

Table 8. Academic patenting activity, by type of first assignee (patent families)

	Number of *University-owned patents* (a)	**Number of *University-owned patents*** (b)	**Number of *Company-owned Patents*** (c)	**Number of *Academic patents*** (d)	**Percentage of university-owned patents** [(a)/(d)]	**Percentage of university-owned patents** [(b)/(d)]
Germany	774	1092	1187	1863	41.5%	58.6%
Austria	51	63	30	93	54.8%	67.7%
Spain	179	202	304	506	35.4%	39.9%
France	265	728	666	1394	19.0%	52.2%

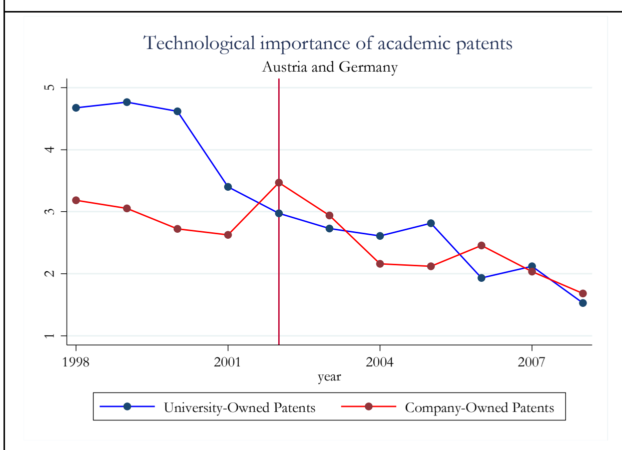
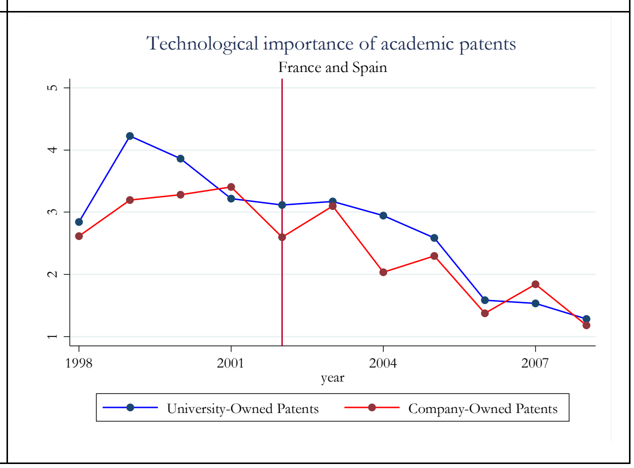
Only patents with a domestic university or domestic company as assignee are considered: patents assigned solely to individuals, public research organizations and foreign organizations are excluded. Only granted patents with priority years: 1998-2008. *University-owned patents* (Column a) are those in which a university appears as the priority applicant in the European patent family protecting the invention (these figures exclude patents co-applied with non-university institutions); In column (b) figures do include also co-applications with other types of assignees; (c) *Company-owned patents* are those where university researchers are listed as inventors in the patent document and the patent has been assigned solely to a company; (d) *Academic patents* are those in which university researchers appear as inventors, regardless the patent ownership.

Figure 2. Ownership of *Academic patents*



Countries in the treated group are Austria and Germany. Countries in the control group are France and Spain. *Academic patents* are those where academics appear as inventors in the patent document irrespective of whether they have been applied for by universities. Only patents assigned to domestic universities or domestic companies are considered in the analysis. *University-Owned academic patents* are those in which universities appear as the unique applicant in the European patent family protecting the invention (these figures include patents co-applied with non-university institutions). *Company-owned academic patents* are those invented by academics and assigned to solely domestic companies.

Figure 3. Quality of *Academic patents*: university- and company-owned

Figure a	*Figure b*
	

Technological importance is measured by the long-term citations. Only patents assigned to domestic universities or domestic companies are considered in the analysis. *University-Owned academic patents* are those in which universities appear as the unique applicant in the European patent family protecting the invention (these figures include patents co-applied with non-university institutions). *Company-owned academic patents* are those invented by academics and assigned to solely domestic companies.

To further investigate this issue, we focus on the two countries that experienced the professor's privilege abolishment (Austria and Germany) and we compare the technological quality of *Academic Patents* (before and after the policy change), with company patents (before and after the policy change), controlling for the ownership of the academic patents.[24] Although the method used for identifying academic inventors in Germany and Austria might be subject to criticism, it does not affect the econometric results, as the errors in the identification should be uniformly distributed over time (before and after the abolishment of the professor's privilege).

In the specification, we include the variable (*University Ownership*) that identifies academic patents assigned to universities. We thus estimate the following general model:

$$y_p = \beta_0 + \beta_1 Post_t + \beta_2 Academic\ Patent_p + \beta_3 Academic\ Patent_p * University\ Ownership_p + \beta_4 Post_t * Academic\ Patent_p + \beta_5 Post_t * Academic\ Patent_p * University\ Ownership_p + X_p\gamma + \varepsilon_p \quad (3).$$

As for the previous models, the dependent variable y_p represents the *Invention Quality* (IQ), while $Post_t$ identifies patents issued in the year of the IP reform and subsequent years. $Academic\ Patent_p$ Identifies patents invented by university professors, irrespective of whether they have been applied by for universities or companies. $University\ Ownership_p$ is a dummy that takes a value of one if *p* is assigned to university. ε_p is a mean zero random error. X_p is a set of covariates that control for patent characteristics which may affect the dependent variables. Depending on the models, we do control for technological field effects, year fixed effects, country fixed effects, trend and country-specific effects.

Results presented in Table 9 show that the average quality of academic inventions assigned to companies has increased after the reform. The coefficient is highly significant at 1% level in all models and implies that the technological importance of company-owned patents invented by university professors increased by about 26% (*exp*(.234)-1, Column 7), on average. However, in line with findings previously shown in the paper (Table 6), a negative and strong impact is found for

[24] We also run models by adding as further controls corporate and academic (university- and company-owned) French and Spanish patents. Results do not substantially differ and are available upon request from the authors.

university-owned academic patents, with an estimated reduction of invention quality of about 35% (*exp*(-.426)-1, Column 7).

The negative impact of the professor's privilege abolishment on the average technological importance of the academic inventions assigned to universities is thus in line with the findings of Table 7 and may be due to the higher number of lower quality patents that inexperienced German and Austrian universities had to manage during and after the abolishment of the professor's privilege (Martinez and Sterzi, 2019).

Table 9. Academic inventions: Abolishment of the professor's privilege and long-term citations. PPML estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post	-0.404***	-0.380***	-0.402***	0.147***			0.146***
	(0.00941)	(0.00238)	(0.00132)	(0.00726)			(0.00993)
Academic Patent	-0.0537	-0.197***	-0.275***	-0.289***	-0.274***	-0.274***	-0.288***
	(0.0759)	(0.0279)	(0.0201)	(0.0203)	(0.0205)	(0.0192)	(0.0198)
Academic Patent * University Ownership	0.463***	0.354***	0.446***	0.458***	0.448***	0.451***	0.461***
	(0.127)	(0.0653)	(0.0533)	(0.0544)	(0.0541)	(0.0467)	(0.0482)
Post * Academic Patent	0.256**	0.217***	0.238***	0.227***	0.205***	0.210***	0.234***
	(0.111)	(0.0542)	(0.0414)	(0.0362)	(0.0350)	(0.0285)	(0.0278)
Post* Academic Patent * University Ownership	**-0.518*** **	**-0.525*** **	**-0.479*** **	**-0.410*** **	**-0.378*** **	**-0.389*** **	**-0.426*** **
	(0.160)	**(0.0933)**	**(0.0788)**	**(0.0851)**	**(0.0868)**	**(0.0707)**	**(0.0645)**
Backward Citations			0.0535***	0.0554***	0.0554***	0.0553***	0.0554***
			(0.000765)	(0.000939)	(0.000836)	(0.000936)	(0.00107)
Number of Applicants			0.224***	0.223***	0.222***	0.227***	0.228***
			(0.0399)	(0.0353)	(0.0345)	(0.0327)	(0.0347)
Team Size			0.0834***	0.0840***	0.0836***	0.0842***	0.0846***
			(0.000660)	(0.000695)	(0.000722)	(0.00126)	(0.00116)
Trend				-0.105***			
				(0.00165)			
Constant	1.078***	0.738***	0.125***	211.1***	-0.735***	-0.493***	0.107***
	(0.00701)	(0.0146)	(0.0238)	(3.308)	(0.0183)	(0.0242)	(0.0282)
Observations	124,540	124,540	124,540	124,540	124,540	124,540	124,540
R-squared	0.015	0.057	0.083	0.092	0.095	0.096	0.093

Standard errors clustered at the country level are reported in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

In turn, the positive impact of the IP reform on the average technological importance of the academic inventions assigned to companies may be due to a mix of factors. First of all, given that the changed environment made more difficult for companies to retain the ownership of academic patents, it is reasonable to expect that exceptions only happened when the inventions were of sufficient quality to be worth the hassle. Secondly, an academic patent may be assigned to a company when the company is the main funder of the academic research leading to the patented invention. The abolishment of the professor's privilege might have made clearer the legal IP environment, making more attractive for private companies the financing of university research. Finally, an academic patent may be owned by a company also when professors may have bypassed the university administration; and this may be more likely to happen when professors believe they have a high-valuable invention at hand (Carayol and Sterzi 2019).

8. CONCLUSIONS

As long as policymakers impose a single legal pathway for technology transfer, there is an increasing risk of placing obstacles in the way of formal (and informal) relationships between faculty and industry. The university ownership model is built upon a linear model of technology transfer that underestimates the importance of interactions between the inventor and licensee and, by contrast, overestimates the brokerage role played by the TTO.

This paper distinguishes between the technological importance of a patented invention and the exploitation of the related IP rights, which both contribute to generating the patent value.

We use long-term forward citations as a proxy for the technological importance of the invention, as they reflect the relevance of the patented knowledge in the technological domain and the extent to which it stimulates and facilitates further inventions. As our preferred proxy of the overall patent value we use the number of times a patent has been renewed; patent holders maintain their protection over time only if the value of the patent covers at least the cost of its renewal.

We exploit the heterogeneity characterising IP regimes for university inventions within and across countries in Europe, to estimate the impact of the change towards the predominant institutional ownership model on the technological importance of university-owned inventions and their value. We find a significant decrease in the technological importance of university inventions and their overall value in countries abolishing the professor's privilege; we control for changes in the dependent variables for university patents in the remaining countries and for company patents in their own countries. The negative effect on long-term citations, our preferred proxy for technological importance, is strongly significant and robust to different specifications.

As regards our estimates of the impact of change in the IP regime on patent value, we find strongly significant negative effects on renewals. Following the reform, university patents are on average renewed less often. The results are robust to the inclusion of technological importance as a determinant of patent value, suggesting that part of the lower number of renewals of university patents is due to inefficient IP exploitation strategies by TTO managers and university administrators.

Our findings are consistent with previous studies (Czarnitzki *et al.* 2015, Hvide and Jones 2018, Ejermo and Toivanen 2018) which have also found negative effects of abolishment on university patenting activity and entrepreneurship. We add a broad international dimension previously absent in the literature and show that econometric results are robust to different specifications and numerous controls.

Furthermore, by including in the analysis also academic patents, that is, patents in which university researchers appear as inventors regardless the patent ownership, we also provide additional evidence of an increase in the average technological quality of academic inventions owned by companies in countries abolishing the professor's privilege, consistent with a shift of ownership of the academic-invented patents of lower quality from professors and companies to universities.

Nevertheless, our study is not exempt from limitations. Further quantifiable information on technological importance, IP exploitation and patent value would be needed to ascertain the impact of change in the IP regime in the countries considered. Qualitative information from interviews with university inventors and TTOs would also be useful, as well as case studies of university patent management before and after changes to the IP regime in a variety of countries, including information on academic entrepreneurship. The average negative effect on (long-term) citations and renewals (which remains even after controlling for country and sectoral differences) may be more noteworthy for some countries than others, or for some sectors than others. More research, to better understand the mechanisms driving the results is still required, but overall the evidence available indicates the need to consider alternative or complementary approaches to the model of university patent ownership and licensing through the TTOs. Bradley *et al.* (2013, p.636) argue that "a linear model of technology transfer is no longer sufficient or perhaps even no longer relevant". One of the drawbacks of this approach is that it has placed excessive emphasis on the importance of patents as the primary output in the technology transfer process, overlooking other mechanisms for commercialization. These include joint laboratories between academia and industry, spinoffs, research contracts, sponsored research, researcher mobility, joint publications, conferences, expositions and specialised media, informal contacts with professional networks, the flow of graduates from university to industry or simply serendipity (Bercovitz and Feldman 2006; Heinzl *et al.* 2008).

REFERENCES

Aghion, P., and Tirole, J. (1994). The management of innovation. *Quarterly Journal of Economics*, 109(4): 1185-1209.

Arqué-Castells, P., Cartaxo, R. M., García-Quevedo, J., Godinho, M. M., (2016). Royalty sharing, effort and invention in universities: Evidence from Portugal and Spain, *Research Policy*, 45(9): 1858-1872.

Astebro, T.B., Bazzazian, N., Braguinsky, S. (2012). Startups by recent university graduates and their faculty: Implications for university entrepreneurship policy, *Research Policy*, May 2012, 41(4): 663-677.

Astebro, T.B., Braguinsky, S., Braunerhjelm, P., Broström, A. (2016). Academic Entrepreneurship: Bayh-Dole versus the 'Professor's Privilege'. *HEC Paris Research Paper*, No. SPE-2015-1118. Available at SSRN: http://dx.doi.org/10.2139/ssrn.2677283

Backs, S., Günther, M., & Stummer, C. (2019). Stimulating academic patenting in a university ecosystem: An agent-based simulation approach. *The Journal of Technology Transfer*, *44*(2), 434-461.

Bercovitz, J., and Feldman, M. (2006). Entrepreneurial Universities and Technology Transfer: A Conceptual Framework for Understanding Knowledge-Based Economic Development, *Journal of Technology Transfer*, 31: 175-188.

Bercovitz, J., and Feldman, M. (2008). Academic entrepreneurs: Organizational change at the individual level. *Organization Science*, *19*(1): 69-89.

Bradley, S. Hayter, C. and Link, A., (2013). Models and Methods of University Technology Transfer. *Foundations and Trends in Entrepreneurship*, 9 (6): 571-650.

Callaert, J., Du Plessis, M., Grouwels, J., Lecocq, C., Magerman, T., Peeters, B., Song, X., Van Looy, B., Vereyen, C. (2011). Patent statistics at Eurostat: Methods for regionalisation, sector allocation and name harmonisation. *Eurostat Methodologies and Working Papers*, 72 pp. Luxembourg: European Union.

Carayol, N. and Sterzi, E. (2019) The Transfer and Value of Academic Inventions when the TTO is one option, *Mimeo*.

Carayol, N. and Carpentier, E. (2019) Two decades of Academic Inventions in France, *Mimeo*.

Chardonnens, F. (2010). Legislation and technology transfer in Switzerland, *Les Nouvelles*, Licensing Executives Society International Journal, December 2010.

Chukumba, C., and Jensen, R., (2005). University invention, entrepreneurship, and start-ups, National Bureau of Economic Research, NBER working paper No. 11475.

Ciaramella, L., Martínez, C., and Ménière Y. (2017). Tracking patent transfers in different European countries: methods and a first application to medical technologies, *Scientometrics*, 112:817–850.

Cunningham, J. A., Lehmann, E. E., Menter, M., & Seitz, N. (2019). The impact of university focused technology transfer policies on regional innovation and entrepreneurship. *The Journal of Technology Transfer*, 1-25.

Czarnitzki, D., Hussinger, K., and Schneider. C. (2012). The nexus between science and industry: evidence from faculty inventions. *The Journal of Technology Transfer*, 37 (5): 755-776.

Czarnitzki, D., Thorsten D., Hussinger, K., Schliessler, P., and Toole, A.A. (2015). Individual versus institutional ownership of university-discovered inventions, *ZEW Discussion paper*, no. 15-007.

Damsgaard, E. F., and Thursby, M. C. (2013). University entrepreneurship and professor privilege. *Industrial and Corporate Change*, 22(1): 183-218.

Della Malva, A., Lissoni, F., and Llerena, P. (2013). Institutional change and academic patenting: French universities and the Innovation Act of 1999. *Journal of Evolutionary Economics*, 23(1): 211-239.

Dornbusch, F., Schmoch, U., Schulze, N. and Bethke, N. (2012). Identification of university-based patents: A new large-scale approach. *Research Evaluation* 22(1): 52-63

Eisenberg, R. S. (1996). Public research and private development: patents and technology transfer in government-sponsored research. *Virginia Law Review*, 1663-1727.

Ejermo, O., and Toivanen, H. (2018). University invention and the abolishment of the professor's privilege in Finland. *Research Policy*, 47(4), 814-825.

Evans, D., and Leighton, L. S. (1989). Some Empirical Aspects of Entrepreneurship, *American Economic Review*, 79(3): 519-35.

Geuna, A. and Rossi, F. (2011). Changes to university IPR regulations in Europe and the impact on academic patenting. *Research Policy*, 40 (8): 1068-1076

Greenbaum, D. and Scott, C. (2010), Hochschullehrerprivileg - Modern Incarnation of the Professor's Privilege to Promote University to Industry Technology Transfer. *Science, Technology and Society,* 15: 55-76.

Grimaldi, R., Kenney, M., Siegel D. and Wright, M., (2011). 30 years after Bayh–Dole: reassessing academic entrepreneurship. *Research Policy*, 40:1045–1057.

Hall, B.H., Jaffe A. and M. Trajtenberg (2005), Market Value and Patent Citations, *Rand Journal of Economics*, No. 36, Spring.

Hamilton, B.H. (2000), Does Entrepreneurship Pay? An Empirical Analysis of the Returns to Self-Employment. *Journal of Political Economy*, 108(3): 604-631

Harhoff, D. Scherer, and F. M., Vopel, K. (2003), Citations, family size, opposition and the value of patent rights, *Research Policy*, 32(8):1343-1363.

Harhoff, D., and Reitzig, M. (2004), Determinants of opposition against EPO patent grants - the case of biotechnology and pharmaceuticals. *International journal of industrial organization,* 22(4): 443-480.

Heinzl, J., Kor, A., Orange, G. and Kaufmann, H., (2008). Technology transfer model for Austrian higher education institutions, paper presented at the European and Mediterranean Conference on Information Systems, May 25-26, 2008.

Henderson, R., Jaffe, and A. B., Trajtenberg, M. (1998). Universities as a source of commercial technology: a detailed analysis of university patenting, 1965–1988. *Review of Economics and statistics*, 80(1): 119-127.

Hovenkamp, H., Janis, M., Lemley, and M., Leslie, C. (2013). IP and Antitrust: An Analysis of Antitrust Principles Applied to Intellectual Property Law, Austin: Aspen Publishers.

Hvide, H.K. and B. F. Jones (2018). University Innovation and the Professor's Privilege, *American Economic Review*, 108 (7):1860-1898.

Iversen, E., Gulbrandsen, M. and Klitkou, A. (2007). A baseline for the impact of academic patenting legislation in Norway. *Scientometrics*, 70: 393-414.

Jaffe, A., and De Rassenfosse, G. (2017). Patent citation data in social science research: overview and best practices, *Journal of the Association for Information Science and Technology*, 68(6): 1360–1374

Kenney, M. and Patton, D., (2011). Does inventor ownership encourage university research-derived entrepreneurship? A six university comparison. *Research Policy*, 40: 1100-1112.

Lanjouw, J.O., and Schankerman, M., (2004). Patent Quality and Research Productivity: Measuring Innovation with Multiple Indicators. *The Economic Journal*, 114(495): 441-465.

Lerner, J. (1994). The importance of patent scope. An empirical analysis. *The RAND Journal of Economics,* 25 (2): 319-333

Lissoni, F. (2012). Academic patenting in Europe: An overview of recent research and new perspectives. *World Patent Information*, *34*(3): 197-205.

Lissoni, F., Pezzoni, M., Poti, B., and Romagnosi, S., (2013). University Autonomy, the Professor's Privilege and Academic Patenting: Italy, 1996–2007. *Industry and Innovation*, 20(5): 399-421.

Loise, V., and Stevens, A. J. (2010). The Bayh-Dole Act turns 30. *Les Nouvelles*, Licensing Executives Society International Journal, December 2010: 185-194.

Macho-Stadler, I., and Perez-Castrillo D., (2010). Incentives in university technology transfers. *International Journal of Industrial Organization,* 28: 362-367.

Martinez, C. (2011). Patent families: when do different definitions really matter? Scientometrics, 86(1): 39-63.

Martínez, C. and L. Bares (2018). The link between technology transfer and international extension of university patents: evidence from Spain. *Science and Public Policy*, 45, 6: 827-842.

Martinez, C. and V. Sterzi (2019), University patenting and the quest for technology transfer policy models in Europe, in: Varga, A. and Erdos, K. (Eds.), Handbook of Universities and Regional Development, Edward Elgar (forthcoming).

Mejer, M. (2011). Entrepreneurial Scientists and their Publication Performance. An Insight from Belgium. ECARES Working Paper 2011–017. European Center for Advanced Research in Economics and Statistics. Université Libre de Bruxelles. Brussels.

Mowery, D. and B. Sampat (2005). The Bayh-Dole Act of 1980 and University-Industry Technology Transfer: A Model for Other OECD Governments? *Journal of Technology Transfer*, 30:115–127

Rosell, C. and Agrawal. A. (2009). Have university knowledge flows narrowed? Evidence from patent data. *Research Policy,* 38: 1–13

Sampat, B.N., Mowery, D.C., Ziedonis, A.A., (2003). Changes in university patent quality after the Bayh-Dole act: a re-examination, *International Journal of Industrial Organization*, 21(9):1371-1390.

Schacht, W. (2012). The Bayh-Dole Act: Selected Issues in Patent Policy and the Commercialization of Technology. *CRS Report for Congress,* https://fas.org/sgp/crs/misc/RL32076.pdf

Schmoch, U. (2007). Patentanmeldungen aus deutschen Hochschulen", Studien zum deutschen Innovationssystem no. 10-2007.

Schmoch, U. (2008). Concept of a technology classification for country comparisons. Final report to the World Intellectual Property Office (WIPO). Karlsruhe: Fraunhofer ISI.

Schoen, A., Heinisch, D., & Buenstorf, G. (2014). Playing the 'Name Game'to identify academic patents in Germany. *Scientometrics*, *101*(1); 527-545.

Shane, S., Locke, and E.A., Collins, C.J. (2003). Entrepreneurial motivation. *Human Resource Management Review,* 13 (2): 257-279.

Spilling, O.R, S. B. Brorstad, E.J. Iversen, E. Rasmussen, and E. Solberg (2015). Virkemiddelapparatet for kommersialisering av forskning – status og utfordringer (kap 2: Patentering) Rapport 18/2015

Squicciarini, M., Dernis, H., and Criscuolo, C. (2013). Measuring patent quality: Indicators of technological and economic value. OECD Science, Technology and Industry Working Papers, 2013(3).

Stephan, P. (1996). The Economics of Science, *Journal of Economic Literature*, 34 (3): 1199-1235

Stern, S. (2004). Do Scientists Pay to Be Scientists? *Management Science*, 50 (6): 835-853.

Sterzi, V. (2013). Patent quality and ownership: An analysis of UK faculty patenting. *Research Policy* 42 (2): 564-576.

Sterzi, V., Pezzoni, M., & Lissoni, F. (2019). Patent management by universities: evidence from Italian academic inventions. *Industrial and Corporate Change*, *28*(2), 309-330.

Takenaka, T. (2005). Technology licensing and university research in Japan. *International Journal of Intellectual Property Law, Economy and Management*, 1(1): 27-36.

Valentin, F., and Jensen, R.L., (2007). Effects on academia-industry collaboration of extending university property rights. *The Journal of Technology Transfer*, 32(3): 251-276.

Verspagen, B. (2006). University research, intellectual property rights and European innovation systems. Journal of Economic Surveys, 20(4): 607-632.

Von Proff, S., Buenstorf, G. and Hummel, M. (2012). University Patenting in Germany before and after 2002: What Role Did the Professors' Privilege Play? *Industry and Innovation*, 19: 23-44.

Webb, C., Dernis, H., Harhoff, D., Hoisl, K. (2005). Analysing European and international patent citations: a set of EPO patent database building blocks. OECD STI Working Paper 2005/9.

Zuniga, P. (2011). The state of patenting at research institutions in developing countries: policy approaches and practices. *WIPO Economic Research Working Papers,* No. 4.

APPENDIX

APPENDIX A1. Further results

Table A1. IQ model: The abolishment of the professor's privilege and long-term citations from companies. PPML estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post	-0.562***	-0.570***	-0.608***	-0.208***			-0.206***
	(0.0417)	(0.0330)	(0.0266)	(0.0283)			(0.0333)
University	-0.0204	-0.148***	-0.137***	-0.0845**	-0.0976**	-0.136***	-0.123***
	(0.0479)	(0.0417)	(0.0413)	(0.0388)	(0.0397)	(0.0397)	(0.0400)
Treat	-0.168**	-0.141**	-0.170**	-0.161**	-0.165**	0.0484	0.119
	(0.0796)	(0.0711)	(0.0719)	(0.0734)	(0.0729)	(0.134)	(0.150)
Post*Treat	0.0519	0.0667	0.0757*	0.0638	0.0643	0.0337	0.0244
	(0.0546)	(0.0485)	(0.0433)	(0.0424)	(0.0432)	(0.0320)	(0.0328)
Post*University	-0.0483	-0.0518	-0.0650	-0.112*	-0.0884	-0.0827	-0.113**
	(0.0622)	(0.0584)	(0.0569)	(0.0610)	(0.0601)	(0.0536)	(0.0533)
Treat*University	0.279***	0.267***	0.244***	0.254***	0.249***	0.324***	0.326***
	(0.0821)	(0.0835)	(0.0805)	(0.0818)	(0.0818)	(0.0981)	(0.0970)
Post*Treat*University	**-0.572*** **	**-0.571*** **	**-0.495*** **	**-0.481*** **	**-0.440*** **	**-0.478*** **	**-0.523*** **
	(0.0631)	(0.0611)	(0.0590)	(0.0633)	(0.0642)	(0.0589)	(0.0711)
Backward citations			0.0543***	0.0569***	0.0567***	0.0556***	0.0558***
			(0.00233)	(0.00247)	(0.00234)	(0.00174)	(0.00180)
Number of applicants			0.249***	0.234***	0.240***	0.230***	0.228***
			(0.0397)	(0.0322)	(0.0343)	(0.0310)	(0.0312)
Team size			0.0709***	0.0752***	0.0744***	0.0764***	0.0770***
			(0.00349)	(0.00405)	(0.00406)	(0.00423)	(0.00405)
Trend				-0.0443***			
				(0.00214)			
Constant	0.977***	0.714***	0.106	88.56***	-0.969***	-1.049***	-0.172**
	(0.0765)	(0.0660)	(0.0962)	(4.270)	(0.112)	(0.0818)	(0.0843)
Technological field dummies	NO	YES	YES	YES	YES	YES	YES
Year dummies	NO	NO	NO	NO	YES	YES	NO
Country dummies	NO	NO	NO	NO	NO	YES	YES
Country*Trend	NO	NO	NO	NO	NO	NO	YES
Observations	363,729	363,729	363,729	363,729	363,729	363,729	363,729

Standard errors clustered at the country level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A2. IQ model: the abolishment of the professor's privilege and originality. OLS estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post	0.0350***	0.0422***	0.0321***	-0.0124***			-0.00573***
	(0.00410)	(0.00298)	(0.00170)	(0.00320)			(0.000750)
University	0.0275**	0.00152	0.0141**	0.00835	0.00798	0.00254	0.00368
	(0.00927)	(0.00656)	(0.00542)	(0.00522)	(0.00530)	(0.00591)	(0.00596)
Treat	0.00118	0.00294	0.00242	0.00129	0.00119	0.0172**	0.0107
	(0.00965)	(0.00616)	(0.00545)	(0.00538)	(0.00538)	(0.00701)	(0.0101)
Post*Treat	0.00259	0.00381	0.00379*	0.00520**	0.00506**	0.00398**	-0.00516***
	(0.00424)	(0.00306)	(0.00173)	(0.00169)	(0.00170)	(0.00144)	(0.00107)
Post*University	-0.0158	-0.0246**	-0.0193	-0.0142	-0.0138	-0.0119	-0.0134
	(0.00939)	(0.00947)	(0.0109)	(0.0113)	(0.0113)	(0.0105)	(0.0103)
Treat*University	-0.00798	0.00179	-0.00703	-0.00843*	-0.00856*	-0.00199	-0.00316
	(0.00936)	(0.00613)	(0.00456)	(0.00428)	(0.00427)	(0.00513)	(0.00530)
Post*Treat*University	**-0.0151**	**-0.0179***	**-0.00162**	**-0.00266**	**-0.00142**	**-0.00388**	**-0.00333**
	(0.00951)	(0.00926)	(0.0108)	(0.0113)	(0.0110)	(0.0105)	(0.0104)
Backward citations			0.0309***	0.0307***	0.0307***	0.0306***	0.0306***
			(0.000951)	(0.000958)	(0.000967)	(0.000933)	(0.000924)
Number of applicants			0.0105***	0.0118***	0.0120***	0.0109***	0.0102***
			(0.00278)	(0.00223)	(0.00227)	(0.00276)	(0.00291)
Team size			0.00669***	0.00623***	0.00622***	0.00627***	0.00631***
			(0.000634)	(0.000612)	(0.000609)	(0.000607)	(0.000617)
Trend				0.00497***			
				(0.000311)			
Constant	0.619***	0.554***	0.400***	-9.514***	0.372***	0.362***	0.415***
	(0.00955)	(0.00770)	(0.00655)	(0.617)	(0.00590)	(0.00649)	(0.0109)
Technological field dummies	NO	YES	YES	YES	YES	YES	YES
Year dummies	NO	NO	NO	NO	YES	YES	NO
Country dummies	NO	NO	NO	NO	NO	YES	YES
Country*Trend	NO	NO	NO	NO	NO	NO	YES
Observations	358,695	358,695	358,695	358,695	358,695	358,695	358,695

Standard errors clustered at the country level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.. Descriptive statistics of the sample are given in Table 5.

Table A3. PV model: the abolishment of the professor's privilege and family size PPML estimates.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post	-0.128***	-0.0890***	-0.0715***	-0.0836***	-0.0722***			-0.0615***
	(0.0336)	(0.0331)	(0.0271)	(0.0269)	(0.0206)			(0.0117)
University	-0.0245	-0.0854***	-0.246***	-0.248***	-0.247***	-0.252***	-0.255***	-0.250***
	(0.0300)	(0.0238)	(0.0401)	(0.0444)	(0.0442)	(0.0445)	(0.0349)	(0.0332)
Treat	-0.315***	-0.287***	-0.251***	-0.267***	-0.267***	-0.270***	-0.157***	-0.167***
	(0.0582)	(0.0441)	(0.0345)	(0.0362)	(0.0362)	(0.0359)	(0.0508)	(0.0426)
Post*Treat	0.0573	0.0424	0.0467*	0.0530*	0.0527*	0.0534*	0.0436	0.0258**
	(0.0351)	(0.0322)	(0.0281)	(0.0278)	(0.0278)	(0.0285)	(0.0282)	(0.0109)
Post*University	-0.0577	-0.0182	-0.0526	-0.0597*	-0.0610*	-0.0521*	-0.0490*	-0.0531***
	(0.0465)	(0.0392)	(0.0329)	(0.0324)	(0.0319)	(0.0305)	(0.0288)	(0.0169)
Treat*University	0.123***	0.0851	0.114**	0.115**	0.116**	0.115**	0.140***	0.141***
	(0.0464)	(0.0875)	(0.0563)	(0.0550)	(0.0549)	(0.0537)	(0.0362)	(0.0324)
Post*Treat*University	**-0.152*** **	**-0.101**	**-0.121***	**-0.111***	**-0.110***	**-0.0976**	**-0.126*** **	**-0.139*** **
	(0.0590)	(0.0968)	(0.0711)	(0.0658)	(0.0662)	(0.0654)	(0.0507)	(0.0419)
Long-term citations		0.0213***	0.0163***	0.0154***	0.0154***	0.0151***	0.0143***	0.0144***
		(0.00232)	(0.00135)	(0.00123)	(0.00125)	(0.00124)	(0.00140)	(0.00146)
Backward citations				0.000125	0.000201	0.000172	-0.000126	0.000468
				(0.00144)	(0.00146)	(0.00143)	(0.00135)	(0.00134)
Number of applicants				0.0478***	0.0475***	0.0503***	0.0427***	0.0379***
				(0.0118)	(0.0116)	(0.0110)	(0.0110)	(0.0108)
Team size				0.0316***	0.0317***	0.0316***	0.0336***	0.0339***
				(0.00194)	(0.00185)	(0.00183)	(0.00125)	(0.00123)
Trend					-0.00128			
					(0.00168)			
Constant	2.085***	1.984***	1.843***	1.752***	4.310	1.733***	1.665***	1.684***
	(0.0473)	(0.0392)	(0.0434)	(0.0362)	(3.375)	(0.0348)	(0.0454)	(0.0375)
Technological field dummies	NO	NO	YES	YES	YES	YES	YES	YES
Year dummies	NO	NO	NO	NO	NO	YES	YES	NO
Country dummies	NO	NO	NO	NO	NO	NO	YES	YES
Country*Trend	NO	NO	NO	NO	NO	NO	NO	YES
Observations	363,729	363,729	363,729	363,729	363,729	363,729	363,729	363,729

Standard errors clustered at the country level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Descriptive statistics of the sample are shown in Table 4.

APPENDIX A2. Propensity score matching (patent management model)

The sample used in the main analysis of the paper (Sections 5 and 6) consists of 363,729 granted patents, of which only 4,047 patents are university patents, representing 1.1% of the sample. In order to reduce heterogeneity and to construct a more balanced sample of patents applied for by companies and universities of similar characteristics (with the exception of the number of renewals and family size), we apply propensity score matching (PSM); we calculate the predicted probability of each patent being applied for by a university (university patent) or a company (company patent) according to its characteristics, as they appear in the list of independent variables in Model (2b). Subsequently, for each university patent we select from the pool of company patents that having the closest propensity score.[25] Our final sample is thus composed of 4,043[26] university patents and 4,043 company patents of similar characteristics, with the exception of the number of renewals, our dependent variable. With regard to the quality of the match, Figure A1 below displays the Kernel distribution for the two groups of patents (university and company patents) before and after the matching, when the nearest-neighbour algorithm is implemented. Prior to the matching, the shape of the distribution differs and there is only a partial overlap between the distributions of the propensity score of the two groups. After the matching, the two shapes are almost identical, suggesting that the PSM has been successful in correcting for the selection bias. Table A4 presents descriptive statistics.

Figure A1. Distributions of the propensity score for university and company patents before and after matching

[25] The STATA module *psmatch2* has been used for matching. We adopt the nearest-neighbor algorithm (Rosenbaum and Rubin 1983; Heckman et al. 1998) and we match each university patent to a company patent.

[26] Three university patents have not been matched to any company patent.

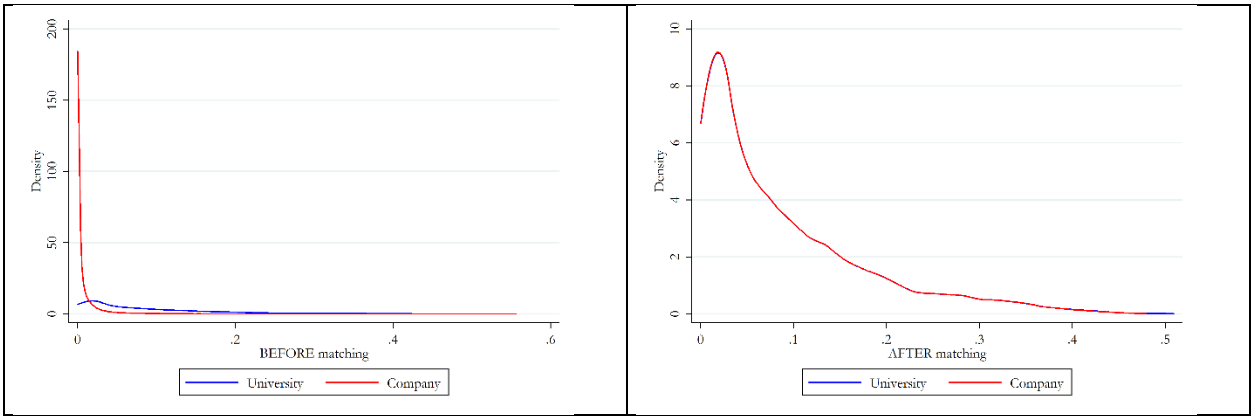


Table A4. Descriptive statistics for the principal variables in the unmatched and matched sample

	Unmatched				Matched			
	University	Company	%Bias	T-test	University	Company	%Bias	T-test
Long-term citations	4.62	3.05	25.4	19.45	4.62	4.74	-2.0	-0.73
Backward citations	3.31	4.11	-34.5	-22.95	3.31	3.37	-2.6	-1.21
Number of applicants	1.06	1.03	12.8	9.84	1.06	1.04	5.0	2.05
Team size	2.94	2.39	33.1	21.28	2.94	3.01	-4.4	-1.67

Other variables included in the PSM and not reported in Table A4 are dummies for the country of the applicant, the priority year and the technological field.

Due to the PSM, we are now comparing university patents and company patents of similar characteristics allowing us to speculate that the difference in the number of renewals is linked principally to the difference in the effectiveness of the IP *exploitation*.

The PPML results based on the PSM are depicted in Table A5. The results are very similar to those produced when all patents are used. Conditional on the observed technological importance (IQ) of the invention[27], as proxied by the number of long-term citations, university patents receive fewer renewals, suggesting that TTO managers exploit patents less effectively. University patents, compared to company patents, have similar observable characteristics, but are expected to be renewed less often. Moreover, in the years following abolishment, the average patent management quality declines still further.

[27] After matching (as shown in Table A4), the averages of invention quality (IQ, long-term citations) are not statistically different in the group of university patents and company patents, confirming that the balance of covariates has been successfully achieved; prior to PSM, universities receive 4.62 (long-term) citations and company patents only 3.05. After matching, the difference between the two groups disappears (t-test of 0.73).

Table A5. PV model: the abolishment of the professor's privilege and renewals. Conditional PPML

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post	-0.377***	-0.356***	-0.357***	-0.357***	-0.102***			-0.120***
	(0.00500)	(0.00714)	(0.00746)	(0.00731)	(0.0295)			(0.0213)
University	-0.0305**	-0.0279**	-0.0315***	-0.0302***	-0.0296**	-0.0278**	-0.0293**	-0.0317**
	(0.0128)	(0.0116)	(0.0108)	(0.0105)	(0.0140)	(0.0129)	(0.0127)	(0.0132)
Treat	-0.00432	0.0109	0.00705	0.00734	0.0159	0.0112	-0.210***	87.85***
	(0.0133)	(0.0129)	(0.0113)	(0.0111)	(0.0100)	(0.0113)	(0.0709)	(2.957)
Post*Treat	0.0169***	0.0105	0.00927	0.00946	0.00288	0.00692	0.0107	0.106***
	(0.00605)	(0.00853)	(0.00899)	(0.00884)	(0.00619)	(0.00710)	(0.00882)	(0.0231)
Post*University	0.0357***	0.0360***	0.0361***	0.0329***	0.0278**	0.0195*	0.0192*	0.0291**
	(0.00956)	(0.00982)	(0.0110)	(0.0109)	(0.0121)	(0.0112)	(0.0113)	(0.0115)
Treat*University	0.0247	0.0112	0.0191	0.0186	0.0281	0.0176	0.0165	0.0298
	(0.0287)	(0.0313)	(0.0285)	(0.0290)	(0.0281)	(0.0307)	(0.0322)	(0.0302)
Post*Treat*University	**-0.107*** **	**-0.0939*** **	**-0.0946*** **	**-0.0915*** **	**-0.0885*** **	**-0.0618** **	**-0.0596** **	**-0.0871*** **
	(0.0145)	(0.0168)	(0.0162)	(0.0164)	(0.0187)	(0.0263)	(0.0276)	(0.0213)
Long-term citations		0.00708***	0.00714***	0.00702***	0.00625***	0.00594***	0.00602***	0.00625***
		(0.000527)	(0.000554)	(0.000555)	(0.000552)	(0.000477)	(0.000442)	(0.000459)
Backward citations				0.00312**	0.00491***	0.00428***	0.00420***	0.00481***
				(0.00138)	(0.00160)	(0.00127)	(0.00134)	(0.00164)
Number of applicants				0.0377	0.0405*	0.0425**	0.0397**	0.0395*
				(0.0281)	(0.0216)	(0.0183)	(0.0196)	(0.0239)
Team size					0.00223	0.00204	0.00154	0.00172
					(0.00240)	(0.00255)	(0.00263)	(0.00230)
Trend					-0.0317***			
					(0.00357)			
Constant	2.534***	2.484***	2.449***	2.398***	65.61***	2.408***	2.548***	2.371***
	(0.00733)	(0.0103)	(0.0318)	(0.0352)	(7.130)	(0.0326)	(0.0772)	(0.0666)
Technological field dummies	NO	NO	YES	YES	YES	YES	YES	YES
Year dummies	NO	NO	NO	NO	NO	YES	YES	NO
Country dummies	NO	NO	NO	NO	NO	NO	YES	YES
Country*Trend	NO	NO	NO	NO	NO	NO	NO	YES
Observations	8,086	8,086	8,086	8,086	8,086	8,086	8,086	8,086

Standard errors clustered at the country level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The sample is composed of 4,043 university patents matched to 4,043 company patents in the same technological field and having the same priority

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