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University patent litigation in the United States: Do we have a problem?☆

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ABSTRACT

In an attempt to increase revenues from patenting activities, some universities have started in recent years to pursue "overzealous" strategies to monetize their existing patents, by selling them to the highest bidder and enforcing them in court. In this paper we find quantitative evidence that patent litigation has an adverse effect on university technology transfer activities, reinforcing prior findings by Shane and Somaya (2007). However, we empirically show that universities do not litigate aggressively over patent infringement: not only do they litigate much less than patent assertion entities (PAEs), but we also observe no increase in terms of their propensity to litigate over the last two decades. Nor do we find any evidence of aggressive litigation strategies.

1. Introduction

Traditionally, universities have been perceived as a support structure for innovation, whose approach to knowledge creation and diffusion influences the entire economy (Nelson, 1993). However, their role in the innovation arena changed after the second academic revolution (Etzkowitz, 2001), when universities started to engage in entrepreneurial activities, not without tensions, in order to transform the outcomes of their inventions into patented and thus marketable products (Etzkowitz, 1990). Higher education institutions (HEIs) have thus changed their role in the innovation ecosystem, by integrating university culture with the commercial assumptions underlying intellectual property (IP) law (Ghosh, 2016). In this perspective, changes in the relationship between HEIs and IP are interesting to study for the innovation system as a whole (Adams, 1990).

Since the passage of the Bayh-Dole Act in 1980, the number of university patents in the United States (US) has significantly increased (Council et al., 2011) and universities have become increasingly involved in technology transfer activities. However, at least for the time being, these activities do not seem to be too fruitful in terms of revenue generation. An extensive study by the Brooking Institution (Valdivia, 2013) shows that 84% of US universities did not break even in technology transfer in 2012. In addition, empirical evidence also shows strong heterogeneity across universities: looking at data from 155 universities, the eight universities with the highest licensing revenue accounted for 50% of licensing revenue across the entire sample, suggesting that few patents granted to academic institutions are likely to be highly valuable (Ryan Jr. and Frye, 2017).

In the attempt to increase revenue streams from patenting activity, some universities are redoubling their efforts to pave the way for sharing and selling their scientific results. For example, in mid-2018, Stanford University reorganized its technology transfer office (TTO) under a new director, centralizing its functions and hiring new business development staff, to provide "a higher return on marketing efforts".[2] At the same time universities are making use of non-traditi onal strategies to monetize their patents (Ouellette and Weires, 2019). Some studies find evidence of an increasing partnership between uni-

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[2] https://hechingerreport.org/think-universities-are-making-lots-of-money-from-inventions-think-again/ (accessed July 2021).

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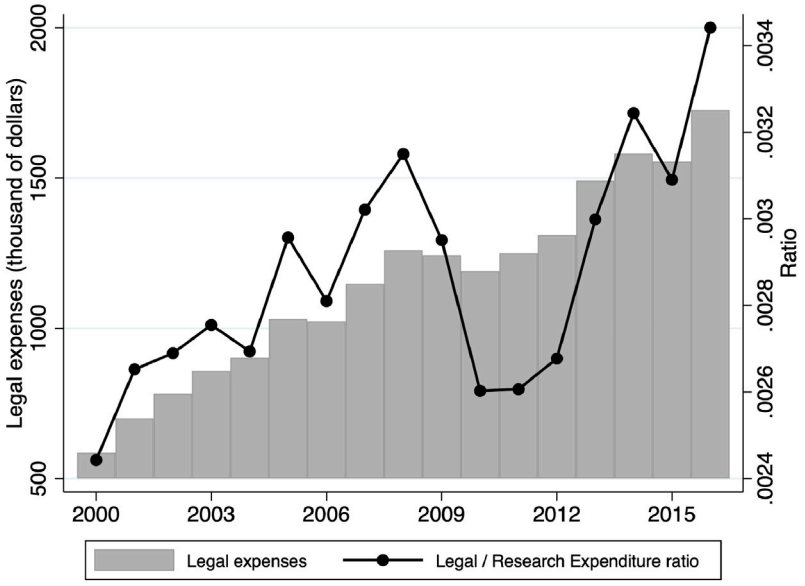

Fig. 1. Average legal expenses (US universities).
Notes: The figure shows the average legal expenses (in thousands of dollars) and its ratio over the total research expenditure for US Universities. Legal expenses are net of reimbursed. Only universities with complete information over the years 2000–2016 are considered in this figure. Own elaboration based on data from AUTM (2016).

versities and patent assertion entities (PAEs) (Feldman and Ewing, 2012; Fusco et al., 2019; Love et al., 2020),[3] whose business model has been much criticized in the US and Europe (Bessen et al., 2011; Cohen et al., 2019; Sterzi et al., 2021; Orsatti and Sterzi, 2023). Other studies reveal that US universities organize auctions (like Pennsylvania State University) or rely on auctions organized by third parties to sell their patents (Cahoy et al., 2016).[4] Finally, more recent studies also show that the presence of universities in the courts has increased significantly over the last twenty years (Firpo and Mireles, 2020; Ascione et al., 2022), sometimes with remarkable success.[5] Accordingly, litigation expenses (and all legal expenses in general) are growing at a faster pace than research expenditure (see Fig. 1).

Since universities play a major role in both the production and the dissemination of knowledge, the way they monetize their patents might have a significant impact on society. In this respect, one relevant issue is that university-created inventions are in many cases publicly funded (Drivas et al., 2017; Thompson et al., 2018) and therefore should be consistent with objectives of national, if not global, interest. Furthermore, greater involvement in litigation activity could reduce the time and resources of universities' TTOs to market technologies and establish licenses (Shane and Somaya, 2007). Finally, by engaging in hold-up practices, universities could also reduce overall innovation (Lemley, 2008; Firpo and Mireles, 2018). In 2008, Mark Lemley wrote an article on the topic, entitled "Are Universities Patent Trolls?", where he argues that, although universities cannot be considered as patent trolls, as non-practicing entities, they could potentially show aggressive behavior in their litigation activities (Lemley, 2008).

In this paper we contribute towards a better understanding of the university patent litigation phenomenon by studying whether universities are becoming more litigious over time and share some similar characteristics with PAEs, and investigating what effect patent litigation has on university efforts in technology transfer activities.

We combine three different sources of empirical data. First, we collect patents granted by the US Patent and Trademark Office (USPTO), characterizing the type of last owner (we consider three categories: university, PAE, and other entities). Second, we collect all litigated patents in infringement actions in the period (2003–2016) identifying, for each of them, the type of plaintiff (as before, we consider three types of owner: university, PAE, and other entities).[6] Third, we use data from the Association of University Technology Managers (AUTM, version 2016), which conducts an annual study of technology transfer efforts at US universities and contains information on technology transfer activities for large US research institutions, universities and hospitals in the years 1991–2016.

We empirically show that, at least to date, universities exhibit different behavior compared to PAEs in many respects. First of all, not only are universities significantly less litigious than PAEs, but their propensity to litigate has not increased over the last two decades. Second, universities and PAEs have different litigation strategies, as far as patent and litigation observable characteristics suggest. Third, although these results are to some extent reassuring, they are in fact balanced by some quantitative evidence showing that patent litigation has an adverse effect on university technology transfer activities — thus reinforcing prior findings by Shane and Somaya (2007).

The remainder of the paper is organized as follows. In Section 2 we provide the background literature and the goals of our research. In Section 3 we investigate whether universities are becoming more litigious and to what extent universities and PAEs litigate similar patents. Section 4 is devoted to the impact of litigation on technology transfer activities of US universities. Section 5 concludes with the discussion of the policy implications of our results.

2. Background

2.1. The problem with university patent litigation

The traditional justification for university patents is that, in the absence of patent protection, academic inventions cannot be effectively transferred to the private sector and thus commercialized. The property right over academic inventions in fact encourages technology commercialization by giving both the universities and their licensees incentives

[3] For example, Intellectual Ventures, one of the largest and most well-known PAEs, has disclosed its relationships with around 50 universities (Feldman and Ewing, 2012).

[4] For example, university patents account for 20% of business for Ocean Tomo (Ledford, 2013).

[5] For example, the California Institute of Technology recently won a $1.1 billion patent verdict against Apple and Broadcom for infringement of patents held by the university on Wi-Fi technology, the largest jury verdict in 2020 and the sixth largest patent verdict ever.

[6] For university patent litigation we collect data from 1993.

to invest in the development of these inventions (Jensen and Thursby, 2001). For example, one stated policy of the Bayh-Dole Act of 1980 is "to promote the utilization of inventions arising from federally supported research or development". Furthermore, patent protection might also facilitate knowledge transfer from universities to the private sector by allowing professors to delegate the promotion of their scientific discoveries to the TTO and prevent the expropriation of complementary investments made for the commercialization of inventions (Hellmann, 2007).

However, university patents can also create incentives for universities to make inefficient investments (Frye and Ryan, 2020). In particular, transferring IP rights to universities may also provide TTOs with a higher incentive to pursue rents from patent enforcement even when it does not foster technology transfer. This situation can occur under two circumstances. First, when patent enforcement by universities takes the time and attention of licensing officers away from other activities required to commercialize university technology, such as marketing, search, and negotiation activities (Shane and Somaya, 2007). Second, when universities engage in hold-up practices (Lemley, 2008; Firpo and Mireles, 2018), enforcing their patents with the main purpose of extracting large licensing fees and imposing a "tax" on innovative companies. Since universities do not sell products, their incentives in dealing with the patent system align in many ways with those of PAEs, which are often accused of such practices (Cohen et al., 2019; Lemley and Feldman, 2020; Sterzi et al., 2021).[7] Like PAEs, universities have a pure financial interest in the patent (Lemley and Feldman, 2020) and can enjoy a privileged position when asserting their patents, such as advantages in litigation tactics and the impossibility of being counter-attacked by the defendant. Their (indirect) costs associated with litigation activities are thus significantly lower than those typical of product companies, making it convenient for universities to assert even weak patents and marginal technologies.

Not surprisingly, as was already the case in 2006, Stanford University and ten other top-tier research universities released a white paper urging universities to carefully consider their involvement as plaintiffs in patent litigation (AUTM, 2007). In particular, the paper underlined the importance for universities of putting forward their primary mission, which is to advance the public good with their inventions and technological developments (Rooksby, 2012). These concerns were also shared by US courts and judges to the point that universities are increasingly considered as for-profit businesses and unlikely to be granted immunity under the experimental use exemption (Rowe, 2005).[8]

In spite of several similarities with PAEs, universities are however very distant from their business model, thus reducing concern about their behavior in court. First of all, contrary to PAEs, universities use what they receive from litigation activities largely for financing research activities. Second, universities are at the origin of their patents, contrary to PAEs, which often acquire patents in the secondary market,[9] and the inventor usually receives some revenue from the patent commercialization. Third, universities are concerned about their reputation, which significantly increases their (indirect) litigation costs, thus making it less worthwhile to litigate weak patents (Firpo and Mireles, 2020). For example, the list published by the Electronic Frontier Foundation (EFF) reporting the names of universities that have formed a limited liability company (LLC) to monetize their patents garnered significant media attention and caused considerable indignation among the public.[10]

2.2. Existing research

Is university patent litigation activity an efficient mechanism for technology transfer or, rather, has the objective of extracting large licensing fees and imposing a "tax" on innovative companies? From a theoretical point of view, both arguments are sound. On empirical grounds, only few studies have examined university patent litigation, and they provide only partial answers.

Ascione et al. (2022) provide a detailed portrait of infringement cases initiated by universities in the US, showing an increasing presence in court in the last twenty years. In particular, they observe a constant rate of change starting from the late 1990s, with an average annual number of new infringement cases initiated by universities between 20 and 40 in the years 2005–2019. They also find that patent quality is an important determinant in universities' decisions to litigate, suggesting that litigation is on average legitimately used by universities as a market feature to protect the proprietary rights of valuable innovation, rather than merely a means to collect money.

Shane and Somaya (2007) warn about the potential negative effects of an excessive presence of universities in courts. In particular, they focus on the effects that patent litigation can have on universities' efforts to license their technologies. Relying on an unbalanced panel of 116 universities litigating their patents between 1991 and 2000, they find that litigation has a negative effect on new licenses, but no effect on other types of technology transfer activities (such as new patents filed and invention disclosures). Furthermore, they also corroborate their results by interviewing technology licensing office directors who suggest that litigation often disrupts overall TTO activity since it reduces the resources available for marketing technologies and establishing licenses.

Rooksby (2011) and Firpo and Mireles (2018, 2020) describe the characteristics of cases of infringement lawsuits initiated by universities (and the patents involved in them) and question the potentially strategic nature of university behavior in these litigations. In particular, the study by Rooksby (2011) covers 57 cases between 2009 and 2010, involving 125 patents. The author concludes that certain characteristics, such as the preference for a jury rather than a judge, suggest that the behavior of universities resembles that of for-profit actors. Firpo and Mireles (2018) study litigation cases filed by universities, foundations and non-profit organizations in the period 2000 to 2015. They find that US universities litigate a significant share of their patents in the Eastern District of Texas and relatively late in their term, that they consider two features of PAE-like behavior, suggesting that universities are asserting patents against a technology that has already been commercialized.[11]

[7] The alignment of the interests of universities to those of PAEs became apparent when university associations lobbied against anti-troll legislation that would also thwart their ability to engage in litigation (Valdivia, 2015).

[8] In particular, a recent opinion by the Federal Circuit (Madey v. Duke) makes clear that universities should not be granted immunity under experimental use (Rowe, 2005), pointing out that "Duke [...] like other major research institutions of higher learning, is not shy in pursuing an aggressive patent licensing program from which it derives a not insubstantial revenue stream".

[9] Interestingly, there is, however, some evidence showing that universities sometimes assert patents not invented by their faculty. For example, the University of New Mexico asserted in 2019 two patents that were purchased from the Industrial Technology Research Institute (ITRI), a Taiwanese entity established and funded by the Taiwanese government.

[10] https://www.eff.org/fr/deeplinks/2021/06/15-universities-have-formed-company-looks-lot-patent-troll

[11] For example, Boston University in 2014 won settlements with 25 companies (included large companies in the tech industry such as Amazon, Apple and Microsoft, among others) it sued for infringing their blue light-emitting diodes (LEDs) patented technology (US5686738) filed nineteen years before. Incidentally, other companies did not settle and the jury found that they infringed the '738 patent and failed to prove the patent's invalidity. However, the defendants appealed to the Federal Circuit, which reversed and made the patent invalid for not meeting the enablement requirement. Another famous case of late enforcement of patents is Carnegie Mellon University, which in 2016 received $750 million from Marvell Technology as a settlement for a case of infringement of two patents (US6201839, filed in 1998 and US6438180,

Finally, more recently, Horner et al. (2022) study the impact of patent litigation involving universities as defendants (rather than plaintiffs) of infringement actions. The authors empirically show that the choice to defend (rather than settle) inadvertently reveals to potential licensees that the university produces technologies with substantial commercial value, increasing the licensing income for TTOs.

Our contribution to the literature is threefold. First, we ask whether universities have changed their propensity to litigate their patents over time, as anecdotal evidence and descriptive statistics seem to suggest. In doing so, we expand the work by Ascione et al. (2022) by estimating the universities' propensity to litigate, and comparing it with the propensity of PAEs and other entities. In our estimates we control for the characteristics of patent portfolios that are found to be predictors of patent litigation. Second, we strengthen the analysis of Firpo and Mireles (2018) by comparing university litigated patents with patents litigated by PAEs, and by adopting an econometric approach which allows for controlling for patent characteristics and heterogeneity across sectors and years. Third, we investigate the effects of patent litigation on university technology transfer activities by extending the analysis of Shane and Somaya (2007) and considering a more recent and longer period (1993–2016).

3. Analyzing universities' behavior in patent litigation

Recent evidence points to an increasing presence of universities in the courts (Firpo and Mireles, 2020; Ascione et al., 2022). However, it is not clear whether this is due to a general change in the propensity to litigate or, rather, is the consequence of other factors such as, for example, the generally increasing attention universities pay to patent activity, or the increasing research investments in complex (and less science-based) technologies, that are traditionally more litigated, or even the increasing quality of university patents.

More generally, the decision to enforce a patent in court depends on two factors. First, the characteristics of the technology protected by the patent. For example, since litigation activity is very costly, it is quite rare to observe low-quality patents litigated in court. Similarly, patents in the information and communications technology (ICT) sector are more litigated than patents in other sectors as they rarely come with a clear notice of their boundaries (Menell and Meurer, 2013). Second, the *propensity* of the patent holder to enforce the patent.

In this section we investigate whether, along with the growing presence in courts, universities have also increased their propensity to litigate their patents (Section 3.2). We then compare university litigated patents with patents litigated by PAEs and by other entities, in order to characterize their litigation strategy (Section 3.3).

3.1. Data sources

We combine two main broad sources of data. First, we collect the population of US patents from the Patent Assignment Database (PAD, 2017 Version) in order to identify the type of last patent owner, and in particular patents owned by universities or PAEs. We use EPO PATSTAT Person Augmented Table (EEE-PAT) databases (Van Looy et al., 2006) to retrieve the list of university names that we then search for in the list of US patent owners. For PAEs and their subsidiaries we use a list provided by Darts-IP.[12] This list, updated in 2021, contains 546 PAE groups and 1,815 unique firms that have been identified among the plaintiffs or defendants in litigation cases. In our data we have a total of 3,676,412 unique patents filed since 1990, where 3.83% percent (140,902) are owned by *universities* and 1.70% percent (62,333) by *PAEs*.[13] Patent characteristics are collected from Patent View[14] and 2020 OECD USPTO Patent Quality Indicator (Squicciarini et al., 2013).

Second, we use data from US Patent Litigation Docket Reports (PLDR, 2019 version), which contain complete patent litigation data on cases filed in US district courts from January 1, 2003, to December 31, 2016, for a total of over 55,000 cases (Schwartz et al., 2019). PLDR provide information on the type of litigation (infringement actions, patent invalidity, etc.), the names of the parties involved in the litigation, the litigation venue, and the identification of litigated patents. We consider only patent litigation cases identified as infringement cases, where the plaintiff is patent holder and sues defendant(s) for infringement of a utility patent, for a total of 43,663 cases and 33,676 unique patents. Also in this case, we identify whether the plaintiff is a university, a PAE or another entity; the residual category ("Other entities") is mainly represented by product companies. Table 1 shows the frequency for each of the three categories. Cases where universities appear as plaintiff ("University") is still quite a rare occurrence (1.33% of all cases), while PAEs file a more significantly number of patent infringement lawsuits, accounting for almost 30% of cases.

Table 1
Number and share of infringement cases by type of plaintiffs.
Source: Own elaboration based on data from US Patent Litigation Docket Reports.

	Frequency	Percent	Cum
University	579	1.33%	1.33%
PAE	12,969	29.70%	31.03%
Other entities	30,115	68.97%	100%
Total	43,663	100.00%	

Notes: Litigation years: 2003–2016. Infringement actions only. University cases include cases where universities are co-plaintiffs with other types of entities. PAE cases include cases where PAEs are co-plaintiffs with other types of entities (universities excluded).

We then combine PAD with the PLDR database in order to distinguish which patents have been litigated and which have not. By matching the two databases we identify 27,802 litigated patents out of the 33,676 mentioned above.[15] As we gather data on the last assignee for each patent granted by the USPTO, our analysis excludes patents that have undergone litigation prior to the last recorded transaction. Consequently, our sample size is narrowed down to 22,065 litigated patents. We thus identify 460 university patents (2.08%), 2,349 PAE patents (10.65%) and 19,256 patents litigated by other entities (87.27%).

3.2. Are universities becoming more inclined to litigate their patents?

3.2.1. Descriptive evidence

The first aspect we want to explore is whether universities are becoming more litigious over time. In doing so, we look at the number of infringement actions filed by universities (alone or as co-plaintiff) in the US and their contribution to the overall number of infringement actions by year of litigation. At first glance, Fig. 2 suggests that the presence of universities in court has increased significantly in the last decade; in

filed in 1999) whose purpose was to reduce "noise" on hard drives. This case set the record for the largest payment in a patent case related to a computer science invention (Rooksby, 2016).

[12] The matching is carried out by constructing a matching score (the Levenshtein distance or edit distance) between names of US patent owners and the list of university names and PAEs.

[13] In the case of multiple owners, we apply the following rule: if at least one co-owner is a university, the patent is considered a university patent; if at least one co-owner is a PAE and there is no university among the other owners, the patent is considered a PAE patent. In all other cases, we consider that the patent belongs to the so-called "other entities" group. The three categories are therefore mutually exclusive. The same rule applies for the identification of the type of plaintiff.

[14] https://patentsview.org/download/data-download-tables

[15] This discrepancy is due to the fact that PAD does not report those patents that are directly filed by the applicant (rather than by the inventor) and that are not transferred.

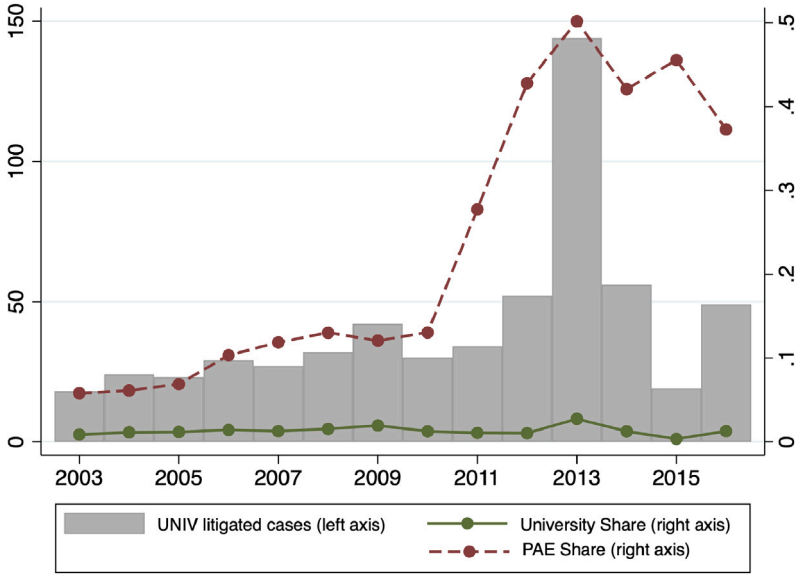

Fig. 2. University patenting litigation activity in the US.
Notes: The Figure shows the number of university litigated cases by year, the contribution to the total number of litigated cases and the contribution of PAE litigated cases. The year corresponds to when the case starts. The sample covers only infringement actions filed between 2003 and 2016, for a total number of 43,663 cases.
Source: Own elaboration based on data from US Patent Litigation Docket Reports.

particular, in the last five years covered by our sample (2012–2016), universities have litigated, on average, more than 50 cases per year. However, the observed increase in litigation activity follows the general trend as the contribution of university litigation to overall litigation remains stable (with universities litigating, on average, about 2% of all cases). In particular, universities do not follow the same pattern as PAEs, whose presence in court has significantly increased, starting from 2010 (see Fig. 2).

These figures tend to suggest that universities have not become more inclined to litigate their patents, or at least that they have not become more litigious than other actors. However, they cannot say much about changes in universities' litigation strategies. As previously discussed, the decision to litigate a patent may be the result of two different factors: on the one hand, the intrinsic characteristics of the patent itself, and on the other hand, the strategy of the owner, who may opt for more or less aggressive behavior. The first kind of difference is linked to the inherent diversity among the patenting activities of the considered actors. For instance, university inventions are typically more fundamental and require substantial investment to be commercialized compared to those of firms (Thursby et al., 2001). In addition, their patenting activity is concentrated in a relatively small number of fields, and their distribution differ greatly from that of all US patents, with at least 25%–30% of university patents belonging to patent classes related to the biological and medical sciences (Trajtenberg et al., 1997).

In order to estimate the propensity to litigate for the three types of actors we focus on ($UNIVERSITY$, PAE, and $OTHER$), we follow a two-step procedure: first we estimate the probability of observing a patent held by one of the three groups as a function of its observable characteristics. In the second step, we estimate the likelihood of observing the patent litigated in court. The following subsection presents the econometric specification.

3.2.2. Econometric specification

Our main analysis is based on a Logit model relating patent litigation probabilities to a set of explanatory variables. The response variable ($Litigation$) is a dichotomous variable whereby litigated patents are designated as "1", while non-litigated ones are coded with "0". The model is the following:

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

where X represents a set of explanatory variables that affect the likelihood of a given patent being litigated. As suggested by the literature (Lanjouw and Schankerman, 2001; Allison et al., 2003; Harhoff et al., 2003; Bessen, 2005; Cohen et al., 2019; Ascione et al., 2022), an important factor in explaining patent litigation is the technological importance of the patent (patent quality). We proxy patent quality with the number of citations received by the focal patent ($5Y\_filing\_cit$). Known as "forward citations", citations received by a patent imply that the patented invention is being used for the creation of new inventions (Henderson et al., 1998). Hence, it is common to consider a patent that receives a large number of citations to be of high technological quality. Since citations are truncated by nature and this truncation is increasing for more recent patents, the older a patent the more citations it receives on average (Hall et al., 2005). In line with the literature (Squicciarini et al., 2013) we consider a fixed window from the publication date to compute the total number of forward citations. We choose a window of five years in order to consider a period which anticipates the moment in which the patent is eventually litigated (the average patent age at the time of litigation being ten years). However, this choice could underestimate the quality of university patents as they receive more citations later in time (Czarnitzki et al., 2012; Sterzi, 2013).

In addition to patent quality, we control for other variables that are considered important predictors of patent litigation. The first variable is $Originality$, which captures the breadth of the technologies that are recombined to develop a new patent, and is a proxy for the scientific novelty of the patent (Hall et al., 2001).[16] We control for the number of $Claims$, which define novel features of the invention. Generally, this measure is associated with the technological breadth or the market value of a patent and reflects a greater risk of conflict with competitors (Tong and Frame, 1994). We then include $Renewals$, which indicate the number of years a patent is valid and $Patent\_scope$, which gauges the breadth of the patent and is thus expected to be correlated with the probability that the patent can be infringed (Lerner, 1994;

[16] It ranges between 0 and 1 where values close to one indicate that the patent contains original knowledge while values close to zero mean that the patent has little originality.

Fischer and Henkel, 2012).[17] We also control for applicants' country, by including a dummy (US) which takes the value of one when at least one applicant comes from the US. This variable is meant to control for the different costs of trial compared to the cost of settlement for domestic and foreign applicants and the disadvantage for foreign entities in detecting infringements in the US market. Moreover, since there are pronounced differences in litigation rates across technology fields and years (Lanjouw and Schankerman, 2001), we also control for technological sector (WIPO 35 technological classes), while grant year fixed effects control for changes across years affecting the propensity to litigate. Finally, we insert two dummies ($OTHER$ and PAE) identifying the patent owner, which measure differences between the groups in the average propensity to litigate. The omitted category is the dummy ($UNIV$) identifying patents owned by universities.

The main descriptive statistics of the variables under study are provided in Table A.1 in Appendix and show that there are considerable differences between the three groups. First of all, PAEs show higher levels of litigiousness than the other two groups (PAEs litigate about 3.6% of their patents, while universities and other entities litigate only 0.3 and 0.5%, respectively). However, the portfolios held by the three entities show substantial differences, and we therefore consider the comparison of litigation rates with caution. For example, patents held by PAEs are characterized by a relatively high quality, while those litigated by universities are relatively more original. Furthermore, we observe a larger share of US entities among PAEs than other groups. These differences may lead to a bias in our estimates as it is not possible to measure the impact of a given ownership on the likelihood of litigation.

In order to deal with this issue, we propose a Double-Robust Inverse Probability Weighting (IPW) procedure where group determinants are included to further protect against the bias due to observables (Funk et al., 2011). IPW is a common approach to adjusting for observed confounding factors in observational studies (see Narita et al. (2023) for a discussion on this approach). In our case, IPW creates a pseudo-population in which there is no confounding, such that the average outcome in the pseudo-population approximates the average outcome that would have been observed if belonging to a group had been randomly assigned. The doubly robust standardization is applied as a two-step procedure (Uysal, 2015). First, a multinomial logit model is fitted to investigate the impact of the three-fold applicant classification of patent observable characteristics. For each entity class, predictions are obtained for each patent i based on the fitted model and these are used to derive the weights. The second step is to fit the Logit model of Eq. (1), using the weights as calculated in the first step. Notably, this double robust procedure increases protection against model misspecification (Funk et al., 2011).

In Appendix, Table A.2 provides the results of the first step. Among the characteristics of the patents, in order to increase the goodness of fit of the multinomial logistic regression model,[18] we also include the binary variable $Transfer$ which takes the value of one if a given patent has been transferred at least once.[19] As shown in Table A.1, universities show, on average, a lower transfer rate than the other two groups (only 10% of patents held by universities were transferred), meaning that their patent portfolios mainly consist of patents filed by their faculty.

As expected, we observe an improvement in the balance in the sample after applying the IPW (see Table A.3 in Appendix),[20] thus confirming the benefit of using this method to take into account the differences between the three groups in terms of quality and other characteristics of their patents.

[17] $Patent\_scope$ is measured by counting the number of distinct 4-digit IPC classes the invention is allocated to Lerner (1994).

[18] The analysis has been reproduced excluding the variable $Transfer$ obtaining the main results.

[19] Employer assignments are not considered as transactions.

[20] Panel A shows the covariate balance before weighting. The very high F-statistics indicate that the patents in the sample are significantly different across the three groups. Panel B and Panel C provide the regressors balance after weighting in the full sample and CS sample, respectively. The balance in Panel C is certainly better than the original data for all variables under study. In fact, a drastic reduction is observed in all F-statistics. The only variable for which the balance is less (but still) effective is Fwd_cits5, for which an important difference is still observable between the three groups even after weighting.

[21] Common support is ensured by employing *Minima and Maxima Comparison* approach (Caliendo and Kopeinig, 2008).

[22] In case of multiple types of plaintiffs, we consider as "UNIVERSITY" the case where there is at least one university among the plaintiffs, and as "PAE" the case where there is at least a PAE among the plaintiff but no universities.

3.2.3. Results

Table 2, Columns 3–6 presents the estimates of the second-step of our analysis (IPW Logit), along with simple Logit models (Columns 1–2). Columns (2), (4) and (6) account for the interaction term between all regressors and the patent group ownership, namely $OTHER$ and PAE ($UNIVERSITY$ being the reference case). Samples in Columns (5) and (6) have been trimmed to ensure common support (CS) across the three groups.[21]

Overall, our results point to a lower propensity to litigate for universities, compared both to PAEs and other entities. However, this propensity gap is strongly reduced after we remove the portfolio effect (i.e. by rebalancing the sample). In particular, the incremental propensity to litigate is reduced by a factor of three for "other entities" and by half for PAEs in column 5 compared to the naive regression results in Column 1. For a PAE patent, the odds of being litigated are 6.509 times as greater than the odds for a patent belonging to a university group. The odds for being litigated are 29.3% higher for other entities compared to universities (see Column 5).

In order to investigate whether the propensity to litigate has changed over time, we use Model (5) of Table 2 to compute the predicted probabilities for the three group of entities by year of patent filing. Predicted probabilities are shown in Fig. 3 where estimated differences are more or less constant over time. Furthermore, universities appear to be the least litigious entities in almost all the years considered in the analysis. These results suggest that the increasing presence in courts is not explained by an increase in litigiousness, but by the fact that, alongside the heightened quantity of patents, they have patents in their portfolios that are more prone to be litigated than in the past.

3.3. Do universities look like PAEs?

The previous section already gives a partial answer to this question. The main results of the previous analysis suggest that universities generally appear unlikely to litigate their patents, especially when compared to PAEs that have significantly increased their presence in court in the last fifteen years. However, it tells us nothing about how they behave when they litigate their patents in court.

In this section we thus enrich the previous analysis by looking for similarities and differences between the strategic behaviors of the above-mentioned groups in court. In doing so, we rely on the restricted sample of litigated patents (PLDR, 2019). Our database consists of 43,663 infringement cases and 33,676 unique patents, for a total 87,919 patent-litigation pairs. As before, we identify three categories of cases ("UNIVERSITY", "PAE", "OTHER") according to the type of plaintiff.[22]

In order to compare the groups' behavior, we investigate four main dimensions that usually correlate with PAE litigation.

The first dimension under study is litigation intensity, proxied by the number of defendants per patent-litigation case ($Defendants$). The number of defendants refers to the sum of all the defendants involved in a litigation case. PAEs have often been accused of making demands on many companies at once to get nuisance settlements (Allison et al.,

Table 2
Logit odds ratios of probability of litigation.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Naive logit Unweighted sample		IPW logit Weighted sample		IPW logit Weighted sample (CS)	
Ownership (REF: UNIVERSITY)						
OTHER	1.963***	1.520***	1.810***	1.654***	1.293**	1.446***
	(13.45)	(6.251)	(3.863)	(5.316)	(2.385)	(4.776)
PAE	11.45***	9.909***	7.200***	6.921***	6.509***	6.865***
	(44.36)	(30.05)	(15.42)	(19.15)	(18.27)	(19.56)
Originality	1.759***	0.544**	1.305	1.200	2.670***	1.491
	(13.09)	(2.424)	(0.962)	(0.395)	(4.760)	(0.885)
Claims	1.015***	1.014***	1.006***	1.013***	1.013***	1.012***
	(48.26)	(7.835)	(6.715)	(4.087)	(16.70)	(4.273)
Patent_scope	1.062***	1.000	1.096***	0.985	1.049**	0.813**
	(10.73)	(0.0115)	(4.233)	(0.270)	(2.014)	(2.275)
5Y_filing_cit	1.002***	1.003***	1.000	0.999***	1.002***	1.004***
	(34.63)	(9.732)	(0.230)	(2.667)	(8.279)	(4.065)
Renewal	1.151***	1.178***	1.193***	1.265***	1.118***	1.200***
	(39.94)	(12.68)	(7.034)	(6.414)	(9.357)	(7.582)
US	3.134***	1.697***	2.616***	2.322***	2.127***	1.720***
	(63.17)	(4.415)	(9.622)	(3.636)	(9.466)	(3.480)
Originality × OTHER		3.019***		0.220**		1.485
		(4.34)		(2.47)		(0.85)
Claims × OTHER		1.000		0.993**		0.998
		(0.03)		(2.18)		(0.64)
Patent_scope × OTHER		1.061*		1.179**		1.338***
		(1.94)		(2.29)		(3.13)
5Y_filing_cit × OTHER		0.999**		1.001***		0.996***
		(2.42)		(2.68)		(2.95)
Renewal × OTHER		0.979		0.917**		0.940***
		(1.61)		(2.09)		(2.81)
US × OTHER		1.915***		1.603**		1.593***
		(5.36)		(1.97)		(2.92)
Originality × PAE		12.260***		1.821		1.929
		(8.09)		(1.12)		(1.24)
Claims × PAE		1.001		1.004		1.005*
		(0.56)		(1.18)		(1.88)
Patent_scope × PAE		1.081**		1.061		1.323***
		(2.28)		(0.88)		(2.85)
5Y_filing_cit × PAE		0.998***		1.003***		1.000
		(3.72)		(7.87)		(0.17)
Renewal × PAE		0.950***		0.930***		0.921***
		(3.71)		(2.80)		(3.51)
US × PAE		1.390**		0.847		1.173
		(2.43)		(0.65)		(0.86)
Constant	0.001***	0.002***	0.001***	0.001***	0.002***	0.002***
	(127.90)	(93.51)	(38.50)	(60.15)	(63.68)	(77.64)
Observations	3,633,249	3,633,249	3,633,249	3,633,249	3,632,758	3,632,758
Field dummies	YES	YES	YES	YES	YES	YES
Filing Year dummies	YES	YES	YES	YES	YES	YES
Pseudo R2	0.109	0.110	0.511	0.519	0.155	0.161
LR test	28,027.30***	28,226.08***	6,175.26***	10,124.07***	7,007.98***	12,423.17***
LL	−114,327.03	−114,227.64	−0.58	−0.57	−0.51	−0.51

Notes: The sample consists of US granted patents filed between 1990 and 2016. *** p < 0.01, ** p < 0.05, * p < 0.1; Coefficients represent relative risk ratios, absolute z-statistics are in parentheses. The reference group is $UNIV$. LL stands for the log Likelihood of the equation. Columns (5) and (6) observations have been trimmed to ensure common support (CS) across the three groups.

2010; Chien, 2010; Bessen et al., 2011; Lemley and Feldman, 2020) and of naming multiple defendants in their cases; this is because the cost of proving more infringements does not increase linearly, considering that the legal apparatus built for one defendant can be used against many (Allison et al., 2009, 2010; Feng and Jaravel, 2020), thus creating economies of scale (Jeruss et al., 2012). Their strategy of naming multiple unrelated defendants caught the attention of Congress, which, in 2011 passed the America Invents Act (AIA), which set a stricter joinder standard in patent infringement suits. Since after AIA plaintiffs had to file more lawsuits in order to sue the same number of defendants, our analysis on $Defendants$ is limited to the years 2003–2011.

Second, we consider whether the patent has been litigated in the Federal District Court of Texas Eastern ($Texas$), which has earned a reputation for being friendly towards patent holders and characterized by expeditious dockets (Coursey, 2009), thereby attracting numerous opportunistic patent litigations (Rooksby, 2011; Cohen et al., 2016; Firpo and Mireles, 2018; Cohen et al., 2019). The Supreme Court addressed rules affecting forum shopping incentives in the case TC Heartland LLC v. Kraft Foods Group Brands LLC (2017); it narrowly interpreted the patent venue statute and restricted where patentees can file infringement suits (Bone, 2017).

The third dimension accounts for the age of the patent at the time of the litigation (Age), where age is defined as the time lag between grant date and litigation date. According to the literature, PAEs strategy involves litigating patents late in their patent term, when the associated technology has usually already been developed and sold (so-called hold-up strategies) (Bessen et al., 2011; Risch, 2012; Chien, 2013; Love, 2013; Feng and Jaravel, 2020; Firpo and Mireles, 2018).

Patent quality is our fourth main dimension, which correlates with the technological importance of the invention and the intensity with which the patent is used in R&D activities. Many authors questioned the quality of patents owned and litigated by PAEs, sometimes with inconsistent results (Allison et al., 2003; Shrestha, 2010; Fischer and

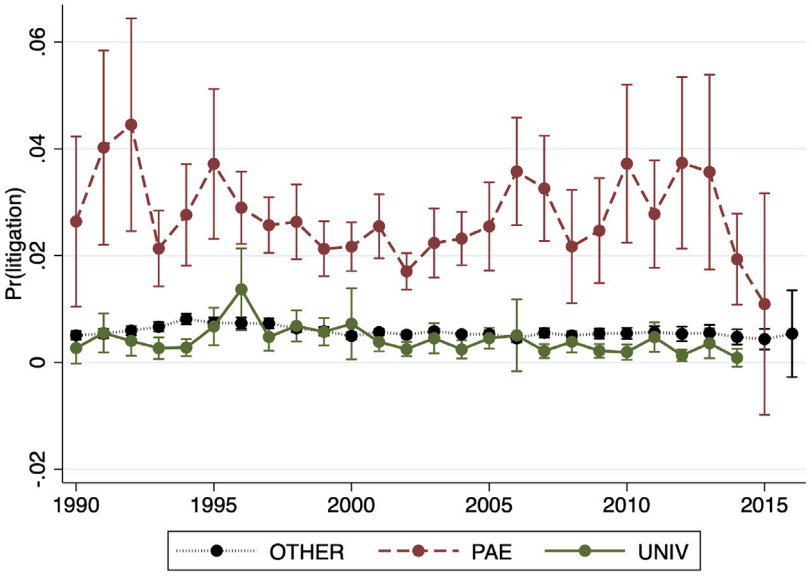

Fig. 3. Predicted probabilities of patent litigation by group and over time.
Notes: The figure shows the prediction of patent litigation by group and by year, using Model (5) of Table 2. The year corresponds to filing year. The intervals of confidence are at 95% significance level.

Henkel, 2012; Miller, 2012; Lu, 2012; Sterzi et al., 2021). For example, Shrestha (2010) and Fischer and Henkel (2012) find that PAEs' patents receive more citations than other patents, therefore concluding that many PAEs hold "high value" patents. However, others point out that, when used in litigation, PAEs' patents are weak (Chien, 2013; Allison et al., 2017; Cohen et al., 2019). In this section we consider two measures of patent quality. First, as in the previous section, we measure patent quality according to the number of forward citations received in a 5-year window after publication date ($5Y\_filing\_citations$); second, we propose a measure of patent quality which targets the value of the patents during the years of litigation, which correlates with the use of the patent at the time of litigation. In particular, we consider the total number of citations received in the year of the litigation and in the four years before ($5Y\_litigation\_cit$).

In Appendix, Table A.4 presents the descriptive statistics of the variables. Sharp differences are observed between PAEs and other entities, with the former exhibiting higher values in all respects. There are also dissimilarities between PAEs and universities. However, these differences can be due to some patent characteristics, such as, for example, the technological field and year of litigation. We use OLS to estimate a model that isolates the relationship between patent trolling behavior and group belonging, controlling for patent characteristics, filing years and technological sectors. We employ a multiple regression framework since it retains the independent variables in their original form, thus interpretation of the model is easier than with alternative multivariate procedures, such as Linear discriminant analysis or Multivariate analysis of variance.

In our regressions, the dependent variable is thus one of the aforementioned patent-litigation proxy for patent trolling, taken one at a time, and as regressors we include two dichotomous variables, litigated patents belonging to PAEs and other entities (university-litigated patents being the reference category), three measures of patent characteristics that can correlate also with the type of plaintiff ($Originality$, $Claims$ and $Patent\_scope$), and the fixed effects for both litigation year and technological sector (WIPO 35 technological classes). In this way, we are able to provide the magnitude of the differences between litigated patents belonging to a university group and a PAE and $OTHER$ group, respectively, and their statistical significance.

The results are shown in Table 3. The first row shows the differences between the university and other entities groups, while the second row presents the comparison between PAEs' and universities' litigated patents.

Our estimates highlight important differences in litigation strategies between the groups investigated. In particular, we find major difference between universities and PAEs for three important variables characterizing patent trolling behavior. First, contrary to PAEs, universities have a significantly lower propensity to litigate in East Texas Federal Court: the OLS estimates suggest that, everything else held fixed, cases initiated by PAEs are 11% more likely to be filed in East Texas Federal Court than cases initiated by universities. Second, universities litigate their patents against a lower number of defendants per case. Third, university patents are relatively more used at the time of the litigation (Column 5). However, no significant differences with PAEs are observed for the age of the patent at the time of litigation and the number of citations in the five years following patent publication date.

We also find important differences in the litigation strategies between universities and other entities according to the patent characteristics under study. In fact, their patents differ in all dimensions except for the number of defendants: university-litigated patents are relatively more litigated in Texas, they are also older, more cited during the first five years of the lifetime of the patent, and also more cited at the time of the litigation.

Finally, in order to observe whether the differences across groups have increased over time, we compute the predicted values from Table 3 for each litigation year. In doing so, we observe that differences are quite stable over time for all the variables (see Figs. A.1, A.2, A.3, A.4, and A.5 in Appendix), suggesting again that the litigation behavior of PAEs and universities has not changed over time and no similarities in strategies are observed between these two types of actors.

4. The effects of patent litigation

In light of the reassuring results of the previous section, it seems interesting to investigate whether the universities' involvement in litigation is associated with an increase in their technology transfer activities. To do so, we rely on the seminal paper by Shane and Somaya (2007), which mainly points to a negative impact of litigation in a period when this phenomenon was in its early stage (1991–2000).

Since the presence of universities in court has significantly increased in the last ten years (Ascione et al., 2022), it is relevant to understand whether the effects of litigation are still the same now that TTOs are

Table 3
OLS regression results.

Variables	(1) Defendants	(2) Texas	(3) Age	(4) 5Y_filing_cit	(5) 5Y_litigation_cit
Reference group: UNIVERSITY					
OTHER	−0.413	−0.0277**	−1.820***	−1.147**	−5.895***
	(0.602)	(2.200)	(7.394)	(2.151)	(4.615)
PAE	4.057***	0.112***	−0.240	0.353	−3.014**
	(4.591)	(7.949)	(0.944)	(0.604)	(2.270)
Observations	42,066	87,098	87,098	87,098	87,098
R-squared	0.065	0.193	0.116	0.077	0.078
Patent characteristics	YES	YES	YES	YES	YES
Litigation year dummies	YES	YES	YES	YES	YES
Field dummies	YES	YES	YES	YES	YES

Notes: Unit of observation: patent-litigation case. Litigation years: 2003–2016; Absolute t-statistics (in parentheses) are based on standard errors clustered at the case level; ***p < 0.01,**p < 0.05, *p < 0.1; OLS of the variable of interest against the dummies $OTHER$ (=1) and PAE (=1); Control variables: $Originality$, $Patent\_scope$, $Claims$, and litigation year and technological fixed effects (WIPO 35 classes). Patent characteristics are: originality, number of claims and patent scope. The analysis is restricted to the period 2003–2011 for the variable $Defendants$ to take into account that after AIA plaintiffs had to file more lawsuits in order to sue the same number of defendants.

more experienced in both litigation procedures and technology transfer activities.

4.1. Data sources and description

In this section, we update the analysis of Shane and Somaya (2007) by considering an extended period (1993–2016) where universities have significantly increased their presence in court.[23] For this purpose we create a dataset by merging three data sources. The first is the Association of University Technology Managers (AUTM, version 2016) survey, which contains information on technology transfer activities for large US research institutions, universities and hospitals in the period 1991–2016. AUTM reports key variables related to technology transfer activities. In particular, the database includes yearly information on the number of new licenses (and options) ($New\_licenses$), the number of new exclusive licenses (and options) ($New\_exclusive\_licenses$), the number of new patent applications ($New\_patents\_filed$), the number of new invention disclosures ($New\_inventions\_disclosures$) and the number of new start-ups ($New\_startups$). $Research\_funding$ is the expense, expressed in million of dollars, of universities' research and development expenditures from all sources, and $Industry\_funding\_share$ is the proportion of the funding financed by the industry. TTO_staff_FTEs represents the number of full time equivalents (FTEs) employed by the university technology transfer office in a particular year; it is used as proxy of the office's size. Our sample is composed by 171 US universities for which data from at least two years is accessible.[24] Our sample of universities accounts for 79.3% of all patents issued in the US to American universities and for 53.8% of all the patents issued to national and foreign universities in the US. We define a university as a higher education institution that operates following a consistent set of policy principles. Consequently, in a manner analogous to that of Shane and Somaya (2007), we combine data from many campuses of the same university into a single university organization. Further, again in accordance with Shane and Somaya (2007), we exclude the many University of Texas campuses from our research because we do not know the most suitable aggregation method to apply to them.[25]

The data on patents filed by universities in the AUTM database are derived from the database described in Section 3.1. In particular, following Shane and Somaya (2007), we create two kinds of controls using these data: the first is a dummy variable which takes value 1 when a university has no filed patents in that specific year, 0 otherwise ($Zero\_patent$); the second are five variables which represent for each year the share of patents filed in the year of interest and in the four previous years in the five main technological groups ($Chemistry$, $Electrical\_engineering$, $Instruments$, $Mechanical\_engineering$, and $Other\_fields$; the latter is omitted to avoid multicollinearity). These patent variables are used to take into account differences in patent activity and specialization, which could influence universities' technology transfer activities.

The third source is Clarivate DARTS-IP data on patent infringement lawsuits with at least one university as plaintiff. Clarivate DARTS-IP data allows to cover a longer period of time compared to USPTO's Patent Litigation Docket Reports Data used in Section 3. We use information on litigation start and decision dates in order to calculate the lawsuit duration. It should be noted that the decision outcome is not always available, as the proceedings often end with a settlement outside the court. In such situations, in our analysis we consider the case closed after five years since the last date for which we have available information.[26] The variable $University\_Litigation$ corresponds to the number of days in year t during which the university is involved in infringement lawsuits. It approximates the allocation of university time and resources. This number is then divided by 365 to be expressed in years. As a university may be involved in several litigations per year, this variable may be greater than 1. Unfortunately, our dataset does not provide us with information regarding the suits filed by licensees alone as in Shane and Somaya (2007). However, the typology of co-plaintiffs enables the definition of two categories of university patent litigation. Cases where the university is involved in litigation with at least one PAE or company as co-plaintiff are referred to as "University co-plaintiff" in our study. In the absence of either PAEs or companies among the co-plaintiffs, the case is identified as "University-Alone". Then, we create the variables $University - Alone$ and $University\_co-plaintiff$ analogous to $University\_Litigation$, so that they correspond to the number of days in year t that the university is involved in infringement lawsuits alone or with PAE and/or companies as co-plaintiffs, respectively. Furthermore, we create the variable $End\_of\_lawsuit$, which corresponds to the number of litigation cases concluded during the year, in order to capture the effect on technology transfer activities after the end of a litigation case. We are able to

[23] In doing so, we try to follow their empirical strategy as much as possible.

[24] 71 of these institutions have participated to the survey in all the 24 years considered, while another 60 are present for at least ten years.

[25] It is important to note that AUTM data reflect the activities carried out by universities in their fiscal year, corresponding to the academic year. Thus, the fiscal year 1993 corresponds to the period from 1 July 1992 to 30 June 1993. To ensure consistency, the litigation and patent variables are also constructed according to this definition.

[26] Litigation cases can be composed of different actions (e.g. preliminary hearings, main proceedings...), and therefore associated with different dates. In the absence of a decision outcome, the case is considered closed five years after the date associated with the most recent action. In addition, each of these actions may result in a decision outcome. In the case where the most recent outcome is anterior to the date of the last action, the case is considered closed five years after the last action.

Table 4
Descriptive statistics.

Variables	Obs	Mean	Sd	Time span	Source
New licenses	2,494	33.000	45.479	1996–2016	AUTM
New exclusive licenses	2,488	13.682	17.671	1996–2016	AUTM
New patents filed	2,805	69.623	110.677	1993–2016	AUTM
New invention disclosures	2,838	124.174	166.350	1993–2016	AUTM
New startups	2,695	4.115	6.455	1994–2016	AUTM
University litigation	3,142	0.476	1.930	1993–2016	DARTS-IP
University - Alone	3,142	0.180	1.502	1993–2016	DARTS-IP
University co-plaintiff	3,142	0.349	1.311	1993–2016	DARTS-IP
End of lawsuit	3,142	0.088	0.453	1993–2016	DARTS-IP
Research funding	2,819	317.718	460.936	1993–2016	AUTM
Industry funding share	2,730	0.082	0.070	1993–2016	AUTM
TTO staff FTEs	2,803	11.474	17.744	1993–2016	AUTM
Zero patent	3,142	0.176	0.381	1993–2016	OECD Patent Quality
Chemistry	3,142	0.362	0.300	1993–2016	OECD Patent Quality
Electrical engineering	3,142	0.178	0.193	1993–2016	OECD Patent Quality
Instruments	3,142	0.113	0.127	1993–2016	OECD Patent Quality
Mechanical engineering	3,142	0.030	0.057	1993–2016	OECD Patent Quality
Other fields	3,142	0.008	0.030	1993–2016	OECD Patent Quality

Notes: Sample of 171 US universities for which AUTM data is accessible for at least two years between 1993 and 2016.

identify 406 infringement cases involving AUTM universities from 1993 to 2016, where we define a suit "active" if the linked dockets were open for any portion of a given year.

Table 4 presents the descriptive statistics of the above-mentioned variables. The differences in the number of observations are due to missing data in the variables from the AUTM database.

4.2. Empirical analysis

As the dependent variables are non-negative integer values, the estimates are made using the Poisson panel fixed effects method. Fixed-effects models are used to eliminate any potential bias from unobserved time-invariant heterogeneity at the university level. Furthermore, year dummies control for factors that change over time and are common to all universities.

Econometric results are shown in Table 5; each column shows a different model where the dependent variable changes. In Column 1 we test the effect of university litigation on the number of new licenses (and options), in Column 2 on the number of new exclusive licenses (and options), in Column 3 on the number of patents filed, in Column 4 the number of new invention disclosures and, finally, in Column 5 on the number of new startups. To avoid reverse causality problems, the estimates are performed with the independent variables lagged by one year. The variable $End\_of\_litigation$ is also included with an additional lag, that is for year $t-2$ ($End\_of\_litigation\_(prior\_year)$). First, the regressions are estimated using the total number of litigation cases initiated by universities ($University\_Litigation$ in Table 5). Then, the estimates are repeated, this time distinguishing between cases where universities are considered to be alone and those where they are co-plaintiffs ($University-Alone$ vs $University\_co-plaintiff$ in Table 6).

Overall, main results displayed in Table 5 shows that the involvement of universities in patent litigation has a negative and significant effect on most of their technology transfer activities. In particular, the time spent in patent litigation by universities has a negative and significant effect on both the total number of new licenses (Column 1) and the number of new exclusive licenses (Column 2). According to our estimates, an increase of one litigation-year in the prior year leads to a decrease of 3.6% in the number of new licenses and of 3% in new exclusive licenses. These results are in line with Shane and Somaya (2007).

Second, invention disclosures and the creation of new start-ups are also negatively affected by the time spent on litigation procedures (Columns 4 and 5); a one-unit increase of $University\_Litigation$ induces a drop of new invention disclosures by 1.2% and of new start-ups created by 3.8%. The result for new invention disclosures differs from Shane and Somaya (2007), who find no significant relationship with the time spent by universities in patent litigation. One possible interpretation of this puzzling result is that the active involvement of university in patent litigation may be perceived as dangerous for the culture of academic research by the faculty who can become more reluctant to disclose their inventions.

In contrast, in Column 3 we observe a positive effect, albeit not statistically significant, of $University\_litigation$ on the number of new patents filed. Since our model controls for the number of invention disclosure, this means that universities involved in litigation activities are slightly more inclined to patent the inventions disclosed by the faculty.

Interestingly, unlike Shane and Somaya (2007), our results do not indicate the existence of a catch-up effect in technology transfer activities (through the variable $End\_of\_lawsuit$, lagged by one and two years). Therefore, the negative effects on licensing and disclosures discussed previously do not seem to be offset by a rebound effect after the end of lawsuits. The only exception is observed for the effect on the number of new start-ups (Column 5). In particular, given the average length of litigation in our sample (4.62 years),[27] we can say that the time spent on one litigation decreases the number of new start-ups created by 17.49%.[28] On the other hand, the catch-up effect over two years is only 3.58%,[29] which does not compensate for this decrease. The difference between the two effects is significant at the 10% significance level (p-value = 0.0523), confirming that the negative effect outweighs the catch-up effect at this risk threshold.

[27] This average duration is also driven by the cases for which we do not have a decision outcome date and that we consider closed after five years.

[28] $(0.962 - 1) * 4.62 = -0.1749$

[29] $1.045 * 0.991 - 1 = 0.0358$

Table 5
Fixed-effects Poisson results.

Variables	(1) New licenses IRR	(2) New exclusive licenses IRR	(3) New patents filed IRR	(4) New invention disclosures IRR	(5) New startups IRR
University litigation	0.964***	0.970**	1.008	0.988**	0.962*
	(0.00865)	(0.0151)	(0.00683)	(0.00503)	(0.0225)
End of lawsuit	0.992	1.017	1.015	0.999	1.045**
	(0.0286)	(0.0303)	(0.0176)	(0.00908)	(0.0210)
End of lawsuit (prior year)	0.974	0.976	0.999	0.995	0.991
	(0.0375)	(0.0258)	(0.0180)	(0.00770)	(0.0196)
Invention disclosures	1.001	1.001**	1.001***		1.001***
	(0.000503)	(0.000365)	(0.000287)		(0.000311)
Research funding				1.000	
				(2.94e−05)	
Industry funding share	0.288**	0.607	1.695	0.990	1.089
	(0.178)	(0.328)	(0.804)	(0.246)	(0.452)
TTO staff FTEs	0.998	0.996*	0.994**	1.001	1.000
	(0.00238)	(0.00225)	(0.00244)	(0.000928)	(0.00290)
Zero patent	13.04**	0.902	0.887	1.951	0.710
	(13.19)	(0.708)	(0.685)	(1.057)	(0.694)
Chemistry	11.30**	0.846	0.788	1.652	0.689
	(11.25)	(0.681)	(0.622)	(0.907)	(0.677)
Electrical engineering	19.34***	1.207	1.062	2.362	0.751
	(18.95)	(0.976)	(0.811)	(1.308)	(0.749)
Instruments	12.03**	0.743	0.879	1.917	0.521
	(12.51)	(0.555)	(0.707)	(1.073)	(0.557)
Mechanical engineering	8.453*	0.146**	0.569	1.698	0.594
	(10.03)	(0.136)	(0.480)	(1.015)	(0.651)
Observations	2,178	2,169	2,410	2,439	2,297
Number of universities	144	143	145	146	136
Wald chi2	411.23***	291.41***	5780.93***	1079.34***	2795.26***
Year Controls	YES	YES	YES	YES	YES

Notes: Columns 1, 2 are from 1996 to 2016. Columns 3 and 4 are from 1993 to 2016. Column 5 is from 1994 to 2016. The results are expressed as incidence-rate ratios (IRR). Robust seEform in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 6
Fixed-effects Poisson results - University-Alone vs University co-plaintiff.

Variables	(1) New licenses IRR	(2) New exclusive licenses IRR	(3) New patents filed IRR	(4) New invention disclosures IRR	(5) New startups IRR
University - Alone	0.967	0.973*	1.015***	0.988	0.932**
	(0.0271)	(0.0148)	(0.00581)	(0.0104)	(0.0319)
University co-plaintiff	0.962***	0.968	1.001	0.988**	0.971
	(0.0138)	(0.0199)	(0.00772)	(0.00536)	(0.0228)
End of lawsuit	0.992	1.018	1.018	0.999	1.045**
	(0.0289)	(0.0301)	(0.0179)	(0.00929)	(0.0224)
End of lawsuit (prior year)	0.974	0.976	0.999	0.995	0.992
	(0.0372)	(0.0255)	(0.0193)	(0.00769)	(0.0219)
Observations	2,178	2,169	2,410	2,439	2,297
Number of universities	144	143	145	146	136
Wald chi2	413.84***	322.10***	5752.80***	1081.72***	2789.09***
Year Controls	YES	YES	YES	YES	YES
Control variables	YES	YES	YES	YES	YES

Notes: Columns 1, 2 are from 1996 to 2016. Columns 3 and 4 are from 1993 to 2016. Column 5 is from 1994 to 2016. The results are expressed as incidence-rate ratios (IRR). Robust seEform in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

In Table 6, the effect of university involvement in litigation is broken down into cases where universities are co-plaintiffs with either PAEs or companies, and cases where they initiate litigation alone or with other types of entities (mostly administration and individuals). While in the former case, firms or PAEs may be considered to be the leaders in the procedure and at the origin of the litigation (leaving the universities with a secondary role), in the latter case the university is considered to be putting more effort into conducting the litigation.

Overall, results[30] show that the negative effect of $University\_Litigation$ on the number of new licenses and new invention disclosures is mostly driven by the $University\_co-plaintiff$ effect (Columns 1 and 4). Conversely, the involvement of universities in litigation without companies or PAEs as co-plaintiffs ($University - Alone$) has a negative effect on the number of new exclusive licenses and startups (Columns 2 and 5). Also, the negative effect of $University - Alone$ on the number of start-ups is greater compared to that of $University\_Litigation$ in Table 5 (−6.8% vs −3.8%), with a fairly constant catch-up effect (4.5%). Hence, considering the average duration of the so-called "University-Alone" litigation (4.68 years) in the sample, involvement in one lawsuit of this type leads to a decrease of 31.96% in the number of start-ups created, while the catch-up effect over two years is about 3.67%, which, again, does not compensate for this negative impact. The difference between these two opposite effects is statistically significant at 5% (p-value = 0.0192).

The main difference between the two tables is the positive and significant effect of $University - Alone$ on the number of new patents

[30] The specifications control for the same variables of Table 5, but estimates are not displayed to make the table more readable.

filed in Table 6. This result suggests that litigation activities make TTO managers and university administration inclined to patent more of the inventions disclosed by the faculty (and bear the associated costs) when the university is clearly engaged in the enforcement of its intellectual property. The filing of new patents can in fact help universities to negotiate with defendants in court and, eventually, persuade unwilling licensees to agree to pay.

5. Concluding remarks

Over the past two decades, universities' IP policies have undergone a significant transformation. Initially focused on patent protection and licensing innovation, they have now shifted towards developing comprehensive commercialization strategies through their TTOs. This shift is driven by the increasing importance of revenue generation in the realm of technology transfer operations.

Recent evidence, particularly in the US, indicates a substantial uptick in university monetization activities. Notably, TTOs have adopted a more 'patent-centric' approach, aiming to integrate entrepreneurship and commercialization into the core missions of academic institutions (Carter-Johnson, 2020). While this growing emphasis on monetization activities can bolster university funding, there remains a lack of consensus regarding its effectiveness in promoting technology transfer.

Effective technology transfer should in fact encompass not only the public information disclosed in patents but also the transfer of valuable know-how. However, a majority of licensing requests from universities predominantly prioritize the monetization of patented inventions, rather than comprehensive technology transfer (Lemley and Feldman, 2020).

In the first part of our research, we investigate whether universities exhibit behavior akin to PAEs and display an increased inclination to litigate their patents compared to the past. This inquiry arises from the fact that the behavior of universities, as non-practicing entities, in navigating the patent system might, in many aspects, resemble that of PAEs rather than traditional product companies (Lemley, 2008).

To this end, we build an original database that covers all patents granted by the USPTO until 2016 for which we identify the type of patent holder (in particular, whether it is a university or a PAE) and, eventually, if it has been litigated in infringement actions in the US in the time span 2003–2016. Our findings can be summarized as follows. First of all, universities do not seem to engage in aggressive litigation: the propensity to litigate their patents is lower than that observed for PAEs and other entities. These differences persist even when considering potential portfolio influences through the employment of the Double-Robust IPW methodology. In particular, controlling for patent characteristics and portfolio effect, we find that the odds of being litigated are more than six times higher for a patent owned by a PAE than for a patent owned by a university. In addition, the odds of being litigated for patents belonging to other entities (mainly product companies) are 29.3% higher compared to universities. These differences remain relatively stable throughout the time frame analyzed in our study; as a result, even though universities have become increasingly involved in patent litigation cases (Ascione et al., 2022), there is no clear indication of a growing trend in their aggressiveness in patent litigation over the last two decades. Second, through a comparison across four distinct dimensions — litigation intensity, litigation location, patent age, and patent quality — universities' litigation strategies appear significantly different from those of PAEs and other entities. In particular, unlike PAEs, universities do not typically file most of their patent lawsuits in the Eastern District of Texas, known for its patent-holder-friendly reputation. Moreover, universities rarely engage in multi-defendant patent litigation, and their patents typically tend to be highly cited at the time of litigation. Finally, when juxtaposing patents litigated by universities with those of other entities, disparities emerge across all dimensions except the number of defendants involved. These findings underscore the distinct and unique strategic behavior adopted by universities when contrasted with PAEs and other entities.

To complete the analysis on university patent litigation, in the second part of the paper we explore how patent enforcement undertaken by universities impacts their technology transfer activities. This issue is particularly important as technology transfer activities contributed around six billion dollars to the US gross domestic product in the period 1996–2015 (Carter-Johnson, 2020). To answer this question, we rely on fixed effect count panel models to study the effect of patent litigation on a set of key variables related to university technology transfer activities, namely the number of new licenses, new exclusive licenses, new patents filed, new invention disclosures, and new startups. Overall, we document a negative impact of patent litigation on almost all the variables considered, with the exception of patenting activity. Our results reinforce the findings of Shane and Somaya (2007), who examined the relationship between patent litigation and patent licensing in the US during the period 1991–2000. Furthermore, differing from the prior study, our investigation does not unveil the existence of a catch-up effect in technology transfer activities. The detrimental effects observed in licensing and disclosures, as previously discussed, do not seem to be counteracted by a resurgence following the conclusion of lawsuits. This remains true except for the instance of the count of new startups, where we do find evidence of a rebound effect.

From a policy perspective, our findings bring to the forefront the intricate question of the incentives put in place by the Bayh-Dole Act. In particular, literature asks whether the Act, aimed at improving commercialization of university patents, has led to unintended consequences, given the different objectives of universities and policymakers. Our findings suggest caution in encouraging universities to litigate their patents: while our analysis does not uncover evidence of universities pursuing aggressive patent litigation, it does reveal that patent litigation has a detrimental impact on university technology transfer activities. Moreover, it is possible that universities may become increasingly engaged in infringement lawsuits in the future as they become more familiar with patent litigation practices. At the same time, most of the TTOs continue to fall short in generating sufficient revenue to sustain their operations, and this is unsustainable in the long run. Therefore, universities' demeanor may evolve toward a more aggressive stance to mitigate the substantial costs associated with such activities. Such aggressive behavior may take place not only through direct litigation, but also through the sale of patents to PAEs, as the latter possess greater experience in IP enforcement.

In this context, our results add on to the literature about university technology transfer, providing new evidence on the tension between maximizing revenues and fostering innovation. TTOs should refrain from aggressively asserting their rights. Their primary focus should be on achieving knowledge transfer objectives rather than prioritizing revenue generation driven by market imperatives. To do so, they may favor the involvement of their faculty from the beginning of the technology transfer process, promoting science-industry collaborations, and facilitating ex-ante licenses. While this shift in TTOs' objectives would enhance their social impact, its implementation would be facilitated by alternative revenue streams, which would ensure universities' own financial sustainability. In this regard, policymakers can play a key role in two ways: first, by using funding allocation criteria as a leverage to modify incentives, thereby prioritizing effective technology transfer rather than monetization; second, by increasing the overall budget, thus providing universities with long-term financial sustainability and reducing the necessity to seek alternative funding sources.

A few last remarks concern the limitations of our work and future research. First, we cannot observe the real time and effort spent by TTOs in litigating their patents. For example, we cannot identify with confidence if and when parties settle. Furthermore, we do not observe all the work put into patent enforcement that does not result in litigation. However, we have no reason to think that its omission leads

to systematic biases in our results. Second, in the comparison between university and PAE patents, we rely on a list of PAEs identified as such by Darts-IP. Although this list accurately contains all companies that IP specialists consider to be PAEs, it is possible that small and lesser-known PAEs are not being identified, as patent holders often set up shell companies and unknown subsidiaries to hide patent ownership (Morton and Shapiro, 2013). Since, in these cases, it is reasonable to expect that these companies hold weak patents that are intended to be used opportunistically (Sterzi, 2021), we believe that their omission tends to reinforce our results indicating different litigation strategies between universities and PAEs. In terms of future research avenues, it would be interesting to study the effect of university patent litigation on the trajectories of patented research and knowledge diffusion. In our analysis we find a negative impact of patent enforcement on the technology transfer activities of universities involved in patent litigation. The negative effect of patent litigation could be broader, however, by forcing operating companies to stop using litigated technology and to change their R&D agenda. In addition, it would be interesting to include in the analysis all university patents that are transferred to PAEs in order to study if and when partnership with PAEs is seen as an alternative to direct litigation in court. Early research (Fusco et al., 2019; Caviggioli et al., 2020; Love et al., 2020) shows that universities are increasingly partnering with PAEs, to whom they sell high-quality (but relatively old) patents, especially in the information and communication technology sector.

CRediT authorship contribution statement

Grazia Sveva Ascione: Concept, Design, Analysis, Writing, Revision of the manuscript. **Laura Ciucci:** Concept, Design, Analysis, Writing, Revision of the manuscript. **Claudio Detotto:** Concept, Design, Analysis, Writing, Revision of the manuscript. **Valerio Sterzi:** Concept, Design, Analysis, Writing, Revision of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix. Tables and figures

See Tables A.1–A.4 and Figs. A.1–A.5.

Table A.1
Descriptive statistics of USPTO patents (1990–2016).

Variable	OTHER		PAE		UNIV		Total	
	mean	sd	mean	sd	mean	sd	mean	sd
Litigation	0.005	0.072	0.036	0.187	0.003	0.056	0.005	0.075
Originality	0.743	0.197	0.761	0.176	0.784	0.182	0.745	0.197
Claims	16.895	12.010	20.851	16.451	17.691	13.379	16.992	12.163
Patent_scope	1.917	1.188	1.884	1.163	2.370	1.490	1.934	1.203
5Y_filing_cit	10.560	34.921	23.493	76.185	9.804	33.435	10.752	36.007
Renewal	9.199	4.215	10.045	4.482	8.640	4.258	9.192	4.224
US	0.488	0.499	0.645	0.478	0.560	0.496	0.493	0.499
Transfer	0.190	0.393	0.436	0.495	0.081	0.272	0.191	0.393
Obs.	3,436,482		61,772		134,995		3,633,249	

Notes: The sample consists of US granted patents filed between 1990 and 2016.

Table A.2
Multinomial logit odds ratios of applicant type.

Variables	(1) OTHER	(2) PAE
Originality	0.693***	1.166***
	(18.76)	(4.480)
Claims	0.994***	1.007***
	(21.55)	(16.01)
Patent_scope	0.920***	0.961***
	(31.72)	(7.883)
5Y_filing_cit	1.002***	1.005***
	(8.124)	(16.29)
Renewal	0.964***	1.046***
	(22.19)	(14.21)
US (=1)	0.841***	1.694***
	(25.53)	(43.89)
Transfer	2.443***	7.201***
	(82.17)	(139.4)
Constant	5.475***	0.142***
	(43.64)	(23.59)
Observations	3,633,249	
Field dummies	YES	
Year dummies	YES	
Pseudo R2	0.220	
LR test	166,987.50***	
LL	−2.569	

Notes: The sample consists of US granted patents filed between 1990 and 2016. *** p < 0.01, ** p < 0.05, * p < 0.1; Coefficients represent relative risk ratios, absolute z-statistics are in parentheses. The reference group is $UNIV$. LL stands for the log Likelihood of the equation.

Table A.3
Covariates balance.

	Panel A Unweighted sample			
	OTHER	PAE	UNIV	F-test
Originality	0.743	0.761	0.784	2,964.61
Claims	16.895	20.851	17.691	3,447.71
Patent_scope	1.917	1.884	2.370	9,296.60
5Y_filing_cit	10.560	23.498	9.804	3,974.423
Renewal	9.199	10.045	8.640	2,416.24
US (=1)	0.488	0.645	0.560	4,293.78
	Panel B Weighted sample			
	OTHER	PAE	UNIV	F-test
Originality	0.787	0.765	0.797	69.55
Claims	45.476	18.441	6.014	8.02
Patent_scope	2.291	2.105	1.229	11.18
5Y_filing_cit	462.928	14.453	2,705.234	40.14
Renewal	9.591	9.027	3.048	26.21
US (=1)	0.635	0.593	0.057	71.50
	Panel C Weighted sample (CS)			
	OTHER	PAE	UNIV	F-test
Originality	0.765	0.765	0.767	3.25
Claims	19.158	18.379	18.675	45.40
Patent_scope	2.064	2.104	2.102	22.84
5Y_filing_cit	18.208	13.551	16.157	192.39
Renewal	9.190	9.025	9.067	37.83
US (=1)	0.570	0.592	0.560	30.50

Notes: The sample consists of US granted patents filed between 1990 and 2016. Values reported are the means of $OTHER$, PAE and $UNIV$ groups. Panel A presents the unweighted no-constant OLS regression of the given variable on the group dummies, namely $OTHER$, PAE and $UNIV$. Panel B and Panel C present the weighted no-constant OLS regression of the given variable on the group dummies, namely $OTHER$, NPE and $UNIV$. Panel C observations have been reduced to ensure common support in the distribution of weights among the three groups. The F-test is based on the null hypothesis that the three coefficients are equal to each other.

Table A.4
Descriptive statistics (2003–2016) by assignee typology and sector.

Variables	Full sample mean	sd	OTHER mean (A)	PAE mean (B)	UNIV mean (C)	(1) t-test	(2) t-test	(3) t-test
Defendants	6.94	14.87	5.67	12.48	5.31	−36.90***	0.77	8.81***
Texas	0.20	0.40	0.13	0.36	0.07	−81.05***	5.84***	22.01***
Age	10.24	5.33	9.44	11.82	11.35	−62.82***	−13.79***	3.28***
5Y_filing_cit	14.72	24.59	12.95	18.47	11.70	−30.97***	1.98**	9.60***
5Y_litigation_cit	20.75	37.34	18.13	25.99	22.33	−29.10***	−4.47***	3.28***
N. Obs.	87,098		57,387	28,289	1,422			

Notes: (1), (2) and (3) represent, respectively, the t-values of the tests on the difference between the following sample means: (A)-(B), (A)-(C) and (B)-(C). ***p < 0.01,**p < 0.05, *p < 0.1. The statistics and tests referred to the variable $Defendants$ are calculated over the period 2003–2011.

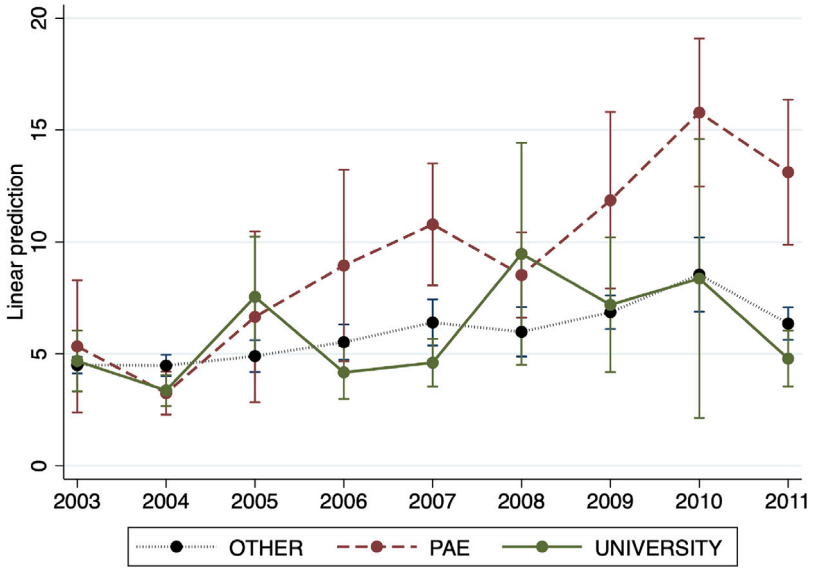

Fig. A.1. Predicted values of the variable $Defendants$ by group and over time.
Notes: The figure shows the prediction of $Defendants$ by group and by litigation year. The intervals of confidence are at 95% significance level.

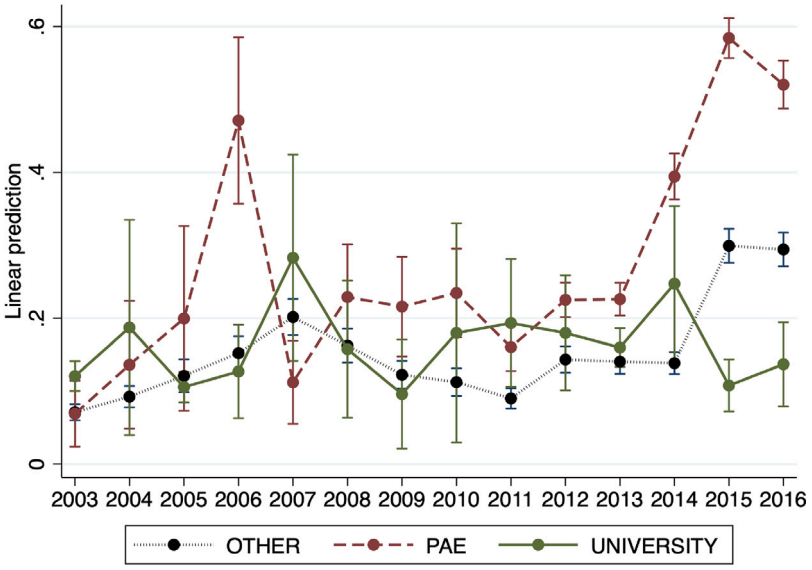

Fig. A.2. Predicted values of the variable *Texas* by group and over time.
Notes: The figure shows the prediction of *Texas* by group and by litigation year. The intervals of confidence are at 95% significance level.

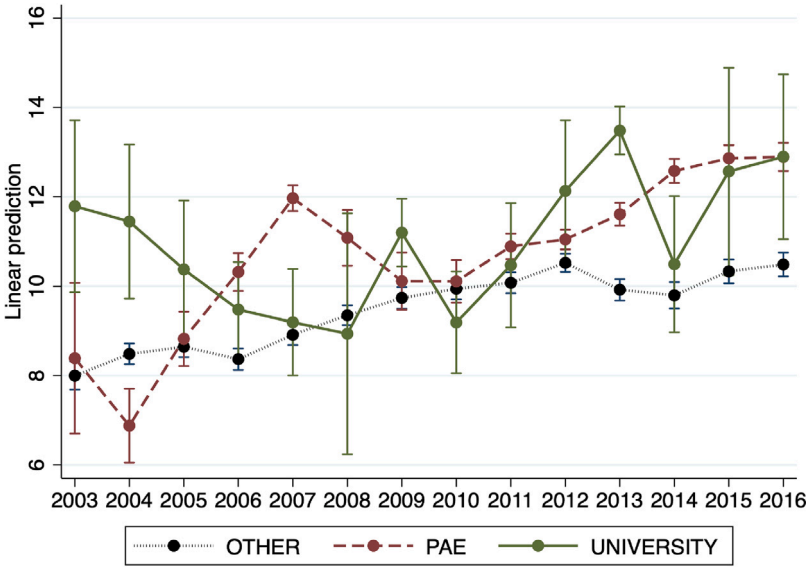

Fig. A.3. Predicted values of the variable *Age* by group and over time.
Notes: The figure shows the prediction of *Age* by group and by litigation year. The intervals of confidence are at 95% significance level.

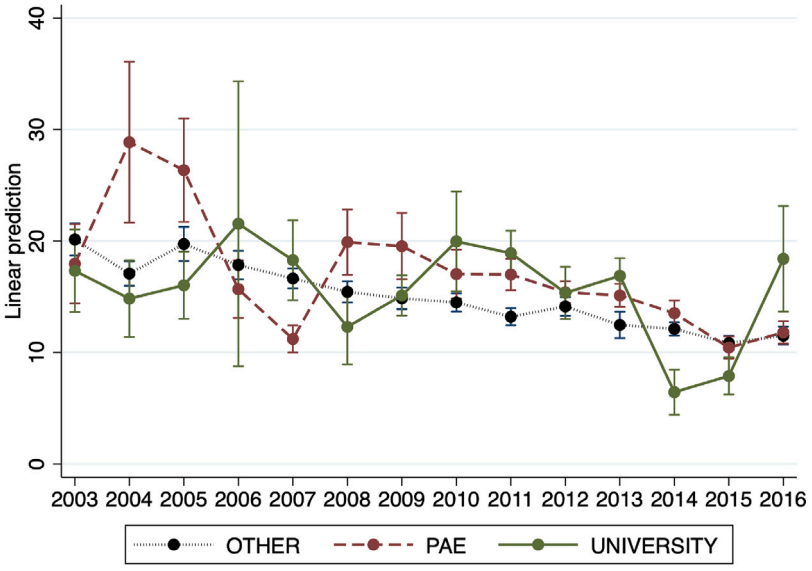

Fig. A.4. Predicted probabilities of the variable *5Y_filing_cit* by group and over time.
Notes: The figure shows the prediction of *5Y_filing_cit* by group and by litigation year. The intervals of confidence are at 95% significance level.

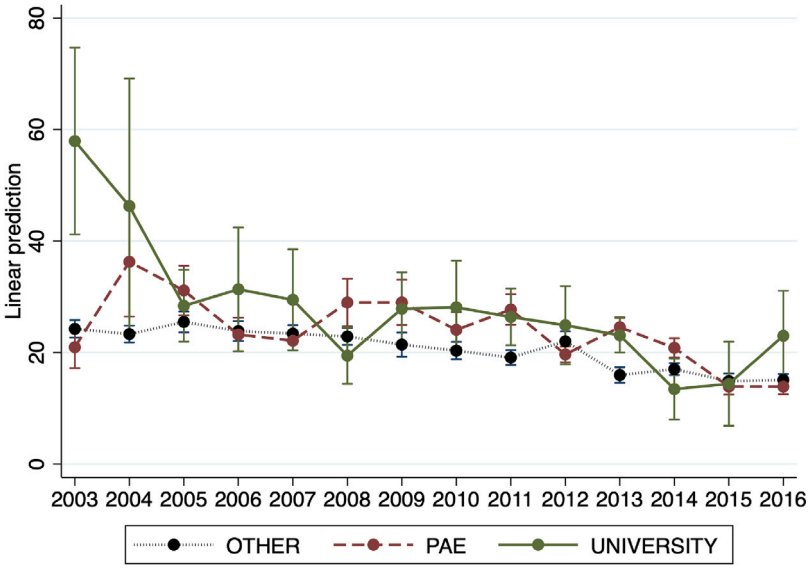

Fig. A.5. Predicted values of the variable *5Y_litigation_cit* by group and over time.
Notes: The figure shows the prediction of *5Y_litigation_cit* by group and by litigation year. The intervals of confidence are at 95% significance level.

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