Shielded Innovation

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ABSTRACT

We show that increased litigation risk has driven innovators to shield themselves by shifting innovation out of industry and into universities. We show both theoretically and empirically that litigation by Non-Practicing Entities (NPEs) pushes innovation to spaces with reduced litigation threat. Innovation has shifted into universities (and away from public and private firms) in exactly those industries with the most aggressive NPE litigation, precisely following extensive NPE litigation. The extent of innovation shielding is large and significant. An increase of 100 NPE lawsuits in an industry shifts up the university share of innovation by roughly 70% in subsequent years (t=5.34).

JEL Classification: D20, K10, O31.

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1. Introduction

No firm or sector of the global economy is untouched by innovation. In equilibrium, innovators will flock to (and innovation will occur where) the returns to innovative capital are highest. In this paper, we show a startling shift in the United States innovation landscape over the last 30 years: Innovation is now being done more at universities than ever before. The reason, as we explain both theoretically and empirically, is that there has been a massive shift in the cost of undertaking and commercializing innovation in the private sector. In particular, the incidence of Intellectual Property (IP) litigation has increased drastically in the recent decades; this has led innovators to "shield" themselves in universities, which have reduced litigation risk.

The rise in IP litigation has been nearly entirely driven by the emergence of a new organizational form, often referred to as the *Non-Practicing Entity (NPE)* or *Patent Assertion Entity (PAE)*.[1] NPEs do not produce products; rather, they amass patents just so that they may assert them. The emergence of NPEs has a subtly asymmetric impact on innovation: NPEs claim patent license fees and/or litigate infringement, so it makes most sense for them to target firms and organizations that produce commercial products.[2] In other words, NPEs predominantly target *firms* (both large firms like Apple, Pfizer, and Google, and small firms like FindTheBest.com), while *universities* are almost completely shielded from NPE lawsuits.

We show both theoretically and empirically that the emergence of NPE-driven litigation pushes innovation to spaces shielded from litigation costs (i.e., spaces where

[1] In our discussion, we use the terms *NPE* and *PAE* synonymously, referring (as defined in our data set) to "firms that derive the majority of their revenues from licensing and enforcement of patents." Some other sources consider universities to be "NPEs," as they do not produce commercial products; however, in our analysis universities are not treated as NPEs because their revenues are not predominantly derived from patent assertion.

[2] The reason stems from the property right of the "patent" itself, which affords its owner the sole right of commercialization of the patented intellectual property for the patent term.

innovation can be conducted at lower threat of litigation). We find strong cross-sectional support for our main result: it is only in the industries targeted by NPEs where we see large shifts of innovation to universities.

Universities' role in innovation in the United States has taken a particularly interesting path over the past four decades, marked by a landmark 1980 law. The passage of the Bayh-Dole Act of 1980 essentially allowed non-profit universities the right to all IP developed onsite—even the IP developed using federally granted funds, for which the property rights had previously defaulted to the government. This sparked a boom in applied research at universities, both in terms of investment dollars and resultant spin-out firms and products. For instance, dollars invested by universities in R&D skyrocketed from roughly $10 billion in 1979 to over $66 billion in 2012 (National Science Foundation (2014)), over a 50% larger growth rate than private business R&D over the same time period. Technology companies such as Sun Microsystems, along with blockbuster drug treatments such as Lipitor and Propecia, trace their beginnings to university based innovations.

While the changing nature of university involvement in innovation is a relatively recent development, the ascendance of NPEs is even more recent. NPEs have only really begun to ramp up their IP litigation in the last twenty years. Importantly, in the last decade, NPEs have been the major driver of the substantial rise in IP litigation (see Figure 3). While NPEs have their proponents and opponents, the increased litigation risk resulting from NPEs is unquestioned. Further unquestioned is the focus of NPE litigation on *producing firms*, i.e., private-sector firms innovating and commercializing products.

In this paper, we show that the rise of NPE litigation has pushed innovation out of industry and into universities. We first develop a parsimonious model of innovation, showing that threat of downstream litigation increases within-university development of innovations, while decreasing the time from first public release to product finalization. We show moreover that the main effect—shielding of innovation within universities—is more pronounced when litigation imposes especially high costs on innovating firms.

Next, we provide empirical evidence of innovation shielding in the U.S. innovation landscape. We collect data on all patents granted in the United States over the past four decades and separate those granted to universities from those granted to private entities. We further classify each patent into a technology class (essentially, the industry to which the patent applies). We find that a striking shift has occurred in recent years: in precisely the industries that are targeted by NPEs, innovation has shifted towards universities and away from both public and private producing firms. Not only that, but the shift we observe occurs precisely following a period of prolonged NPE litigation. The economic magnitudes are large. For instance, an average increase of 100 cases brought by NPEs precipitates a roughly 70% increase in the university share of innovation (t=5.34).

We split our sample into the industries that are most- and least-litigated by NPEs. We find that the innovation shift in response to NPE activity – while large and statistically significant in both groups– is over twice as large in the highly-litigated group. Similarly, we test whether the effects are stronger in industries where innovative activity has been more concentrated, and find that the value of shielded innovation (and the innovation shifting effect) is concentrated in those industries that have more ongoing innovation.

Lastly, in addition to showing that public and private firms are reducing their innovation shares in precisely those industries being targeted by NPEs, we use fine, firm-level information to show that publicly traded firms are reducing overall R&D expenditures significantly (in concert with patenting), in the industries most targeted by NPEs.

The remainder of the paper proceeds as follows. Section 2 develops a parsimonious model of innovation both inside and outside a university. Section 3 presents our data collection procedures, along with summary statistics. Section 4 provides our main results on the shifting of innovation in targeted industries to universities. Section 5 concludes.

2. Model

We develop a model in which innovation towards a product takes place both inside and outside a university setting. While inventions are developed in a university, they are safe from litigation but cannot be commercialized. Once developement moves outside the university and commercialization begins, the innovator begins to profit, but may be targeted in litigation.

Formally, we assume that there are three stages in an innovation's life cycle:

1. *university development*, during which the product is developed within a university, at flow cost ρ_u, and cannot be sold,[3]
2. *public development*, during which development continues at flow cost $\rho_p \leq \rho_u$, while the product is commercialized and sold at flow value $f(v)$, where v is the instantaneous state of product development, and

[3] Of course, the vast majority of products are exclusively developed outside of universities, so the idea that all products start in "university development" is a simplification. The key implication of the model is that the presence of litigation leads the innovator to extend the university development phase; in the context of our empirical work, this can be interpreted as meaning that litigation in an industry should increase that industry's within-university development share.

3. *pure commercialization*, during which the product is sold at flow value $f(\bar{v})$, where $\bar{v}$ is the state of the product development at the end of the public development phase.

We assume that the innovator discounts the future with exponential discount rate δ, and that the value function f is increasing and concave. We also normalize f so $f(0) = 0$ and one unit of product development accrues each period.

The innovator's utility is then given by:

$$U \equiv \underbrace{-\int_0^r \rho_u e^{-\delta t} dt}_{\text{university development}} + \underbrace{\int_r^s (f(t) - \rho_p) e^{-\delta t} dt}_{\text{public development}} + \underbrace{\int_s^\infty (f(t) - \rho_p) e^{-\delta t} dt,}_{\text{pure commercialization}} \tag{1}$$

where r is the length of the university development phase and $s - r$ is the length of the public development phase.

Deriving (1), we obtain the first-order condition for optimization of r:

$$-(f(r^*) + \rho_u - \rho_p) e^{-\delta r^*} = 0. \tag{2}$$

Solving (2), we find $r^* = f^{-1}(\rho_p - \rho_u)$. University development continues exactly until the returns to commercialization exceed the marginal cost of public development over university development. (In particular, as expected, if $\rho_p = \rho_u$, so that public development is as effective as university development, then there is no university development phase.)

Similarly, we obtain the first-order condition for optimization of s:

$$\frac{(f'(s^*) - \delta \rho_p)}{\delta} e^{-\delta s^*} = 0. \tag{3}$$

Solving (3), we find s^* defined implicitly by the equality $f'(s^*) = \delta\rho_p$: Publc development continues until the marginal return for further development equals the (discounted) marginal cost.

Now, we introduce the possibility that a commercializing firm may be sued, and examine the impact of litigation on the innovative process. Starting at the beginning of the public development phase, litigants arrive with Poisson rate $\lambda > 0$. Each litigation event costs the innovator c. The innovator's utility given litigation takes the form

$$U \equiv -\int_0^r \rho_u e^{-\delta t} dt + \int_r^s (f(t) - \rho_p) e^{-\delta t} dt + \int_s^\infty (f(t) - \rho_p) e^{-\delta t} dt - \underbrace{\int_r^\infty c\lambda e^{-\lambda t} e^{-\delta t} dt}_{\text{litigation costs}}. \tag{4}$$

Deriving (4), we obtain the modified first-order condition for r:

$$(c\lambda - e^{\lambda \hat{r}^*}(f(\hat{r}^*) + \rho_u - \rho_p))e^{-(\delta+\lambda)\hat{r}^*} = 0; \tag{5}$$

the first-order condition for s is unchanged.

Proposition 1. *Given the threat of litigation, the university development phase is longer than if litigation were absent, that is,* $\hat{r}^* > r^*$.

Proof. First, we see that

$$(c\lambda - e^{\lambda r^*}(f(r^*) + \rho_u - \rho_p))e^{-(\delta+\lambda)r^*} = ce^{-(\delta+\lambda)r^*} > 0. \tag{6}$$

Moreover, the derivative of

$$(c\lambda - e^{\lambda r}(f(r) + \rho_u - \rho_p))e^{-(\delta+\lambda)r} \tag{7}$$

with respect to r is

$$(e^{\lambda r}(\delta(f(r) + (\rho_u - \rho_p) - f'(r)) - c\lambda(\delta+\lambda))e^{-(\delta+\lambda)r}. \tag{8}$$

As the value function f is increasing (so that $f' > 0$) and $f(r) + (\rho_u - \rho_p) < 0$ on $[0, f^{-1}(\rho_p - \rho_u)] = [0, r^*]$, we see that (8) is negative—i.e., (7) is decreasing—on $[0, r^*]$. Combining this observation with (6), we see that the solution $\hat{r}^*$ to (5) must be outside of the range $[0, r^*]$, so that $\hat{r}^* > r^*$, as desired.

Proposition 2. *Given the threat of litigation, the public development phase is shorter than if litigation were absent.*

Proof. This follows immediately from Proposition 1 and the fact that the first-order condition for s under threat of litigation is the same as if litigation were not possible. Given litigation, the optimal product release time is s^*, but the university development phase has length $\hat{r}^*$, which is larger than r^* by Proposition 1. Thus, the public development phase given threat of litigation has length $s^* - \hat{r}^* < s^* - r^*$.

The comparative static of $\hat{r}^*$ with regards to litigation costs, c, is straightforward: We have

$$\frac{\partial \hat{r}^*}{\partial c} = \frac{\lambda}{c\lambda(\delta+\lambda)+(f'(\hat{r}^*)-\delta(f(\hat{r}^*)-\rho_p+\rho_u))e^{\lambda\hat{r}^*}} > 0.$$

That is, an increase in the cost of litigation to the innovator further lengthens the university development phase.

Surprisingly, the comparative static of $\hat{r}^*$ with respect to the frequency of litigation, λ, is ambiguous:

$$\frac{\partial \hat{r}^*}{\partial \lambda} = \frac{c(1-\lambda\hat{r}^*)}{c\lambda(\delta+\lambda)+(f'(\hat{r}^*)-\delta(f(\hat{r}^*)-\rho_p+\rho_u))e^{\lambda\hat{r}^*}}.$$

An increase in the frequency of litigation lengthens the university development phase if (locally) the university development phase is relatively short ($\hat{r}^* < \frac{1}{\lambda}$), and shortens the university development phase otherwise.

Taken together, the results suggest that introducing litigation into an industry where it was previously absent should push innovation into universities. We would not see this effect, however, if outside-university development did not entail threat of litigation—litigation in the pure commercialization stage has no impact on the process of product development. Litigation does not affect the total product development time.

Increases in the cost-burden of litigation always push more strongly towards university development, whereas there is no clear prediction as to the impact of a change in the frequency of litigation. In the model, the increased within-university development caused by litigation is inefficient, all else equal. However, a full welfare analysis would require evaluating the welfare returns from litigation.[4]

3. Data

We obtain patent data from Thompson Innovation on all utility patents granted in the U.S. between 1925 and 2013. The U.S. Patent and Trademark Office (USPTO) defines *utility patents* as patents issued for the invention of a new and useful process, machine, manufacture, or composition of matter, or a new and useful improvement thereof; such a patent generally permits its owner to exclude others from making, using, or selling the invention for a period of up to twenty years from the date of patent application filing. Approximately 90% of the patent documents issued by the USPTO in recent years have been utility patents.

For each granted utility patent, we collect data on assignee name, application date, and international patent classification code (IPC code). Using the assignee names, we identify patents granted to U.S. universities using the assignee–university concordance table created by the USPTO Patent Technology Monitoring Team.[5] The USPTO relies on the Technology Assessment and Forecast database, which includes alphabetical listing of more than 390,000 names of assignees whose names appear on the printed patent applications. The concordance table only contains academic institution names that were assigned one or more U.S. utility patents between calendar years 1969 and 2012. For patents not assigned to a university, we use the Kogan et al. (2012) database to identify patents produced by public

[4] For the specific case of NPE litigation, which we examine in the empirical analysis, we (Cohen et al. (2015)) and others (e.g., Bessen et al. (2014)), suggest in other work that the net welfare value of litigation may be negative.

[5] See http://www.uspto.gov/web/offices/ac/ido/oeip/taf/univ/org_gr/universities_g.htm.

firms.[6] To identify patents produced by private firms, we follow a two-step procedure: (1) we exclude 419,799 *individual innovator* patents that have the individual listed as the "innovator" and "assignee"; (2) after excluding the individual innovator patents, we remove patents produced by assignees that produced fewer than a threshold number of patents over the sample period.[7] The remaining patents are marked as *private firm patents*.

We use International Patent Classification (IPC) codes to identify main technology groups of patents, as IPC codes allow us to link patenting activity to industry groups (SIC codes) through the concordance file developed by Silverman (2002) and later improved by Kerr (2008).[8,9] The IPC code is used to classify patents and utility models according to the different areas of technology to which they pertain. The Strasbourg Agreement established the IPC in 1971 and since then, the IPC has been used in more than 100 countries for classifying patent documents. The first character of an IPC code identifies the major category of the patent and is called a "section symbol." Section symbols range from A (Human Necessities) to H (Electricity). The other categories include Performing Operations, Transporting (B), Chemistry, Metallurgy (C), Textiles, Paper (D), Fixed Constructions (E), Mechanical Engineering, Lighting, Heating, Weapons (F), and Physics (G). A two-digit number, called a "class symbol," follows the section symbol. For example, A01 represents "Agriculture; forestry; animal husbandry; trapping; fishing." The fourth character identifies the "subclass." For example, A01B represents "Soil working in agriculture or forestry; parts,

[6] We thank Leonid Kogan, Amit Seru, Noah Stoffman and Dimitris Papanikolaou for providing both patent and citation data.
[7] For the threshold, we use the average number of patents produced by public firms, so that the private and public firm samples are comparable in terms of innovative intensity. We have tried the analysis using absolute cut-offs as well, and found results similar in both magnitude and significance.
[8] This concordance has been used in several other studies, including those of McGahan and Silverman (2001) and Mowery and Ziedonis (2001).
[9] Lerner and Merges (1997) note that the IPC and U.S. patent classification systems differ in several aspects and conclude that the IPC scheme better reflects the economic importance of new inventions, as opposed to the technical focus of the U.S. scheme. They conclude that the IPC is a better measure to capture patent scope.

details, or accessories of agricultural machines or implements, in general." With this hierarchical structure, the IPC code system contains 128 classes and 648 subclasses. In our analysis, we collapse patenting activity to the subclass (i.e., 4 digit IPC) or class (i.e., 3 digit IPC) levels. We exclude patents that do not have IPC code identifications.

A patent may be related to multiple subclasses or classes; we include multiple-classed patents in all assigned patent subclasses. As can be seen in Figure 2 and Table 1, patent applications have increased dramatically since 1926. Both university- and non-university patents show similar time series patterns in terms of the numbers of patent applications and applications' technology spans.

It is important to note that our data is based on "granted" patent applications. A typical application takes roughly twenty-four months to process over the sample period. However, this hides the fact that processing times have been increasing (as applications have skyrocketed), and toward the end of the sample, applications may not be seen for 5-6 years.[10] By the time a patent is eventually approved, then, there may be a 7-8 year span from application to grant date. While the long gap from application to grant impacts the comparability of summary statistics on patents granted (relative to patents applied for) in the last few years of the sample (which is why we examine the sample through 2006), in terms of the cross-sectional analyses we run throughout the paper, the gap has only a minor impact (as we show empirically by running our tests with and without the final years). Also, the gap suggests that our results for recent years are in some sense conservative—in coming years, we are likely to see an increase in the shielded innovation effect we document.

[10] We found evidence of this delay in the patent sample, and the evidence was corroborated in our conversations with patent examiners at the USPTO.

Our patent litigation data comes from the RPX database. RPX Corporation primarily collects data on NPEs' litigation activity and patent portfolios. RPX defines an NPE as "A firm that derives the majority of its revenue from licensing and enforcement of patents." Under this definition, traditional legal entities established to license and enforce patents encompass the majority of NPEs.[11] RPX has collected data going back to 1977, capturing from Public Access to Court Electronic Records (PACER) the complete universe of litigation filed by more than 4000 NPEs (approximately 850 parent companies, and 3300 affiliates).[12] We begin our analysis with 1988, as the handful of patents asserted in NPE litigation prior to 1988 do not have assigned IPC classes. We also note that not all NPE patent assertions involve formal litigation filing; for example, NPEs send "demand letters" to communicate the threat of litigation to practicing firms. Patent assertions not tied to formal litigation are unreported by nature, so there is unfortunately no comprehensive dataset of such actions. However, it is widely believed that informal patent assertions have been in decline—and are projected to decline further—because as many more NPEs are now suing (see Table 2 and Figure 3), non-legally binding letters simply claiming infringement are becoming less credible. The equilibrium result is that the economically large alleged IP infringements appear to be addressed through lawsuits (all of which are in our data), and this is becoming increasingly true over time. We thus feel that RPX's systematic and exhaustive collection of NPE lawsuit data likely captures the economically important (and increasingly dominant) component of NPE behavior, even though it does not capture informal patent assertions. This view is supported by government sources (Executive Office of the President (2013)), and recent survey research (see Feldman and

[11] Additionally, individual inventors may be counted, while universities will not be counted (unless they have enforcement subsidiaries, in which case they will be counted solely for the assertion actions taken through the subsidiary).

[12] RPX's data is systematic, and not based on self-reporting.

Lemley (2015)), along with anecdotal accounts.[13]

As mentioned above – and can be seen in Figure 3 – nearly the entire rise in IP litigation activity has been driven by NPE litigation. In Table 2, we tabulate the number of litigation events by NPEs taking place in each IPC section over the years. As can be observed from this table, litigation is mainly concentrated in certain technology groups, namely "G" and "H" (Physics and Electricity, respectively)—in both categories, NPE litigation has increased over tenfold in the last fifteen years of the sample period.

We note that a given litigation action (as defined by a docket filed in court) includes at least one patent, with each patent (potentially) belonging to multiple IPC sections. For example: take a litigation event that refers to two NPE patents, and assume each patent is associated to two IPC sections. In this case, the single litigation action can contribute to four different cells (if there is no overlap in IPC sections of the two patents). Furthermore, a single patent can be used in litigating multiple parties in multiple lawsuits.

The figures reported in Table 2 are then based on 10,933 dockets in which RPX identifies an NPE as the plaintiff. According to RPX, roughly 69% of NPEs' patents were acquired externally (purchased) by the NPEs and their subsidiaries, whereas 19% were originally assigned to them. The remaining 12% are a blend of originally assigned and acquired patents. In these 10,933 dockets litigated between 1988 and 2013, 3,981 unique patents were asserted. Close to 50% of these 3,981 patents were asserted more than twice.

[13] For instance, one executive we spoke with relayed to us his reply to NPEs that send demand letters: "If you have a truly viable case you will sue; otherwise, don't waste my time with this letter(!)."

4. Analysis

4.1 Does Past Litigation Activity Shift Innovation Activity?

We begin by testing the central prediction of our model, namely that introducing litigation into an industry where it was previously absent should push innovation into universities. To measure litigation activity, we use the number of litigation actions by NPEs at the patent subclass level (4-digit IPC code).

We take an agnostic approach in defining the past litigation activity, as some litigation actions take a long time to be resolved through the court system. Therefore, we calculate average number of litigation events in the past three, four, and five years, to capture overall NPE activity in a technology group. The pooled sample mean of past litigation activity for the past three years (*Litigation 3*) is 0.23 with a standard deviation of 2.13. Past litigation activity shows considerable variation across IPC subgroups: in the Physics and Electricity sections, the pooled sample mean of three-year past litigation activity (*Litigation 3*) is 2.05 with a standard deviation of 9.02.

We use *University Share* as our main outcome variable. To calculate this variable for a given year, we compute the ratio of university patent applications to total patent applications. We include IPC subgroup fixed effects to capture unobserved IPC subgroup-invariant factors that are correlated with being more attractive to university research activity. Likewise, we include year fixed effects to control for variation in litigation activity specific to a given year, along with any time trends in research or patenting. This will pick up, for instance, time-series reductions in federal-support for university research.[14] In Table 4, we

[14] See Congressional Budget Office's (2005) report, "R&D and Productivity Growth."

report various specifications to show the incremental value of each past litigation activity measure on overall fit of the model to data. We use standard errors that are clustered at the year level, to broadly allow for any cross-series dependency in university research output.[15]

The results show that if the average number of litigation events increases by 100, the university share in that IPC subgroup should increase by 0.73% (*t*=5.87).[16] Compared to the unconditional university share of 1.05%, this increase represents a 70% shift in innovation activity towards universities. As tabulated in Table 2, certain IPC sections such as Mechanical Engineering, Physics, and Electricity experience hundreds of litigation events in a given year. Thus, our results suggest that the patenting activity shift to universities is economically large. Results in Columns 2 and 3 of Table 3 show that using past three and four years of litigation data give similar results, with comparable magnitudes.

In Columns 4-6 of Table 3, we use the three-digit IPC classification system to define both university share and litigation activity. In this IPC "class" level analysis, we find similar results. The unconditional university share within IPC class is 1.2% (*t*=3.43), which goes up to 3.0% if average number of litigation events in the past three years within the same IPC class goes up by 100 cases. Overall, the evidence in Table 3 strongly supports the model's prediction that increased litigation pushes industries' innovation into universities.

As noted before, our data presents challenges which we attribute to patent application processing times. While patent processing time does not differ within-class across applicants (in particular, universities and non-university entities face the same

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[15] The statistical significance of our estimates does not change if we cluster the errors by IPC subgroup.

[16] When we cluster the errors by IPC class, we get (*t*=3.59). In addition, a small portion of our database uses three digits to define a four-digit IPC subclass (1.64% of observations). We include these observations in our sample but excluding them does not change the results.

processing times within a given class, thus making it unclear how *University Share* would change due to processing time changes), we perform a subsample analysis to explore and mitigate any impacts of processing time. In Table 4, we redo the analysis performed in Table 3 removing the final years of our sample (2012 and 2013). Although the economic impact lowers slightly (48%, (t=2.94)), it remains economically large and statistically significant.

4.2 Innovation Activity Shift: High- vs. Low-Litigation Environments

Our model, along with the evidence presented in the previous section, suggests that NPE litigation threat is pushing innovation to spaces shielded from litigation risks. Now, we provide cross-sectional corroborating evidence *within* different classes of patenting and litigation.

In this section, we split the litigation activity into two parts: (1) technology groups in which litigation activity plays a large role, and (2) other technology groups. A glance at Table 2 indicates that litigation in which NPEs act as the plaintiff predominantly occur in the Physics and Electricity related IPC sections. Thus we split the sample based on this classification. Table 5 reports the results.

We first note that the mean and standard deviation of litigation proxies in the "High Litigation" subsample (Columns 4-6 of Table 5) are over ten times larger than those of the "Low Litigation" subsample (Columns 1-3 of Table 5). For instance, for *Litigation 3*, the (mean, sd) in Columns 1-3 are (0.097, 0.823) for low litigation environments, as opposed to (2.353, 10.07) in Columns 4-6 for active litigation environments.

From the estimated coefficients in Table 5, therefore, the meaningful shifting of innovation into shielded environments is coming nearly entirely (both economically and statistically) from the active litigation environments.

The results in Table 5 thus provide stronger evidence that NPE litigation activity leads to innovation shielding when the probabilities and costs of litigation are high. In the framework of the model, this result is consistent with the prediction that increasing cost of litigation to innovators further lengthens the university development phase, and thus empirically should increase the share of university-originated patents. Technology groups that have been targeted by NPEs in the past tend to have more university-generated patents today.

4.3 Innovation Activity Shift: Active vs. Quiet Innovation Environments

Next, we split the sample into two parts with respect to innovation activity. If higher innovation in the past attracts the threat of litigation; this threat itself may drive technology groups with higher innovation to a higher university share in the future. It is also plausible that innovation activity itself may be correlated with commercialization value. If commercialization value also attracts litigation, then by sorting technologies by number of patents produced, we can create subgroups to investigate how university share changes in the future if commercialization attracted litigation in the past.

To do so, we split the sample by total number of patent applications within a four-digit IPC code. We call industries in which the number of granted patent applications is less than 85 (sample mean) *quiet innovation* environments; these low-innovation industries are oftentimes mature industries in which the value generated by patents is likely to be limited. Quiet innovation industries might be less likely targets of NPEs.[17] Table 6 presents the results of the analysis in which we separate the quiet innovation environments from the other *active innovation* environments. We find that active innovation environments lead the shift universities when litigation activity increases: The estimates in quiet innovation environments are statistically 0 (and even flip signs), while in active innovation environments the impact of past NPE litigation is large and statistically significant.[18]

4.3 Private and Public Firm Innovation

Our model shows that as innovation shifts *into* universities (the shielded environment), it moves *out* of commercializing firms. In this section, we use the public firm- and private firm-share of innovation to empirically validate this prediction. Table 7 runs regression specifications identical to those shown in Table 3, but replacing *University Share* with *Public Firm Share* (Columns 1-3) and *Private Firm Share* (Columns 4-6).

Table 7 provides evidence of the shift in innovative activity in *precisely* the direction predicted by the model: commercial firms' innovation share is falling, but solely in those industries being targeted by NPEs, and solely following periods of aggressive NPE litigation. Putting Table 7 side-by-side with Table 2, we see that the *Firm Share* innovation declines shown in Table 7 are in the exact industries and times where *University Share* is concurrently rising. Taken together, these provide strong evidence of the shielded innovation shift – and

[17] Cohen et al. (2015) provide a detailed analysis of factors that are likely to be drive by NPE driven litigation.

[18] Again, in estimating economic magnitudes, Columns 1-3 (active innovation environments) have means and standard deviations of litigation activity five- to ten-times larger than those in Columns 4-6 (quiet innovation environments).

that the shift is being driven by the cross-sectional and time-series variation of increases in costs associated to IP litigation.

Tables 8 and 9 examine the out-of-industry shift even more finely at the firm level. Table 8 examines the impact of NPE litigation activity on firm-level R&D. The dependent variable is R&D expenditures (scaled by assets). In addition to the main variable of interest – litigation activity by NPEs – a number of firm level characteristics are included, along with time, industry, and even firm-level fixed effects across the specifications.

All columns of Table 8 show a consistent message – NPE litigation not only drives patenting share down at the aggregated public firm level (Table 7), but also causes a significant reduction in R&D expenditures at the firm level. To get an idea of the economic magnitude of this effect, the coefficient of -0.0034 (t=4.86) in Column 9 implies that a one standard deviation increase in NPE litigation in a firm's industry drives the firm to reduce future R&D expenditures by 12% (-0.72% over a mean R&D/A of 5.8%).

Table 9 delivers the same message, but regarding patenting at the firm level. Here, we again use fine firm and time fixed-effects. Given that the private firms in our sample (by definition) need not file any public documents on any detailed firm-level characteristics over time, we cannot include these in the regression specification. For comparability, we use the same specification for public firms. The results in Table 9 echo Table 8 – at the firm-level, NPE litigation activity reduces patenting in precisely those industries being targeted, following periods of aggressive NPE litigation targeting.

5. Concluding Remarks

We document and explore a long-term and ongoing change in the landscape of U.S. innovation: a burgeoning shift of innovative activity to environments shielded from litigation risk. We develop a parsimonious model and show both theoretically and empirically that the emergence of a litigating organizational form (such as NPEs) will push innovation to spaces shielded from litigation costs, where innovation can be conducted under lower litigation threat. We demonstrate the predicted shielding effect clearly in the data. Using the entire universe of U.S. patents granted over the past forty years, we show that in precisely those industries that NPEs most aggressively litigate, innovative activity has been shifting away from public and private firms, and toward universities. Furthermore, the observed shift occurs precisely following periods of prolonged litigation activity by NPEs. The magnitudes of the shift are large. An average increase in 100 cases brought by NPEs in the preceding years shifts up the university share of innovation in an industry by roughly 70% (t=5.34). The impacts of these shifts to shielded innovation are larger in both highly innovative industries and highly litigated industries.

The United States patent system is, quite literally, as old as the nation itself (in Figure 1, we show United States Patent #1, signed by George Washington). However, this does not mean that the patent system is indestructible, nor that it – without change – will continue to serve its charge of protecting and encouraging U.S. innovation. In fact, we show that the landscape of innovation has begun to undergo an important shift. We are the first paper to document the shift to university-shielded innovation, and to tie the shift to its potential origins. We have caught the shift to shielded innovation early. A full accounting of the current, and expected trend, in shielded innovation is of first-order importance in charting the future of innovation, and ultimately its impact on U.S. and broader global growth.

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Figure 1 - Patent #1, signed by George Washington

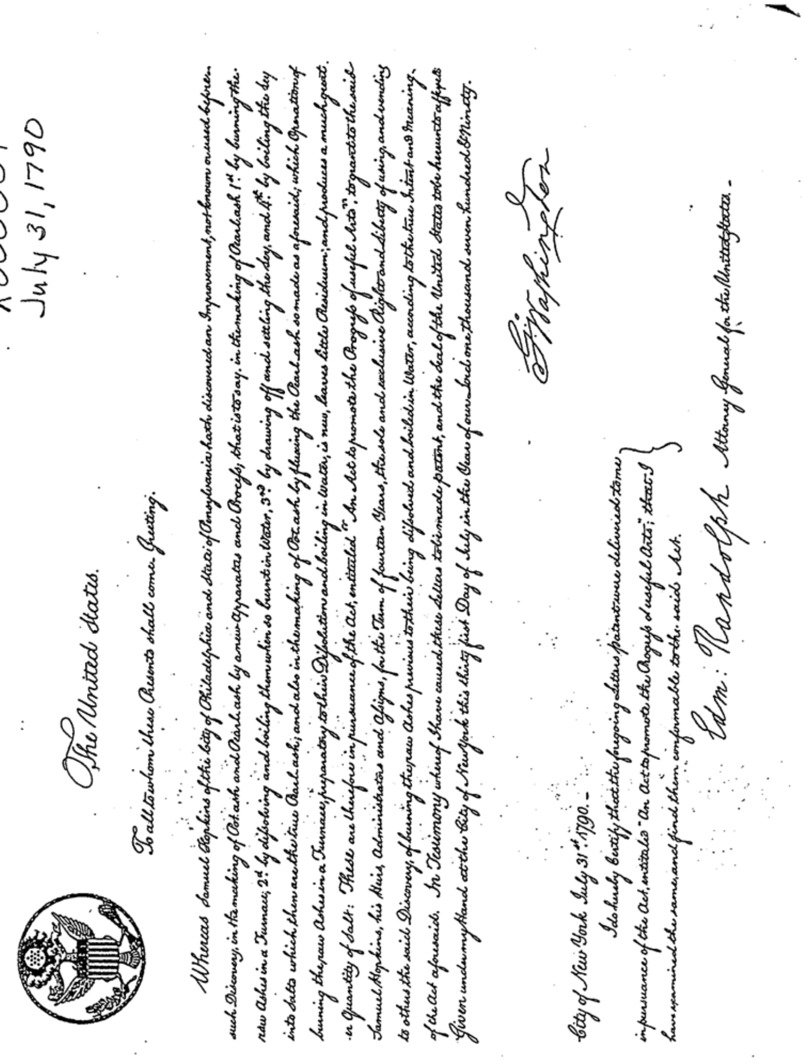

Figure 2 – Patents Granted by Application Year Since 1925

This figure reports the number of utility patents granted by patent application year. *Utility patents* are granted for invention of a new and useful process, machine, manufacture, or composition of matter, or a new and useful improvement thereof, such a patent generally permits its owner to exclude others from making, using, or selling the invention for a period of up to twenty years from the date of patent application filing. The reported numbers are based on patents with at least one technology class (IPC code) reported in Thompson Innovation.

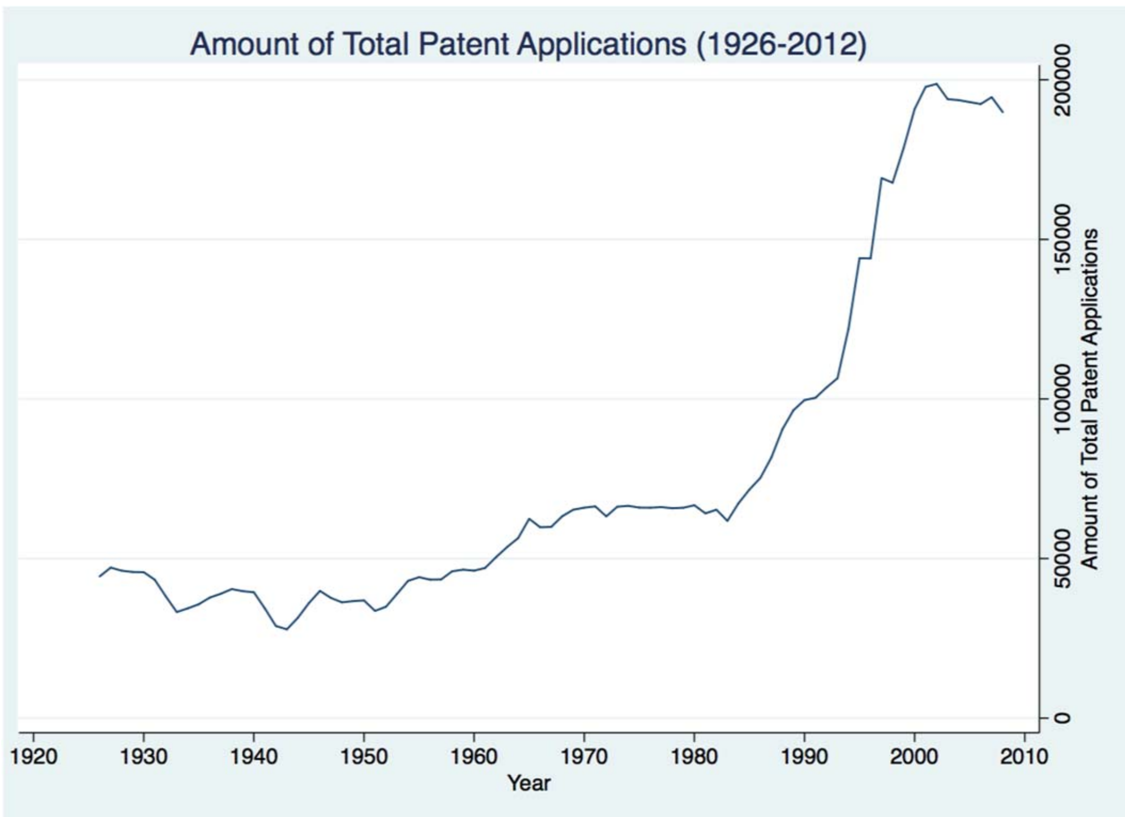

Figure 3– Patent Litigation by Plaintiff Type

This figure reports the rate of litigation activity by plaintiff type (Non-practicing entity or Practicing entity). We use RPX to identify docket numbers in which an NPE (as defined by RPX) is a plaintiff. We use Audit Analytics to identify dockets in which PACER case code is 830 (Patent Litigation). From these cases, we exclude the dockets in which the docket has an NPE as a plaintiff to identify PE filed dockets.

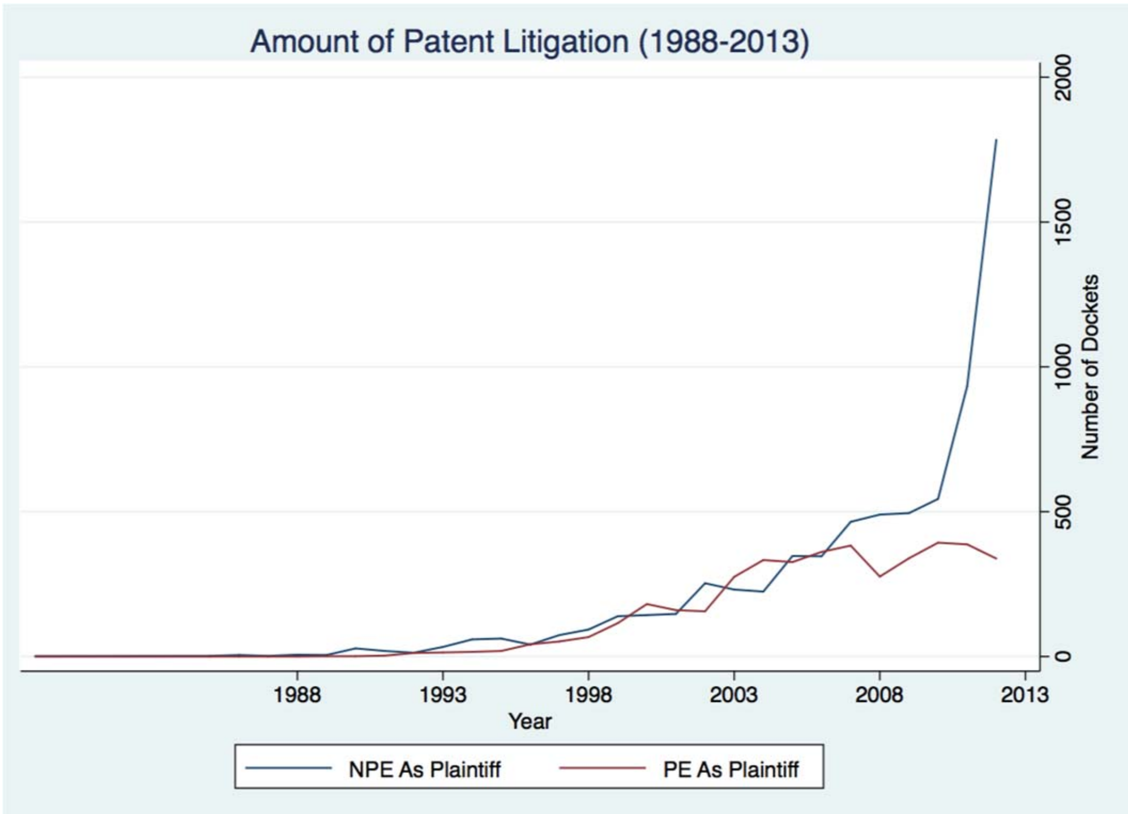

Table 1 - Summary Statistics on Patents Granted by Application Year

This table reports statistics on the number of utility patents granted to universities, public firms, and private firms by decade starting from 1926. Utility patents are granted for invention of a new and useful process, machine, manufacture, or composition of matter, or a new and useful improvement thereof. We exclude patents if a technology class (IPC code) is not reported in Thompson Innovation database. In determining whether the applicant is a university, we use assignee name – university name concordance table created by U.S. Patent and Trademark Office Patent Technology Monitoring Team. To identify patents produced by public firms, we use Kogan et al. (2012) database that maps patents to CRSP public firm identifiers (permnos). We then eliminate two types of patents to identify patents produced by private firms. First, we exclude 419,799 patents that have the same individual's name as the "innovator" and assignee names. Then, we exclude patents produced by assignees that produced less than a threshold number of patents over the sample period. The remaining patents are marked as private firm patents. Technology Span refers to number of 4-digit IPC codes referred in the patent applications. University share is the ratio of number of university patents applications to all patents applications. Public (private) share is the ratio of number of patents applications of public (private) firms to all applications. In Panel A (B) summarizes the statistics pertaining the university (public & private firm) patents. In Panel C, we report sample statistics of variables used in Table 3 to 7, where the unit of observation is Year-IPC-Patentee Type (university/public firm/private firm). If a patent belongs to multiple IPCs, it is counted towards each of the IPC classes. In Panel D, we report sample statistics of variables used in Table 8, where the unit of observation is firm-year. Market Value of Equity, Book to Market ratio, and Past Return are obtained from Compustat and CRSP databases. Total Assets of the firm are as of the end of the previous fiscal year. Market Value of the equity is measured as of the end of the previous fiscal year. Book-to-market ratio (B/M) is the ratio of book value of equity to market value of equity as of the end of the previous fiscal year. Book value of equity is calculated as sum of stockholders equity (SEQ), Deferred Tax (TXDB), and Investment Tax Credit (ITCB), minus Preferred Stock (PREF). Past Return is the 12-month return prior to fiscal year end. Patent Stock is the number of patents the firm applied for in the past five years. We define past litigation activity by calculating the average of number of litigation in the past 3,4 or 5 years (Litigation3, Litigation4, and Litigation5). A litigation activity refers to a docket in Public Access to Court Electronic Records (PACER) system in which a non-practicing entity (NPE) is listed as a plaintiff. We collect information on asserted patents from these dockets to identify the litigation frequency over years by IPC Subclass. If a litigated patent has multiple IPCs, this litigation will count towards each and every IPC subclass of litigated patent. For each year, we calculate total number of litigation in each IPC subclass by adding up all the litigation events.

Panel A. University Patent Share

Patent Application Years	Number of Non-University Patent Applications	Number of University Patents Applications	Technology Span of Non-University Patents	Technology Span of University Patents	University Share
1926-1935	378,276	35	1.18	1.15	0.0001
1936-1945	354,387	78	1.30	1.34	0.0002
1946-1955	373,599	106	1.40	1.95	0.0003
1956-1965	477,100	66	1.71	2.53	0.0001
1966-1975	637,642	1,238	2.23	2.37	0.0019
1976-1985	651,178	3,679	2.99	3.02	0.0056
1986-1995	936,264	11,560	3.42	3.96	0.0122
1996-2005	1,752,044	26,531	4.07	5.28	0.0149

Panel B. Public and Private Firm Patent Share

Patent Application Years	Number of Public Firm Patents Applications	Public Share	Number of Private Firm Patents Applications	Private Share	Number of Unassigned Applications
1926-1935	25,029	0.0662	611	0.0016	348,136
1936-1945	57,263	0.1615	858	0.0024	305,473
1946-1955	64,359	0.1722	1,245	0.0033	253,311
1956-1965	96,985	0.2033	3,059	0.0064	340,368
1966-1975	230,745	0.3612	25,386	0.0397	426,435
1976-1985	225,520	0.3444	51,644	0.0789	351,746
1986-1995	275,126	0.2903	112,398	0.1186	488,592
1996-2005	504,714	0.2838	194,320	0.1093	601,848

Panel C. Private and Public Firm Patent Share

	University Share	Public Firm Share	Private Firm Share	Litigation3	Litigation4	Litigation5
Mean	0.0109	0.2291	0.1047	0.2299	0.2497	0.2723
Median	0.0000	0.2102	0.0873	0.0000	0.0000	0.0000
St. Dev	0.0316	0.1602	0.0965	2.1282	2.3987	2.6942
P5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P 25	0.0000	0.1000	0.0323	0.0000	0.0000	0.0000
P 75	0.0098	0.3333	0.1516	0.0000	0.0000	0.0000
P 95	0.0541	0.5206	0.2734	0.4000	0.5000	0.3333

Panel D. Sample Statistics on Public Firms

	Future R&D/Assets	Total Assets	Market Value of Equity	B/M	Past Return	Patent Stock	Litigation
Mean	0.06	5127.24	2897.55	0.68	0.20	33.03	58.52
p50	0.00	288.67	224.17	0.54	0.06	0.00	0.80
Sd	0.19	38956.07	13582.53	0.70	0.94	300.71	137.62
p5	0.00	9.40	8.78	0.11	-0.63	0.00	0.00
p25	0.00	59.07	51.30	0.30	-0.21	0.00	0.00
p75	0.06	1499.51	1050.87	0.86	0.37	0.00	34.00
p95	0.27	17097.30	11416.18	1.65	1.40	60.00	382.00
N	72,949	72,949	72,949	72,949	72,949	72,949	72,949

Table 2 – Litigation Activity across IPC Sections (1988-2013)

In this table, we tabulate litigation activity across IPC sections. The first character of an IPC code identifies the major category of the patent and is called as "section symbol". Section symbol ranges from A to H, where consisting of a letter from A ("Human Necessities") to H ("Electricity"). The other categories include Performing Operations, Transporting (B), Chemistry, Metallurgy (C), Textiles, Paper (D), Fixed Constructions (E), Mechanical Engineering, Lighting, Heating, Weapons (F), and Physics (G). Litigation refers to a docket in Public Access to Court Electronic Records (PACER) system in which an non-practicing entity (NPE) is listed as a plaintiff. A docket includes at least one patent and each patent may belong to multiple IPC sections. Furthermore, a patent asserted in litigation can be used to litigate multiple parties in multiple lawsuits. Thus a docket may affect several sections of this table.

Application Year	A	B	C	D	E	F	G	H	Total
1988	0	0	2	0	0	0	0	3	5
1992	0	0	0	0	0	0	1	0	1
1993	0	0	1	0	0	0	2	1	4
1994	0	0	0	0	0	0	0	2	2
1995	0	0	0	0	0	0	0	4	4
1996	0	0	0	0	0	0	0	3	3
1997	1	1	0	0	0	0	8	8	18
1998	1	2	1	0	0	1	5	8	18
1999	1	3	0	0	0	0	21	32	57
2000	2	2	6	0	0	6	5	29	50
2001	1	29	5	0	1	2	88	40	166
2002	7	8	5	0	3	7	92	108	230
2003	10	12	2	0	3	3	88	209	327
2004	22	36	0	0	0	2	252	220	532
2005	29	45	0	0	1	3	340	318	736
2006	59	55	0	0	7	3	321	434	879
2007	87	38	14	2	22	1	325	455	944
2008	55	47	14	0	4	11	424	460	1,015
2009	17	24	11	0	0	12	378	404	846
2010	49	82	15	0	6	25	531	411	1,119
2011	53	60	9	1	2	23	698	601	1,447
2012	69	71	11	1	3	31	638	625	1,449
2013	44	53	3	1	4	7	461	477	1,050
Total	507	568	99	5	56	137	4,678	4,852	10,902

Table 3 – Does Past Litigation Activity Shift Innovation Activity?

In this table, we estimate an OLS model using past litigation activity to predict future patent production in universities compared to all patents (*University Share*). In the first three columns, the unit of observation is year-IPC Subclass code. IPC Subclass refers to the first four characters of IPC code. The explanatory variables include IPC fixed effects, year fixed effects and past litigation activity. In the last three columns, we use IPC Class (e.g. 3 digit IPC code) to define both innovation and litigation activity. Definition and summary statistics of other variables are provided in Table 1. Standard errors are clustered by year and reported in parenthesis. ***, **, and * refer to statistical significance at 1, 5 or 10% level.

	4-Digit IPC Code (Subclass Level)			3-Digit IPC Code (Class Level)		
	University Share	University Share	University Share	University Share	University Share	University Share
Litigation5	0.7257***			0.1874***		
	(0.1237)			(0.0546)		
Litigation4		0.6303***			0.1663***	
		(0.1222)			(0.0520)	
Litigation3			0.5215***			0.1449**
			(0.1323)			(0.0518)
Tech Group FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	12,533	13,159	13,789	2,649	2,783	2,913
R2	0.46	0.45	0.43	0.49	0.47	0.38

Table 4 – Robustness Analysis: Excluding recent Patent Applications

In this table, we replicate our main analysis reported in Table 3 after excluding patent applications filed in 2012 and 2013. We use OLS model using past litigation activity to predict future patent production in universities compared to all patents (*University Share*). In the first three columns, the unit of observation is year-IPC Subclass code (e.g. 4 digit IPC code). In the last three columns, we use IPC Class (e.g. 3 digit IPC code) to define both innovation and litigation activity. Definition and summary statistics of other variables are provided in Table 1. Standard errors are clustered by year and reported in parenthesis. ***, **, and * refer to statistical significance at 1, 5 or 10% level.

	4-Digit IPC Code (Subclass Level)			3-Digit IPC Code (Class Level)		
	University Share	University Share	University Share	University Share	University Share	University Share
Litigation5	0.5228***			0.1195**		
	(0.1779)			(0.0525)		
Litigation4		0.4383**			0.1035**	
		(0.1673)			(0.0470)	
Litigation3			0.3158*			0.0801*
			(0.1712)			(0.0441)
IPC-Subclass Fixed Effect	Yes	Yes	Yes			
IPC-Class Fixed Effect				Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	11,750	12,376	13,006	2,434	2,568	2,698
R2	0.48	0.47	0.45	0.50	0.48	0.38

Table 5 – Litigation Cost Environment and University Patenting Activity

In this table, we estimate an OLS model using past litigation activity to predict future patent production in universities compared to all patents (*University Share*). The unit of observation is year-IPC Subclass code. In the first three columns, we use patents classified with IPC section code A to F, where A refers to technologies related to "Human Necessities"; B refers to Performing Operations & Transporting; C refers to Chemistry & Metallurgy; D refers to Textiles & Paper; E refers to Fixed Constructions; F refers to Mechanical Engineering, Lighting, Heating, and Weapons. In the last three columns, we use patents classified with IPC section code H ("Electricity), G ("Physics"). Definition and summary statistics of other variables are provided in Table 1. Standard errors are clustered by year and reported in parenthesis. ***, **, and * refer to statistical significance at 1, 5 or 10% level.

	Low Litigation Tech Groups			High Litigation Tech Groups		
	University Share	University Share	University Share	University Share	University Share	University Share
Litigation5	1.0902			0.6150***		
	(0.7082)			(0.2042)		
Litigation4		0.5378			0.5163**	
		(0.6639)			(0.1968)	
Litigation3			0.1138			0.4106**
			(0.5929)			(0.1903)
Tech Group FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	9,805	10,293	10,790	2,658	2,792	2,924
R2	0.51	0.51	0.51	0.42	0.40	0.34

Table 6 – Innovation Intensity and University Patenting Activity

In this table, we estimate an OLS model using past litigation activity to predict future patent production in universities compared to all patents (*University Share*). The unit of observation is year-IPC Subclass code. In the first (last) three columns, we use patents in IPC Subclasses with generated more (less) than 50 granted patent applications. Definition and summary statistics of other variables are provided in Table 1. Standard errors are clustered by year and reported in parenthesis. ***, **, and * refer to statistical significance at 1, 5 or 10% level.

	Active Patenting Tech Groups			Quiet Patenting Tech Groups		
	University Share	University Share	University Share	University Share	University Share	University Share
Litigation5	0.8321***			-1.0325		
	(0.2313)			(3.3355)		
Litigation4		0.6831***			0.3050	
		(0.2181)			(2.4031)	
Litigation3			0.5347**			2.0345
			(0.2123)			(2.7361)
Tech Group FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	7,216	7,578	7,933	5,845	6,151	6,473
R2	0.82	0.82	0.82	0.28	0.27	0.26

Table 7 - Does Past Litigation Activity Shift Innovation away from Public and Private Firms?

In the first (last) three columns, we estimate an OLS model using past litigation activity to predict future patent production in public (private) firms compared to rest of the patent producers. The unit of observation is year-IPC Subclass code. Definition and summary statistics of other variables are provided in Table 1. Standard errors are clustered by year and reported in parenthesis. ***, **, and * refer to statistical significance at 1, 5 or 10% level.

	Public Firm Share	Public Firm Share	Public Firm Share	Private Firm Share	Private Firm Share	Private Firm Share
Litigation5	-65.6788***			-7.2886***		
	(4.3619)			(1.1737)		
Litigation4		-54.7457***			-6.9921***	
		(3.8288)			(1.1860)	
Litigation3			-46.0773***			-6.9127***
			(3.8700)			(1.2743)
Tech Group FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	9,954	10,576	11,203	9,954	10,576	11,203
R2	0.75	0.75	0.74	0.69	0.68	0.67

Table 8 - Firm-Level R&D and Litigation

In this table, we regress R&D/Assets on several firm characteristics and Litigation5. Litigation refers to a docket in Public Access to Court Electronic Records (PACER) system in which a non-practicing entity (NPE) is listed as a plaintiff. Litigation refers to log of average number of litigation in the past 5 years in firm's industry. Definition and summary statistics of other variables are provided in Table 1. Standard errors are clustered by firm and reported in parenthesis. ***, **, and * refer to statistical significance at 1, 5 or 10% level.

	R&D/Assets	R&D/Assets	R&D/Assets	R&D/Assets	R&D/Assets	R&D/Assets	R&D/Assets	R&D/Assets	R&D/Assets
Litigation	-0.0029***	-0.0034***	-0.0031***	-0.0027***	-0.0028***	-0.0026***	-0.0037***	-0.0034***	-0.0034***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0007)	(0.0007)
Total Assets		-0.0112***					-0.0393***	-0.0509***	-0.0509***
		(0.0007)					(0.0022)	(0.0040)	(0.0034)
ME			-0.0056***				0.0296***	0.0148***	0.0148***
			(0.0008)				(0.0024)	(0.0038)	(0.0036)
B/M				-0.0315***			0.0148***	0.0232***	0.0232***
				(0.0042)			(0.0041)	(0.0053)	(0.0054)
Past Return					0.0047***		0.0082***	0.0041***	0.0041***
					(0.0015)		(0.0013)	(0.0014)	(0.0011)
Patent Stock						-0.0039***	0.0014***	-0.0039***	-0.0039***
						(0.0005)	(0.0004)	(0.0011)	(0.0008)
Industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Firm	No	No	No	No	No	No	No	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	72,949	72,949	72,949	72,949	72,949	72,949	72,949	72,949	72,949
R2	0.22	0.23	0.22	0.22	0.22	0.22	0.24	0.47	0.47

Table 9 – Firm-Level R&D and Litigation

In the first (second) column, we regress the number of patents produced by a public (private) firm on its patent stock (total number of patents produced in the past 5 years) and litigation activity measure, Litigation5. Standard errors are clustered by firm and reported in parenthesis. ***, **, and * refer to statistical significance at 1, 5 or 10% level.

	Public Firm	Private Firms
	Patents Produced	Patents Produced
Patent Stock	0.0960***	0.1165***
	(0.0008)	(0.0016)
Litigation5	-2.3003***	-1.6719***
	(0.2370)	(0.4615)
Firm FE	Yes	Yes
Year FE	Yes	Yes
N	72,949	22,951
R2	0.77	0.73