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Universities involvement in patent litigation: an analysis of the characteristics of US litigated patents

Grazia Sveva Ascione[1,2] · Laura Ciucci[3,4] · Claudio Detotto[4,5] · Valerio Sterzi[2]

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Abstract
Some recent patent infringement litigations initiated by universities have resulted in multi-million dollar damages and have attracted public attention and stimulated research especially among law scholars. In this paper, we build a brand new database that include patents filed by universities at the United States and Trademark Office (USPTO), their characteristics and, eventually, the information about whether they have been used in infringements lawsuits by universities in the years 1990–2019. Our study is articulated in two parts. First, we show that, although it is still a quite rare phenomenon, patent litigation involving universities has been significantly growing in the last 2 decades. Second, we study the characteristics of university patents that have been litigated vis-à-vis non-litigated university patents. In this respect, we find that public universities and non-US universities are less inclined to litigate their patents compared to private and US universities. In addition, we also find that patent quality is an important determinant in the decision of university litigation. This result holds for patents in the Electrical Engineering sector, which is traditionally prone to opportunistic litigation, and no matter what type of university involved (public vs private, or US vs non-US).

Keywords Patent litigation · Patent quality · University patents

JEL Classification C25 · O3 · K41

✉ Grazia Sveva Ascione
graziasveva.ascione@unito.it

[1] Department of Economics and Statistics, University of Turin, Turin, Italy

[2] BSE, UMR CNRS 6060, University of Bordeaux, Bordeaux, France

[3] Social Sciences, Gran Sasso Science Institute, L'Aquila, Italy

[4] LISA UMR CNRS 6240, University of Corsica, Corte, France

[5] Centre for North South Economic Research (CRENoS), Sassari, Italy

Introduction

Universities, traditionally perceived as relevant actors in the innovation ecosystem, gradually changed their role, integrating their teaching and research mission with the commercial assumptions underlying intellectual property (IP) law (Etzkowitz & Webster, 1998; Ghosh, 2016). Understanding and analyzing the changes which have taken place in the relationship between higher education institutions (HEIs) and IP is thus relevant to the whole innovation (Verspagen, 2006).

In the United States, universities have been involved in technology transfer since the nineteenth century (Meyer-Thurow, 1982), with patenting activities taking off after the passage of the Bayh-Dole Act. Given the importance of universities in the US innovation ecosystem, prominent scholars have closely examined the wave of patenting that followed Bayh-Dole, looking for the impact on innovation dynamics and on universities as actors facing the challenge of commercializing and licensing their inventions for the first time (Mowery et al., 2002a, 2002b). However, the question of whether society benefits most when universities patent (or do not patent) their inventions is intertwined with another debate about university involvement in patent litigation.[1] This phenomenon is of particular interest for several reasons. First, patent litigation between universities has increased dramatically recently (see Fig. 1), particularly in the United States. Second, the extreme cases involving universities, resulting in multi-million dollar damage awards, are proliferating and attracting increasing public attention (Firpo & Mireles, 2020). Finally, the involvement of universities in litigation is important to examine given the growing debate in the academic literature about the strategic behavior they are allegedly prone to. This has led

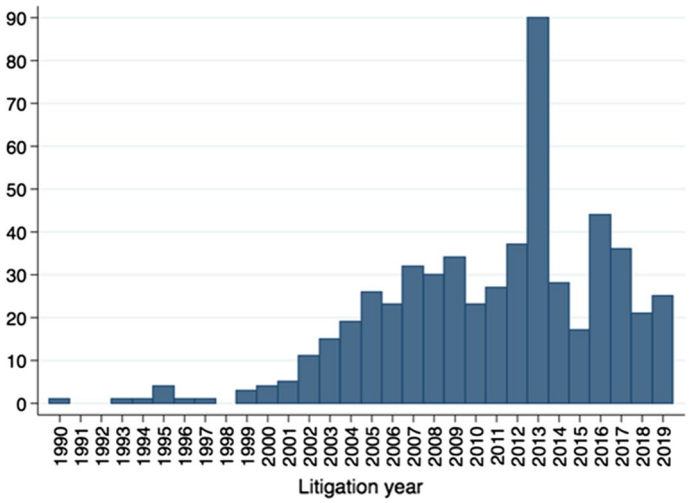

Fig. 1 Number of university infringement actions filed in US (1990–2019). This distribution is related to all patent infringement actions filed in the US by universities in the period 1990–2019. The litigation year corresponds to the year in which the cases started

[1] Beyond the case of HEIs, the literature has largely addressed the effects of patent litigation, and more generally of strong IPR regimes, on incentives to innovate (see among the others (Gossart et al., 2020)).

several authors to question whether universities can be compared to patent trolls (Lemley, 2007).

In our research, we develop a brand-new database of patents filed and eventually litigated by universities in the US. In particular, we collect patent infringement lawsuits involving universities up to 2019 from Clarivate Darts-IP[2] as well as US granted (utility) patents from USPTO Patent Views (2018) and Patent Assignment Database (version 2017) where universities appear as assignees.

Our study is articulated in two parts. First, we describe the phenomenon of university patent litigation and its evolution over time, notably which kind of universities are more prone to litigation, which are the most active and which technological sectors are more involved. Second, we focus on the characteristics of the litigated patents, with a particular interest in their value and on the type of universities involved in litigations (public vs private and US vs non-US). The academic literature has paid a great deal of attention to understanding the link between patent value and litigation. In this respect, the last part of our analysis is in line with works such as Su et al. (2012) who provide a study based on all utility patents issued by USPTO from 1976 to 2010 and Gossart et al. (2020) who focus on the LED sector specifically.

The rest of the paper is organized as follows. In the next section, we present the theoretical background. In "Dataset construction" section, we describe the patent and litigation data; in "US universities in courts: key figures" section, we show the main figures, and, in "Econometric analysis of the characteristics of the university-litigated patents" section, we estimate an empirical model to evaluate the characteristics of the litigated patents by universities in the US in the years 1990–2019. Finally, a discussion of the results and acknowledgment of the limitations conclude the paper.

Theoretical background

Universities' participation in patent litigation

Patent litigation is an important tool for a patent owner to seek monetary compensation from potential infringers or to prevent unauthorized competitors from exploiting its technology, with important implications on innovation dynamics. On the one hand, patent litigation can lead to injunctions or large damages to stop production and sales, which may discourage innovation, especially for small companies that cannot afford the expenses of litigation. Moreover, this loss may go far beyond legal costs, as it hinders business relationships and increases borrowing costs due to possible bankruptcy. On the other hand, patent litigation can help a company to decrease the market-stealing effect (Kafouros et al., 2021) and create a stronger reputation among competitors by signaling that the company will protect its assets if the relevant patents are infringed (Somaya, 2003).

Since the Bayh-Dole Act (1980), universities have been encouraged to take a more aggressive stance on IPRs, as patents were thought to promote innovation, especially in science-based industries such as chemicals, pharmaceuticals and biotechnology (Walsh et al., 2001); however, it is only recently that they have become more sensitive to the economic

[2] https://clarivate.com/darts-ip.

aspects of IP. For years, because of its high costs, complexity and uncertainty,[3] universities have been absent from the courts. Faced with corporate opponents with huge legal budgets and legal teams, most universities could not effectively defend their patents (Chien, 2010). By contrast, in more recent years, not only have universities become increasingly active in the patent market—some of them are among the institutions with the highest number of foreign patent assignments in the US (Fusco et al., 2019)—but they have also increasingly appeared as litigants in the courts (Firpo & Mireles, 2020).

However, while the literature examining university involvement in patenting and technology transfer is quite extensive, commentators have largely overlooked university involvement in patent litigation, an assertive and multifaceted activity with important policy considerations for higher education. Some universities believe that participating as plaintiffs in patent infringement suits is consistent with their research and commercialization mission, although some critics view this activity as conflicting at times with the notion of a university's public mission (Rooksby, 2012; Shane & Somaya, 2007). For example, Winickoff (2013) argues that universities are "public-regarding" organizations and "more than merely a private for-profit corporation", and that their TTOs are obligated to prioritize "social impact" over profit or economic activity. Lemley (2007) echoes this criticism, emphasizing that the objective of university technology transfer should be to maximize the societal benefit of technology rather than the university's licensing revenue, as universities are not merely private for-profit businesses.

The landscape of American universities is highly heterogeneous, with blurred lines between public and private non-profit institutions, which still make up the majority of universities, and a growing but still modest proportion of for-profit universities and colleges (Kinser & Levy, 2007) especially among research institutions.[4] Consistent with the variety in TTOs' size and age, as well as universities separation into for-profit and non-profit organizations, according to Kim and Paau (2011), one could expect that TTOs' orientation towards commercialization could vary consistently. In particular, for-profit institutions usually are more prone to satisfy the demands of investors and stockholders, making profit an important goal. On the other hand, non-profit institutions, whether public or private, receive funding to different extents from the government; as a result, their focus might be on promoting education and research, rather than on earnings.

Furthermore, patent litigation involving universities is increasing at an even faster rate than patent litigation in the US as a whole (Shane & Somaya, 2007), with a particular intensity during the last two decades (see Fig. 1). Unsurprisingly, the increasing presence of universities as patent plaintiffs has attracted the media attention, in part because of the extremely high damages awarded by the US courts or high settlements obtained during negotiations. Overall, universities continue to achieve the highest damage awards and success rates in courts.[5] Among the top ten largest initial adjudicated damages awards in the years 1998–2017, the infringement case initiated in 2009 by Carnegie Mellon University against Marvell Technology Group is ranked fourth, with more than $1 billion in initial

[3] Patent litigation has been called the "sport of kings" because it involves a large amount of money, complexity, and uncertainty (Kline, 2004).

[4] In our sample, we have only four academic institutions which filed patents and that are considered as for-profit institutions. These are: The American Public University, the California Northstate University College of Medicine, the DigiPen Institute of Technology and the National Institute of Technology (United States).

[5] https://www.pwc.com/us/en/forensic-services/publications/assets/2018-pwc-patent-litigation-study.pdf.

damages award.[6] Similarly, the University of Minnesota settled its dispute over patents for Glaxo Wellcome's AIDS drug Ziagen with a multi-year licensing agreement worth 300 million (Virtucio, 1999), while the University of Rochester lost a multi-billion dollar lawsuit and all subsequent appeals to enforce its Cox-2 inhibitor patent against pharmaceutical companies Pfizer and Merck (Pollack, 2003).

Despite the increasing presence of universities in the courts, their patent disputes are rarely without costs and consequences. In particular, two main issues are highlighted in the literature. First, patent litigation can impose costs on universities' reputations since the involvement in litigation has the potential to alienate donors and politicians with ties to defendants (the "fear of retribution" as defined by Rooksby (2013)). Second, involvement in litigation can cost hundreds of thousands of dollars and can waste university human resources and time (Chien, 2010). Patent litigation can in fact paradoxically have a negative impact on the licensing activities of universities themselves; for example, Shane and Somaya (2007) show that the involvement of universities in courts can reduce the productivity of their technology transfer offices (TTOs), which have to incur in additional costs for consulting with attorneys about litigation strategies; these activities keep them busy in drafting documents and attending court hearings rather than focused on marketing, researching, and negotiating activities.

The value of litigated patents

Patent litigation has become a popular topic in the last two decades as it has become increasingly global, with litigants earning, sometimes, billion-dollar awards. The annual median damages award in the years 1998–2017 ranged from a low of $1.9 million to $17.4 million, with an overall median award for the entire 20-year period of $5.9 million.[7] As with the majority of patent law concerns, potential patent litigation damages are outlined in 35 U.S.C. 284 of the Patent Act; they consist primarily of two sorts of damages for patent infringement cases: reasonable royalties and lost profits. Therefore, for what concerns litigation costs, the so-called "American Rule" doctrine dictates that opposing parties in a court dispute must pay their own attorney expenses, regardless of who wins (Roth, 2013). The rule's ratio is that a plaintiff should not be discouraged from bringing a case to court out of concern about excessive fees.

There are a number of studies that attempt to evaluate the likelihood of a patent being litigated by using different methods. Gibbs (2005) examined the relationship between patent value and litigation, emphasizing that the prospective value of a patent is minimized when it is likely to lose in litigation. In this sense, the value of a patent depends largely on the extent to which the innovation can be protected from infringement. Thus, if some patents are more likely to be litigated, they should have particular features that encourage litigation (Gossart et al., 2020; Lanjouw & Schankerman, 2004; Su et al., 2012). This hypothesis is confirmed by several studies, stressing the positive relationship between patent value and probability of being enforced in court (Allison et al., 2003; Bessen & Meurer, 2006; Gossart et al., 2020; Harhoff et al., 2003; Miller, 2012; Su et al., 2012). For example, by analyzing data from Stanford IP Litigation Clearinghouse, Allison et al. (2009) compare

[6] Carnegie Mellon University and Marvell Technology Group settled in 2016. The settlement included an aggregate payment by the company to the university of $750 million.

[7] See footnote 3.

the patents litigated most frequently between 2000 and 2007 to a control set of patents that have been litigated only once in that period. Their results show that the most litigated patents have a larger number of claims, more prior art citations and a larger number of continuation applications.

The question whether universities litigate high-quality patents or not is relevant both for assessing the factors pushing universities to get involved in IP litigation and for the social impact that such involvement may generate. Considering the high costs of litigation, the implication for social impact may differ significantly if these costs are incurred by government-funded universities for defending high-quality inventions rather than low-quality ones. In the former case, litigation is legitimately used as a market feature to protect the proprietary rights of valuable innovation (Kafouros et al., 2016) which could be then disseminated and benefit society. In the latter, both the negative consequences borne by universities TTOs such as a negative impact of the number of new licenses (Shane & Somaya, 2007) and the damage to the defendants might hamper the innovation ecosystem creating a negative social impact (Kiebzak et al., 2016; Nam et al., 2015).

Our contribution

Despite the importance of the topic, very few quantitative studies on university patent litigation exist (Ascione et al., 2021, pp. 59–70). To our knowledge, only Rooksby (2011) and Firpo and Mireles (2018, 2020) collect and examine data on patent litigations initiated by universities in the US. In particular, Rooksby (2011) analyzes 57 cases in 2009 and 2010, finding out that most of the litigated patents relate to the pharmaceutical sector and involve an exclusive license. Firpo and Mireles (2018) study litigation cases filed by universities, foundations and non-profit organizations in the period 2000 to 2015, using the Stanford Non-Practicing Entity (NPE) Litigation Database. The authors look at measures of patent value and explore other litigation-related variables. In doing so, by comparing the average number of forward citations of university litigated patents with the "most litigated patents", as defined by Allison et al. (2009), they find that the former are more cited although they say to take the result with caution since the litigation data come from different sources.

In order to expand the evidence presented in the abovementioned works, our paper provides a detailed portrait of infringement cases initiated by universities in the US and analyzes the characteristics of university-litigated patents (vis-à-vis the non-litigated patents in the portfolio of universities patenting at the USPTO).

In doing so, we extend prior research in several ways. First, we expand the work of Rooksby (2011) and Firpo and Mireles (2018), by considering patent infringement cases filed between 1990 and 2019, and performing an econometric analysis in order to compare the characteristics of litigated and non-litigated patents in the university portfolio. Second, we extend the work by Su et al. (2012), which draws a comparison between all litigated and non-litigated patents, with the difference that we specifically focus on university involvement in patent litigation and emphasizing the evolutionary dimension of the phenomenon. In addition, we investigate the differences between US and non-US universities and public and private institutions, and by patents technological sector.

Dataset construction

The dataset used for this research is created from three main sources. First, we collect patent infringement actions involving universities as plaintiffs from Clarivate Darts-IP. Second, we match these data to other publicly available databases on US patent data (USPTO)—such as Patent Views (Version 2018) and Patent Assignment Database (version 2017). Third, we collect patent characteristics from USPTO-OECD patent quality database (version 2019).

Patent data

The exploitation of patent data presents two main challenges. First, patents' assignees names are not harmonized. Second, the sector of the patent assignee (private business enterprises, universities/higher education institutions, governmental agencies, individuals, etc.) is not reported.

In order to address the first issue, we develop an algorithm to clean and consolidate patent applicants' names.[8] In order to identify the sector of the patent assignee (in particular, whether the assignee is a university) we exploit the information from Ecoom-Eurostat-EPO-Patstat (EEE-PAT) database (Callaert et al., 2011). Whenever a correspondence between the patent assignee at the USPTO and the assignee at the EEE-PAT is not found, we perform an automatic search for keywords in the assignee name to allocate the unassigned entities to a unique sector.[9] By limiting our investigation to granted patents filed since 1990, our sample contains 156,492 university patents, of which 107,114 are patents filed by US universities.

Litigation data

Data on litigation cases are collected from Clarivate Darts-IP, which allows us to identify the type of actors involved (company, university, patent assertion entities, person, and authority). For this study, we collect all patent infringement actions in the US involving universities (including their TTOs, affiliated foundations and schools of medicine) as plaintiff, up to December 31, 2019. Patent litigation data contain information about where the cases were filed, the relevant dates, the patent number, the names of plaintiffs and defendants, the outcome (if any), as well as other information associated with the cases. After having collected all the patent infringement cases, we clean and harmonize plaintiffs' and defendants' names, taking into account different spellings to put together each university with its affiliated research entities.

[8] The matching is carried out by constructing a matching score (the Levenshtein distance or edit distance) between strings. We thank Gianluca Tarasconi for his help https://rawpatentdata.blogspot.com/.

[9] We use the business entities code to individuate private business enterprises, and keywords like "school" or "university" (and other similar words) to identify universities.

Table 1 Types of plaintiffs in university patent litigations (infringement actions 1990–2019)

Type of entities	Nb. of cases	Percent
Universities alone	206	36.92
University + firm	327	58.60
University + PAE	14	2.51
University + individual	3	0.54
University + authority	8	1.43
Total number of cases	558	100

This table corresponds to litigation initiated in the period 1990–2019. Cases where universities participate as co-plaintiffs with more than one type of entity are considered as follows: whenever a PAE appears as co-plaintiff the case is categorized as "University + PAE"; otherwise, whenever a firm (PAE excluded) appears a co-plaintiff, the case is categorized as "University + Firm"

US universities in courts: key figures

The final database includes 574 infringement actions filed in the US and 813 disputed patents issued at the USPTO, of which 521 are university patents—that is patents assigned to universities—and 292 are patents assigned to other types of organizations classified as university co-plaintiffs in the patent infringement action. The average number of patents in dispute per case is 2.76 and about one-third of these cases involve more than two patents. The jurisdiction with the most cases is the District of Delaware,[10] where universities file more than 16% of cases, confirming the findings of Rooksby (2011) and Firpo and Mireles (2018). The District of Texas Eastern and, to a lesser extent, the District of Delaware are among the top four districts in terms of patent holder favorability (Barry et al., 2014; Rooksby, 2011). Interestingly, of the 45 cases filed with the District of Texas Eastern, only three were initiated by a Texas based university, while most cases were filed by non-US universities.[11]

In the following subsections we first present key figures on the university lawsuit phenomenon ("Number and dynamic of university infringement actions filed in the US" section) and then consider its various aspects. Particular attention is paid to compare litigated patents between US and non-US universities and public and private universities ("Relevant characteristics of universities' litigated patents" section) and across technological areas ("Technology" section).

Number and dynamic of university infringement actions filed in the US

Litigation involving universities has been growing in the last 20 years. Figure 1 shows the evolution over time of the number of patent infringement litigation cases involving universities as plaintiffs from 1990 to 2019 (figures for 2019 may be incomplete due to updating delays), where the year corresponds to the year in which litigation cases start. The annual number of litigation suits has only begun to increase significantly over the last two decades.

[10] Figure 2 in Appendix shows the distribution of litigation cases across district courts (first instance).

[11] The decision to file a case in District of Texas Eastern with no apparent ties to venue is considered in the literature as sign of opportunistic litigation (Cohen et al., 2019; Feng & Jaravel, 2016; Rooksby, 2011).

Table 2 Top universities, by number of patent infringement suits in United States (1990–2019)

Research institutions	Country	No. of infringement cases	Rank: patent portolio	Percentage of cases without industry partner (%)
Boston University	US	42	55	95.24
University of California	US	37	1	40.54
Massachusetts Institute of Technology	US	32	3	18.75
University of Texas System	US	26	4	3.85
University of Wisconsin–Madison	US	23	5	21.74
University of South Florida	US	17	25	76.47
National Cheng Kung University	Taiwan	15	64	100.00
Emory University	US	15	44	6.67
University of Michigan	US	15	98	13.33
John Hopkins University	US	15	9	6.67
University of Illinois	US	14	11	7.14
Northwestern University	US	13	15	0.00
University of Strathclyde	UK	12	227	0.00
Queen's University at Kingston	Canada	11	108	0.00
California Institute of Technology	US	10	7	70.00

The table shows the top 15 universities by number of patent infringement suits in the US in the years 1990–2019. The ranking in the penultimate column is based on the number of patents assigned to universities at the USPTO since 1990. The last column shows the percentage of infringement cases initiated by universities in the US without the involvement of industry partner as co-plaintiff

The figure shows a constant rate change starting from the late 1990s, with an average annual number of new cases between 20 and 40 in the years 2005–2019, and a noteworthy peak in 2013 when we observe more than 90 new cases.[12]

Universities can decide whether to litigate alone or together with other entities, such as firms, patent assertion entities (PAEs),[13] individuals and so on. However, Table 1 shows that universities frequently participate as co-plaintiffs in enforcement lawsuits over their exclusively licensed patents. Faced with corporate opponents with huge legal budgets and teams of attorneys, for several years most universities could not afford to go the distance to protect their patents in court (Chien, 2010). Indeed, universities appear as co-plaintiffs with firm and PAEs in the majority of the cases (61%), while they litigate alone only in 206 cases (37% of cases in which they appear as plaintiffs). However, the alone litigation figure represents a relevant share of the total litigation as well, meaning that universities are ready to enforce their rights in court even in those cases not directly involving technology transfer to companies, and this is especially true in the last decade where, on average, universities litigate alone in about 40% of cases (see Fig. 3 in Appendix).

Table 2 provides a clearer picture of the patent university landscape by showing the top 15 universities by number of patent infringement suits in the US in the years 1990–2019,

[12] Among these 90 new cases, 38 were initiated by Boston University and 13 by the National Cheng Kung University.

[13] PAEs are entities that do not manufacture, distribute, or sell products. Their core business consists in negotiating licensing agreements over patents they either file or acquire.

Table 3 US vs non-US universities

	Litigated patents		All patents		Litigation propensity
	Nb. (A)	Percent	Nb. (B)	Percent	% of litigated patents
US	441	91.88	103,615	68.03	0.43
Non-US	39	8.12	48,690	31.97	0.08
Total	480	100	152,305	100	0.31

The table shows the number and percentage of university litigated (infringement actions) patents by university country (i.e., US or not-IS) in the period 1990–2019, as well as the total number of (granted) patents filed by universities since 1990

their country of origin, and their propensity to litigate. Indeed, over the 558 cases involving universities, we observe 93 unique universities as plaintiffs: 48 of them are involved in one or two cases, while 15 universities are involved in ten litigations or more. In most of the cases, top litigant universities are US-based: the only exception are the National Cheng Kung University (Taiwan), the University of Strathclyde (UK) and Queen's University at Kingston (Canada). The most active college is Boston University with 42 litigations, followed closely by the University of California and the Massachusetts Institute of Technology with 37 and 32 cases, respectively. Comparing the ranking of the top universities by the number of litigations with the ranking of the same universities in terms of patents filed, top universities in the patent ranking (such as the University of California, Massachusetts Institute of Technology, University of Texas System, etc.) consistently have a higher number of litigations, with few exception such as Boston University and the University of Michigan, which are heavily involved in litigation despite a relatively low number of patents filed.

Relevant characteristics of universities' litigated patents

In this section, we analyze the relationship between litigation and two relevant patent characteristics: the country of origin of the university and the type of institution, intended as public or private. First, we note a difference in the behavior of American[14] and foreign universities: as shown in Table 3, despite accounting for 32% of patents filed at USPTO, foreign universities are involved in only 8% of litigation. The difference in litigation propensities can be explained by the fact that US universities litigate in their own country, so they are more comfortable with the legal system and it is easier for them to find out when (and if) their patents are infringed.

Second, we compare the propensity to litigate between public and private universities. Since we could not find an official list of private and public universities in the world, we scraped a publicly available website (https://www.4icu.org/) that contains a list of 13,745 entries of universities in North America, Asia, Africa, Europe, and Oceania. To our knowledge, this website is the only one that provides free access to a complete list of universities with the information on type of the university (private vs public) via the variable "*control_type*". For the purposes of this analysis, the four categories of "*control_type*" (public, public-state, public–private partnership, and private) are reduced to public (including

[14] In case of patents co-assigned to US and non-US universities, we considered the patent as American.

Table 4 Public vs private universities

	Litigated patents		All patents		Litigation propensity
	Nb. (A)	Percent	Nb. (B)	Percent	% of litigated patents
Public	214	55.58	72,724	65.00	0.29
Private	171	44.42	39,162	35.00	0.43
Total	385	100	111,886	100	0.34

The table shows the number and percentage of university litigated (infringement actions) patents by university type (i.e., Public or Private) in the period 1990–2019, as well as the total number of (granted) patents filed by universities since 1990. The total number of patents differs from Table 3 since some patents are assigned to universities whose names do not match to our list of public and private universities

Table 5 Frequencies of US university patents and litigated patents by technology fields

	All patents		Litigated patents	
	Nb. (A)	Percent	Nb. (B)	Percent
Electrical Eng.	37,042	24.32	119	24.79
Instruments	34,069	22.37	117	24.38
Chemistry	73,229	48.08	219	45.63
Mechanical Eng.	6,603	4.33	20	4.17
Other fields	1,362	0.90	5	1.04
Total	152,305	100	480	100

The table shows the number and percentage of university litigated (infringement actions) patents by technological fields (5-sector WIPO classification) in the period 1990–2019, as well as the total number of (granted) patents filed by universities since 1990

public, public-state, and public–private partnership universities), and private. In order to match the assignee list of our dataset with the list of universities from www.4icu.org, we use the edit distance algorithm (see footnote 6). The analyses reported here are based on the 0.90 threshold matching score.[15] Moreover, when a patent is jointly owned by different universities, we consider it to be public if at least one of the owners is a public university.

The reason for this analysis is related to the concern expressed in the literature that publicly funded universities use taxpayer money to fund litigation, diverting resources from their mission to advance public knowledge (Rooksby, 2013). Table 4 shows that, on the one hand, public universities own much more patents compared to private ones (65% and 35% respectively); on the other hand, in line with findings from Firpo and Mireles (2018), this difference is much lower when we consider only litigated patents (55.6% versus 44.4%), suggesting that private universities have a higher propensity to litigate compared to public ones. We further investigate this issue in the econometric analysis.

[15] To check the robustness of our results, we use also other two thresholds (0.85 and 0.95). The econometric results discussed in the next section do not significantly vary using these different options, confirming the robustness of our findings.

Technology

Table 5 shows the number of US patents, filed since 1990, assigned to (Column A) and litigated by (Column B) universities, by technology sector according to WIPO's 5 macro sector classification (Squicciarini et al., 2013). The analysis of litigation sectors is particularly relevant because there is evidence in the literature of strategic litigation in the field of Electrical Engineering (Kingston, 2001; Sterzi et al., 2021).[16] However, descriptive statistics do not show a strong heterogeneity across technological classes, as universities litigate more in the field in which they file more patents. The largest number of patents filed and litigated by universities is in Chemistry (46% of all patents litigated), which is also the technological field in which they file the most patents (48% of university patents).

Econometric analysis of the characteristics of the university-litigated patents

Variables and methodology

The descriptive statistics from the last section provide an overall picture of the phenomenon of patent litigation by universities in the US. In this section we try to go one step forward, by relying on an econometric model to identify the main characteristics of litigated university patents compared to non-litigated ones.

In the econometric analysis, we consider all patents filed at USPTO by universities since 1990 and granted until 2014. We drop all patents granted after 2014, because only few of them have been litigated afterwards. The final dataset contains 122,182 patents, of which 469 have been litigated (in infringement cases) by universities, corresponding to about 0.4% of all university patents.

In our econometric exercise, the response variable (*Litigation*) is thus a dichotomous variable whereby litigated patents are designated as "1" while non-litigated ones are coded with "0". Hence a Logit model approach is deemed appropriate here:[17]

$$Prob\left(Litigation_i = 1\right) = F\left(X_i\right) = \frac{e^{\beta' X_i}}{1 + e^{\beta' X_i}}. \quad (1)$$

In other words, the probability of a litigation is assumed to be a function of a vector of explanatory variables, X. One of our main variables of interest is the technological importance of the invention (*Fwd_cits*5), which we proxy with the number of citations received by the focal patent in a window of five years starting from the filing date. Citations received by a patent are one indication that an innovation has contributed to the development of subsequent inventions and they are widely used as proxy of patent quality in the literature

[16] The Electrical engineering sector includes the following subclasses: 1. Electrical machinery, apparatus, energy; 2. Audio-visual technology; 3. Telecommunications; 4. Digital communication; 5. Basic communication processes; 6. Computer technology; 7. IT methods for management; 8. Semiconductors.

[17] We are aware that using conventional logistic regression for data in which events are rare could be an issue (Chowdhury, 2021). However, this problem seems to diminish as the sample size and the number of cases on the rarer of the two outcomes increase (King & Zeng, 2001). However, we also employ a penalized maximum likelihood estimation method for reducing bias in generalized linear models (Firth, 1993) and a rare events logistic regression (King & Zeng, 2001). Results are unchanged.

Table 6 Summary statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Litigation	122,182	0.0038	0.0618	0	1
US (dummy)	122,182	0.7106	0.4535	0	1
Public (dummy)	89,515	0.6510	0.4767	0	1
Elec_Engin (dummy)	122,182	0.2380	0.4258	0	1
Fwd_cits5	122,182	11.8724	35.9946	0	2378
Patent_scope	122,182	2.4732	1.5770	1	17
Claims	122,182	18.2746	14.7394	1	397
Bwd_cits	122,182	15.3116	21.8050	0	254
Npl_cits	122,182	17.5816	25.1289	0	195
Renewal	122,182	10.1855	3.7909	0	20

Unit of observation: patent. Grant years: 1990–2014

on academic inventions (Carayol & Sterzi, 2021; Czarnitzki et al., 2011; Henderson et al., 1998; Sterzi, 2013). Patent quality has been found in the literature as one of the main variables correlated with litigation when plaintiffs are product companies (Bessen & Meurer, 2006; Harhoff et al., 2003). However, non-practicing entities and, in particular, PAEs have been sometimes accused to litigate weak and low-quality patents (Chien, 2011; Cohen et al., 2019; Risch, 2015). In our framework, investigating whether universities assert their most valuable patents is particularly relevant since a negative correlation with patent quality could be a signal of low effectiveness of TTO (or more in general university administrators) for patents that deserve to be asserted or of monetization strategic behavior similar to PAEs. Among the explanatory variables, we also include a larger set of indicators (*Claims*, *Renewals, Bwd_cits*, and *Npl_cits*) that may capture other dimensions of patent value in addition to technological quality captured by forward citations. In general, the higher the value of these indicators, the higher the expected value of the patent (Squicciarini et al., 2013). *Claims* accounts for the number of claims of a given patent, which define novel features of the invention. Generally, it is associated with the technological breadth or the market value of a patent and reflects a larger risk of conflict with competitors (Tong & Frame, 1994). Similarly, *Renewals* is also a proxy for patent value, indicating the number of years a patent is valid. Since maintaining patent protection over time is costly, we assume that valuable patents pay at least for their own renewal and that the more valuable patents will be renewed for a longer time (Sterzi et al., 2019). *Bwd_cits* looks at backward citations, considering all potential sources of knowledge of a given patent, such as prior patents and scientific works (Harhoff et al., 2003). A low number of backward citations could indicate that the invention is in a relatively new and uncrowded technology area (Harhoff & Reitzig, 2004; Harhoff et al., 2003; Lanjouw & Schankerman, 2004). We thus expect the likelihood of litigation to increase with the number of backward citations. *Npl_cits* measures the size of the non-patented literature cited by the patent, which denotes the technical closeness of an invention to scientific knowledge and is found to be correlated with patent value (Branstetter, 2005).

In addition to measure patent value, we also include in our specification *Patent_scope*, which is a variable that estimates the breadth of the patent and is measured by counting the number of distinct 4-digit IPC classes the invention is allocated to (Lerner, 1994) and it is found to be correlated with the probability that the patent can be infringed and thus litigated (Fischer & Henkel, 2012; Lerner, 1994; Sterzi et al., 2021). Moreover, since there

may be significant differences in litigation rates across technological fields and years (Lanjouw & Schankerman, 2001), we also control for technological sector (WIPO 35 technological classes), while grant year fixed effects control for changes across years that affect the propensity to litigate. Table 6 provides the main summary statistics of the variables under study.

Main results

Column (1) of Table 7 provides the results of the logistic regression for our baseline equation. Patent quality is positively correlated with the litigation decision. All the coefficients of patent value indicators are positive and significant, indicating that a patent's market value increases litigation propensity. In particular, a one-unit increase in *Fwd_cits5* leads to a 0.29% increase in the odds of being litigated.

In columns (2)–(5) of Table 7, three dummy variables, *US*, *Public* and *Elec_Engin*, are included in the baseline equation, first one at a time (Columns 2–4), then all together (Column 5). These complementary variables correspond to university (*US*, *Public*) and patent (*Elec_Engin*) characteristics of particular interest as explained above. In doing so, we deepen the descriptive analysis proposed in "Relevant characteristics of universities' litigated patents" and "Technology" sections, and confirm the consistency of the main results. Furthermore, it is interesting to note that the goodness of fit of the model improves significantly with the inclusion of US and Public. This is further justification for the role played by these two features as drivers for patent litigation. *US* controls for the country of the university, the address of the assignee reported in the patent document. It takes the value of one when at least one university among the applicants comes from the US. This variable is meant to control for the different costs of the trial relative to the cost of settlement for domestic and foreign applicants (universities) and for the disadvantage for foreign universities in detecting infringements in the US market. In line with descriptive statistics, the *US* dummy has a positive and significant impact in both columns (2) and (5), meaning that US universities are more likely to litigate their patents than non-US universities (the odds of being litigated for US university patents ranges between 1.8154 and 2.5021 times that of non-US university patents). *Public* takes the value of one when at least one university among the applicants is public. The odds ratios below 1 in columns (3) and (5) indicate that patents held by at least one public university have a lower probability of being litigated than patents held by private universities, in line with descriptive statistics shown in Table 4. In other words, the odds to be litigated for patents owned by public universities are between 19.75 and 22.86% lower than the odds for private-owned patents.[18] Finally, *Elec_Engin* takes the value of one for Electrical Engineering patents (WIPO-5 sectors classification). Controlling for observable patent characteristics, these patents display a higher litigation propensity compared to patents in other sector, as shown in Columns (4) and (5) of Table 7. In particular, the odds for university patents in the Electrical Engineering sector are about 48.33% (Column 4) and 68.58% (Column 5) higher than the odds for patents in other sectors.

Differences in the number of observations are due to missing values (32,667 cases) in the *Public* variable. Additionally, in Column (3), 420 observations were further dropped

[18] In column (3): $0.7714 - 1 = -0.2286$. This corresponds to a decrease of about 22.86% in the odds of being litigated by public university with respect private university.

Table 7 Main results

Variables	(1) Y = litigated patent Odds ratio	(2) Y = litigated patent Odds ratio	(3) Y = litigated patent Odds ratio	(4) Y = litigated patent Odds ratio	(5) Y = litigated patent Odds ratio
Fwd_cits5	1.0029***	1.0030***	1.0026***	1.0028***	1.0026***
	(9.0675)	(10.671)	(8.9037)	(7.7714)	(8.8460)
Patent_scope	0.9929	0.9934	0.9919	0.9643	0.9635
	(0.2677)	(0.2476)	(0.2730)	(1.3935)	(1.3058)
Claims	1.0085***	1.0081***	1.0087***	1.0090***	1.0089***
	(4.9204)	(4.6318)	(4.3875)	(5.3739)	(4.4633)
Bwd_cits	1.0119***	1.0111***	1.0122***	1.0133***	1.0131***
	(8.4050)	(7.7468)	(7.6581)	(10.052)	(8.8963)
Npl_cits	1.0150***	1.0137***	1.0131***	1.0131***	1.0105***
	(9.0337)	(8.3490)	(6.8361)	(8.2241)	(5.6552)
Renewal	1.0798***	1.0783***	1.1046***	1.0896***	1.1133***
	(4.3657)	(4.2716)	(4.7032)	(4.8684)	(4.9997)
US (= 1)		2.5021***			1.8154***
		(5.1267)			(3.2209)
Public (= 1)			0.7714**		0.8025**
			(2.4607)		(2.1203)
Elec_Engin (= 1)				1.4833***	1.6858***
				(3.3644)	(4.2915)
Observations	122,182	122,182	89,095	122,182	89,515
Technology fixed effects	Yes	Yes	Yes	No	No
Grant year fixed effects	Yes	Yes	Yes	Yes	Yes
Pseudo R2	0.1035	0.1089	0.1088	0.0822	0.0884
AIC	5587.294	5555.716	4383.819	5712.230	4483.809
BIC	5927.258	5905.394	4712.730	6023.055	4803.482

Logit regressions

Unit of observation: patent. Grant years: 1990–2014; Robust z-statistics (in absolute value) in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. The dependent variable is one when the university patent has been litigated, zero otherwise. The results are expressed as odds ratios (OR)

for perfectly predicting litigation outcome. We performed two different sensitivity analyses. First, we restricted the sample to 89,095 observations consistently as in Column (3) of Table 7 and we re-did all five models. Second, we eliminated the sector dummy (*Civil engineering*, corresponding to sector 35 in WIPO classification) which causes the 420 observations drop in Column (3) and re-ran all five models. The main results still hold in both cases.

The analysis covers a rather long-time span that could be problematic due to the potential presence of idiosyncratic shocks. So, as a further robustness check, in order to control for university fixed effects, a set of dummy variables is added to all specifications of Columns (1)–(5) of Table 7, representing the most productive universities with at least ten patents. Again, the main results still hold.

Moderating effects analysis

Overall, our results show that the quality of litigated university patents is significantly higher than non-litigated ones. This may suggest that TTOs and university administrations litigate patents covering inventions used by companies that do not intend to reward their economic value. In what follows, we study whether this result varies according to certain patent and university characteristics.

In so doing, we estimate three augmented versions of Eq. (1), which include the interactions of all the patent value measures with *US*, *Public* and *Elec_Engin*. Table 8 shows the results of the three above-mentioned specifications. The set of variables under study are interacted with the *US* dummy (Column 1), *Public* dummy (Column 2), and *Elec_Engin* dummy (Column 3).

First, as shown in Column 1 of Table 8, in case of non-US university patents, a one-unit increase in *Fwd_cits5* leads to a 0.11% increase in the odds of being litigated, while the increase is about 0.36% for US university patents ($1.0011 \times 1.0025 - 1 = 0.0036$). This difference could be explained by the fact that for non-US universities it is more difficult to identify valuable patents that deserve to be litigated because of their remoteness from the US market. Second, the ceteris paribus correlation between technological quality and litigation is lower for patents assigned to public universities compared to those assigned to private universities. In particular, the odds ratio of *Fwd_cits5* is 1.0035 for patents assigned to private universities, while it is about 1.0018 for patents assigned to public universities (see Column 2 of Table 8). This result may be explained considering the higher ability of private universities and their TTOs to identify valuable patents that deserve to be litigated. Finally, Column 3 of Table 8 indicates that the patent technological quality is positively associated with litigation also in the Electrical Engineering sector—a sector traditionally more prone to opportunistic patent litigation (Chien, 2010). Indeed, a one-unit increase in *Fwd_cits5* leads to a 0.19% increase in the odds of being litigated in the case of Electrical Engineering patents, while the increase is about 0.45% for patents in other sectors. Although statistically significant, this difference should be interpreted cautiously because a citation in the Electrical Engineering sector may not have the same value as a citation in other technological sectors (Van Zeebroeck, 2011).

As before, a robustness check is conducted. We control for university fixed effects by including a set of dummy variables to all specifications of Columns (1)–(3) of Table 8, which indicate the most productive universities with at least ten patents. Again, the main results still hold. Finally, we are aware that patenting behavior could differ between for-profit and non-profit universities. We identified only four for-profit institutions in our

Table 8 Moderating effects analysis

Variables	(1) Y = litigated patent Odds ratio	(2) Y = litigated patent Odds ratio	(3) Y = litigated patent Odds ratio
Fwd_cits5	1.0011***	1.0035***	1.0045***
	(2.7010)	(8.3632)	(8.1275)
Patent_scope	0.9725	0.9542	0.9549
	(0.2140)	(1.2158)	(1.4677)
Claims	1.0144***	1.0066*	1.0094***
	(3.3058)	(1.9178)	(4.9253)
Bwd_cits	1.0206***	1.0121***	1.0136***
	(4.8494)	(6.3577)	(8.7589)
Npl_cits	1.0005	1.0158***	1.0110***
	(0.07214)	(6.3288)	(6.5954)
Renewal	1.0752	1.0997***	1.0956***
	(1.2537)	(3.1693)	(4.6623)
US (= 1)	2.3790		
	(1.1787)		
Public (= 1)		0.6566	
		(0.9074)	
Elec_Engin (= 1)			2.0104
			(1.5715)
Interaction terms	US	Public	Elec_Engin
Fwd_cits5	1.0025***	0.9983***	0.9974***
	(4.8368)	(3.2619)	(3.9825)
Patent_scope	1.0141	1.0687	0.9675
	(0.1060)	(1.1959)	(0.4974)
Claims	0.9933	1.0037	0.9935
	(1.4225)	(0.8822)	(1.4511)
Bwd_cits	0.9899**	0.9994	0.9934**
	(2.3310)	(0.2102)	(2.0579)
Npl_cits	1.0134*	0.9942	1.0128***
	(1.8618)	(1.6430)	(2.8702)
Renewal	1.0056	1.0132	0.9919
	(0.09324)	(0.3499)	(0.2165)
Observations	122,182	89,095	122,182
Technology fixed effects	YES	YES	NO
Grant year controls	YES	YES	YES
Pseudo R2	0.1107	0.1112	0.08628
AIC	5556.57	4404.276	5649.031
BIC	5964.527	4883.547	5775.303

Logit regressions

Unit of observation: patent. Grant years: 1990–2014; Robust z-statistics (in absolute value) in parentheses; ***$p < 0.01$,**$p < 0.05$, *$p < 0.1$. The results are expressed as odds ratios (OR). The second part of the table contains the interaction terms. *Fwd_cits5*, *Patent_scope*, *Claims*, *Bwd_cits*, *Npl_cits*, and *Renewal* are interacted with the *US* dummy (Column 1), *Public* dummy (Column 2), and *Elec_Engin* dummy (Column 3), respectively

dataset, namely American Public University System, California North State College of Pharmacy, DigiPen Institute of Technology, and National Institute of Technology. As a further robustness check, we performed the analyses on non-profit entities sample only. Tables 9 and 10 in the Appendix respectively mirror. Tables 7 and 8 without including the abovementioned four for-profit institutions. All results are confirmed.

Discussion and conclusion

Over the past 40 years, the number of patent applications filed by universities with the USPTO has increased dramatically. This is largely due to US institutions increasing their activities in response to the Bayh-Dole Act, but also to the explosive growth of the software and the biotechnology sectors and, since the 2000s, to a greater attention of foreign universities to the US market. University patents granted by the USPTO accounted for about 1% of the total number of patents granted before the 1990s and now stand at nearly 4%.

At the same time, the role of TTOs evolved from ensuring patent protection and simply managing licensing activities to a more "patent-centric" vision (Frye & Ryan, 2020; Kesan, 2008; Pilz, 2020), while attempting to achieve sometimes competing goals (Sherer & Vertinsky, 2020). Extreme consequences of this vision include the tendency to patent as much as possible to alleviate economic pressure to cover their costs, and the involvement of TTOs in patent litigation as "buffer" organizations between the filing university and the defendants (Rooksby, 2011).

Despite the increasing attention paid to the modern rise in patent filings and the involvement of patent trolls in the patent market, the characteristics of universities' increasing interest in litigation have not received equal attention, with the exception of few cases (Firpo & Mireles, 2018, 2020; Lemley, 2007; Rooksby, 2011). In our work, we go further in depth by collecting data on patents filed by universities at the USPTO and infringement suits brought by universities in the years 1990–2019. In doing so, we provide a detailed exploratory analysis that describes this overlooked phenomenon.

Our descriptive results show that university patent litigation has experienced a strong expansion in the last two decades. In particular, we observe a constant rate change starting from the late 1990s, with an average annual number of new infringement cases between 20 and 40 in the years 2005–2019, and a noteworthy peak in 2013 when we observe more than 90 new cases.

Our econometric results show that patent quality is an important determinant in the decision of university litigation. This result holds no matter the type of university (public vs private, or US vs non-US) and across sectors. In particular, this result holds for patents in Electrical Engineering field, which is traditionally prone to opportunistic patent litigation. Furthermore, our econometric analysis highlights other characteristics that correlate with litigation. First, we observe that the propensity to litigate is significantly higher for US universities with respect to non-US universities. Second, we show that public universities are in general less inclined to litigate their patents, confirming that litigation is more a habit of private universities, which have more freedom and, on average, more funds to engage in patent litigation. Third, we observe that university patents in the Electrical Engineering sector show a higher propensity to be litigated compared to university patents in other sectors. Several robustness tests have been performed, all confirming the validity of our results. First, two alternative thresholds are considered for the matching score, in order to verify that this choice does not affect our results. Further, we include a set of dummy variables which indicate the most productive universities with at least ten patents. As third

robustness check, we exclude the for-profit universities from our analysis. Eventually, we performed two sensitivity analyses on Table 7: the former using the smallest sample (Column 3); the latter, removing the sector dummy *Civil Engineering* which causes the perfect failure prediction for 420 observations.

This study also presents certain limitations, which constitute avenues for further research. First, additional characteristics of universities should be included in the analysis in order to take into account the high heterogeneity of the HEIs involved. In this respect, variables concerning human and financial resources employed in technology transfer activity and the previous litigation experience of universities would be of particular interest. Second, the comparison between cases where universities initiate the litigation alone and those where they join industrial partners should be deepened. In this respect, the similarities and differences between the evolution of litigations involving universities and those involving industrial corporations only should be further explored. Third, the use of conventional logistic regression for data in which events are rare could be an issue (Chowdhury, 2021), as the low pseudo-R2 values would seem to indicate. However, our main results are still confirmed when employing alternative techniques, i.e. the penalized maximum likelihood estimation method and the rare events logistic regression.

Appendix

See Figs. 2, 3, Tables 9 and 10.

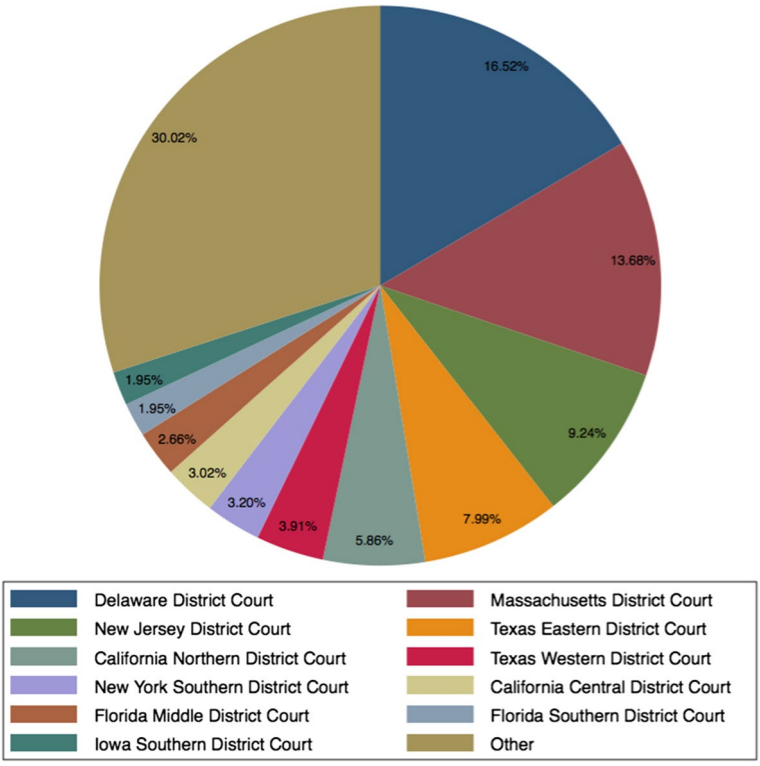

Fig. 2 Venues of litigation. The figure shows the share of infringement cases initiated by universities across district courts. (Color figure online)

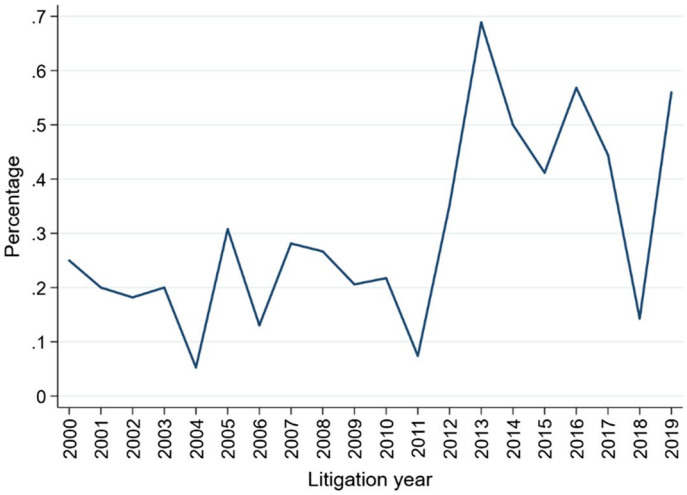

Fig. 3 Share of universities' alone infringement cases (2000–2019). The figure shows the percentage of cases in which universities participate alone in courts in the years 2000–2019. The litigation year corresponds to the year in which cases started

Table 9 Main results

Variables	(1)	(2)	(3)	(4)	(5)
	Y = litigated patent	Y = litigated patent	Y = litigated patent	Y = litigated patent	Y = litigated patent
	Odds ratio	Odds ratio	Odds ratio	Odds ratio	Odds ratio
Fwd_cits5	1.0029***	1.0030***	1.0026***	1.0028***	1.0026***
	(9.0652)	(10.670)	(8.9039)	(7.7683)	(8.8457)
Patent_scope	0.9928	0.9934	0.9918	0.9642	0.9634
	(0.2717)	(0.2513)	(0.2770)	(1.3989)	(1.3112)
Claims	1.0085***	1.0081***	1.0087***	1.0090***	1.0089***
	(4.9131)	(4.6253)	(4.3791)	(5.3700)	(4.4599)
Bwd_cits	1.0119***	1.0111***	1.0122***	1.0133***	1.0131***
	(8.4102)	(7.7518)	(7.6642)	(10.062)	(8.9086)
Npl_cits	1.0149***	1.0137***	1.0131***	1.0131***	1.0105***
	(9.0201)	(8.3362)	(6.8209)	(8.2059)	(5.6363)
Renewal	1.0808***	1.0793***	1.1061***	1.0904***	1.1145***
	(4.3851)	(4.2931)	(4.7267)	(4.8828)	(5.0228)
US (= 1)		2.5016***			1.8146***
		(5.1253)			(3.2181)
Public (= 1)			0.7715**		0.8025**
			(2.4603)		(2.1203)
Elec_Engin (= 1)				1.4837***	1.6866***
				(3.3668)	(4.2949)
Observations	122,179	122,179	89,094	122,179	89,514
Technology fixed effects	Yes	Yes	Yes	No	No
Grant year fixed effects	Yes	Yes	Yes	Yes	Yes
Pseudo R2	0.1036	0.1090	0.1090	0.08228	0.08855
AIC	5586.709	5555.150	4432.981	5709.603	4482.949
BIC	5926.672	5904.827	4996.828	6010.714	4802.622

Logit regressions (non profit universities only)

Unit of observation: patent. Grant years: 1990–2014; Robust z-statistics (in absolute value) in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. The dependent variable is one when the university patent has been litigated, zero otherwise. The results are expressed as odds ratios (OR)

Table 10 Moderating effects analysis

Variables	(1)	(2)	(3)	(4)	(5)
	Y = litigated patent	Y = litigated patent	Y = litigated patent	Y = litigated patent	Y = litigated patent
	Odds ratio	Odds ratio	Odds ratio	Odds ratio	Odds ratio
Fwd_cits5	1.0029***	1.0030***	1.0026***	1.0028***	1.0026***
	(9.0652)	(10.670)	(8.9039)	(7.7683)	(8.8457)
Patent_scope	0.9928	0.9934	0.9918	0.9642	0.9634
	(0.2717)	(0.2513)	(0.2770)	(1.3989)	(1.3112)
Claims	1.0085***	1.0081***	1.0087***	1.0090***	1.0089***
	(4.9131)	(4.6253)	(4.3791)	(5.3700)	(4.4599)
Bwd_cits	1.0119***	1.0111***	1.0122***	1.0133***	1.0131***
	(8.4102)	(7.7518)	(7.6642)	(10.062)	(8.9086)
Npl_cits	1.0149***	1.0137***	1.0131***	1.0131***	1.0105***
	(9.0201)	(8.3362)	(6.8209)	(8.2059)	(5.6363)
Renewal	1.0808***	1.0793***	1.1061***	1.0904***	1.1145***
	(4.3851)	(4.2931)	(4.7267)	(4.8828)	(5.0228)
US (= 1)		2.5016***			1.8146***
		(5.1253)			(3.2181)
Public (= 1)			0.7715**		0.8025**
			(2.4603)		(2.1203)
Elec_Engin (= 1)				1.4837***	1.6866***
				(3.3668)	(4.2949)
Observations	122,179	122,179	89,094	122,179	89,514
Technology fixed effects	Yes	Yes	Yes	No	No
Grant year fixed effects	Yes	Yes	Yes	Yes	Yes
Pseudo R2	0.1036	0.1090	0.1090	0.08228	0.08855
AIC	5586.709	5555.150	4432.981	5709.603	4482.949
BIC	5926.672	5904.827	4996.828	6010.714	4802.622

Logit regressions (non profit universities only)

Unit of observation: patent. Grant years: 1990–2014; Robust z-statistics (in absolute value) in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. The dependent variable is one when the university patent has been litigated, zero otherwise. The results are expressed as odds ratios (OR)

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Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

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