Chilling Effects of Patent Trolls*

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Abstract

We find that, when a firm is sued by non-practicing entities (NPEs), the likelihood of its technology peers being sued increases in the subsequent year. Defendants' technology peers experience significant market value losses around the lawsuit filing date. Moreover, defendants' technology peers respond to NPE litigation risk by increasing R&D investments to develop workaround technologies. However, the increase in R&D incrementally generates fewer patent citations or patents with lower values. Thus, our results highlight broader wealth effects and corresponding real effects of NPE-initiated litigation on defendants' technology peers. These results provide sharp contrasts to the insignificant wealth and real impacts on defendants' technology peers if litigations are initiated by practicing entities (PEs). The new evidence informs the current regulatory and policy debates pertaining to NPEs.

Keywords: Peer losses; Innovation response; Patent-infringement litigation; Non-practicing entities; Technology peers

JEL Classifications: G14; O34; O32; M41; K11

Chilling Effects of Patent Trolls

1. Introduction

The past twenty years have witnessed a secular increase of patent litigation in the United States, largely driven by non-practicing entities (NPEs) which amass patents, not for the sake of producing commercial products, but to claim license fees and/or litigate infringement on their patent portfolios (RPX 2014, 2015). The societal impacts of NPE-initiated litigation are controversial, attracting considerable attention from practitioners, academia, and regulators (Leiponen and Delcamp 2019). One perspective holds that NPEs help deter patent infringement and serve a helpful intermediary role in the secondary market for intellectual properties (Federal Trade Commission 2011). Conversely, the critics argue that NPEs stifle innovation and technological advances by causing big losses to both large and small companies (Executive Office of the President 2013). For example, Bessen, Ford, and Meurer (2011) find that NPE lawsuits were associated with half a trillion dollars of lost wealth to defendants from 1990 to 2010. In addition, Appel, Farre-Mensa, and Simintzi (2019) show that patent-infringement claims made by NPEs adversely affect high-tech startups' ability to grow, create jobs, innovate, and raise capital. Further, Cohen, Gurun, and Kominers (2016, 2019) document a negative impact on research and development (R&D) at defendant firms after NPE lawsuits. The latter camp thus labels NPEs pejoratively as "patent trolls."

The extant debate and literature largely focus on the impact of NPE lawsuits on defendant firms. Yet to assess the societal impact of NPE lawsuits, it is crucial to understand NPEs' litigation strategies and their impacts beyond defendant firms. There are three important open questions pertaining to the broader societal impact of NPE lawsuits. First, are NPE lawsuits "one-time deals," or do they exhibit a legal strategy of sequential rounds? In other words, are peer firms with related

technologies to defendants more or less likely to become next targets by NPEs after the litigations? Second, do NPE lawsuits create negative wealth effects among defendants' technology peer firms? If so, to what extent? Third, do technology peer firms alter their R&D investments in response to NPE litigation risk in a manner similar to defendants? If not, why not? Answering these questions is important for policymakers because it would provide a fuller gauge of the societal impact of NPEs, allowing for a more thorough cost-benefit analysis for NPE regulations. The answers are also important for investors as they would allow them to be aware of the potential wealth contagion effects of NPE lawsuits. The answers would also shed light on managers of innovating firms on the strategic pattern of NPE lawsuits and how peer firms respond to NPE litigation risk.

We start with investigating whether NPE lawsuits exhibit a legal strategy of sequential rounds by examining the likelihood of defendants' technology peers being sued by NPEs. On the one hand, it might be cost-efficient for NPEs to sue all possible firms in one litigation case. If so, when NPEs sue a defendant firm but do not immediately sue its technology peer firms, the likelihood of subsequently receiving NPE litigation for peer firms would decrease after the litigation announcement. On the other hand, it might be strategically effective for NPEs to first target the most vulnerable defendant firms to increase the odds of winning. Therefore, cost and strategic considerations suggest that NPEs are unlikely to sue all potential target firms in a "one-time deal" but instead are likely to engage in sequential litigations over any given asserted patent with a few defendants in every single suit (Hu 2014; Love 2014; Cohen et al. 2016, 2019).[1] As such, defendants' technology peers would expect a higher likelihood of being sequentially sued by

[1] In particular, Cohen et al. (2019) note that relative to practicing entities (PEs), "NPEs are also much more likely to sue many times on any given asserted patent." Practitioner lawyers also point out that compared to PEs, "NPEs appear to bring frivolous or weak cases with significantly greater frequency than regular plaintiffs" (Hu 2014). Love (2014) finds that "NPEs file more than twice as many suits per patent and assert each patent against more than four times as many alleged infringers."

NPEs after the litigation announcement, despite the fact that NPEs might select multiple firms to initiate litigations.

Consistent with the latter argument, our results show that the likelihood of a technology peer being sued by NPEs increases by 14% in the year subsequent to a defendant firm being sued by an NPE. We identify an at-risk technology peer if the firm uses technologies similar to that of the litigated patent within the same Cooperative Patent Classification (CPC). As a comparison, the likelihood of technology peers being sued in the year subsequent to litigations initiated by practicing entities (PEs) increases by only 4%. These results suggest that, different from PE-initiated patent litigations, NPE patent litigations exhibit a unique legal strategy of sequential rounds of lawsuits on any given litigated patent, a strategy which eventually targets a large number of technology peer firms. Such a strategy conceivably could create strong chilling effects among at-risk technology peers, affecting their market valuations and R&D strategies.

We then investigate the impact of NPE lawsuits on the market valuation of at-risk technology peers. Our analysis focuses on "material" litigations, defined as litigations that cause negative cumulative abnormal returns (CARs) greater than -1.5% in a [-1, +1] three-day filing window for defendant firms. We focus on material litigation events for two reasons. First, some litigations are less material in the sense that either the likelihood of unfavorable outcomes is low or the expected loss is negligible. Such immaterial litigations are unlikely to cause significant impacts on defendant firms, let alone creating contagion effects to technology peers. Second and more importantly, the large market reactions from material litigations suggest that these lawsuits are largely unanticipated by investors, which allows us to identify the wealth contagion effects by avoiding potential confounding factors caused by market anticipation. As an identification strategy, we also contrast the results of NPE litigations with those initiated by PEs. While all litigations may

have spillover effects, by utilizing PE litigations as a benchmark, we are able to isolate the spillover effects exclusively due to NPE litigations.

Our results reveal significant market value losses for at-risk technology peers around the filing of NPE-initiated material cases. The average CARs for all at-risk technology peer firms are -1.49% in one day around the litigation announcements. In terms of dollar values, we estimate that at-risk technology peers incur an average market value loss of $29.8 million per firm when NPEs sue their technologically related defendants. We further show that market value losses of technology peer firms surrounding the lawsuit filing date are significantly associated with their probabilities of being sued, suggesting that investors react to sequential lawsuit strategies of NPEs. We also show that the negative market reactions around the filings of patent lawsuits are much more pronounced if the lawsuits are initiated by NPEs rather than by PEs. The average market value loss for each technology peer involved in PE litigations is only $9.2 million. The results are consistent with the findings that the likelihood of being sued for at-risk technology peers is significantly higher for NPE patent litigation but not for PE patent litigations. As another identification strategy, we utilize the staggered passage of state laws that curb NPEs' abusive legal tactics of making bad-faith patent-infringement claims. Our difference-in-differences tests confirm that the state-level anti-troll laws do mitigate the spillover effect of NPE litigation for technology peers, as indicated by the less negative market reaction for technology peers after the passage of anti-troll laws. Taken together, the results show that the uniqueness of sequential litigation strategies of NPEs causes significantly more negative market value losses for at-risk technology peer firms.

A higher probability of being sued increases the expected legal and settlement costs for at-risk technology peers. However, this is not the only reason for their market value losses. The other

source of market value loss is that at-risk technology peers might respond to higher NPE litigation risk by increasing R&D investments in "workaround technologies" that could adversely affect these firms' operational performance. To identify the impact of NPEs lawsuits on at-risk technology peers' R&D investments, we analyze at-risk technology peers who are not sued by NPEs in the previous or following five years for patent infringement related to the same patent class when a defendant is sued by an NPE (i.e., non-litigated peers). As these firms do not incur lawsuits, we are able to avoid the confounding effect on the changes in R&D investments due to higher legal and settlement costs, as documented by Cohen et al. (2016, 2019).

We first show that such non-litigated peers nevertheless incur an average CAR of -1.1% in the [-1, +1] three-day window when a defendant is sued by an NPE, suggesting that these firms *ex ante* still face a significant probability of being sued. Interestingly, we find that non-litigated peers exhibit significant increases in R&D activities in the five-year period following an NPE case filing. Thus, non-litigated peers behave opposite to the defendants who have to cut R&D due to higher legal costs (Cohen et al. 2016, 2019). The increase in R&D activities of non-litigated peers, however, is in line with the the survey by Chien (2014), which finds a "chilling effect" of NPE lawsuits in that at-risk firms not yet sued take actions to lower the likelihood of subsequent NPE lawsuits. It is also consistent with the game theory predictions of Reitzig, Henkel, and Heath (2007) and Henkel and Reitz (2010) that a non-litigated peer may react by proactively replacing the NPE's technology with a non-infringing alternative (i.e., "workaround technology").[2]

Workaround technologies could be either strategic technologies that are mainly for litigation purposes but have less value, or intrinsic technologies that provide long-term value to

[2] According to the model of Reitzig et al. (2007), proactively developing workaround technologies enhances the bargaining position of the inadvertent infringer, since if future royalty negotiations ensue with the NPE, the infringer will agree to pay no more than the remaining R&D costs to develop the workaround technology.

firms (Abrams, Akcigit, and Popadak 2013; Mezzanotti 2021). To differentiate these two types of innovation outcomes, we investigate the values and impacts of the patents generated from non-litigated peers' R&D investments. We document for non-litigated peers a decline in the ratio of patent citations to R&D and the ratio of patent values to R&D in the five-year period following an NPE lawsuit filing, i.e., fewer patent citations as well as lower patent values for each dollar of R&D spending, suggesting that increased R&D investments likely concentrate on strategic technologies. Given the reduction in the values of R&D investments, it is conceivable that these firms could also suffer higher operational risk and lower profitability. Indeed, we find that non-litigated peers report significant reductions in returns on assets (ROA) and cash flows from operations in the five-year period following an NPE lawsuit filing. These reductions are again more pronounced than those following a PE lawsuit filing.

To provide further corroborative evidence that the increase in R&D is consistent with the "workaround technology" motive of at-risk technology peer firms, we explore narrative 10-K risk-factor disclosures of non-litigated peers. A review of the 10-K risk-factor disclosures by 100 non-litigated peers randomly selected from our sample for the year when a technologically related defendant is sued reveals that 42% of them mentioned attempts to develop workaround technology in order to protect their existing products. Given that firms only discuss major risk factors in their annual reports, the results show that not only developing workaround technology is pervasive among technology peers, but NPE litigation risk is also a significant risk factor that managements deem investors should be informed.

Our study makes two primary contributions to the related literature. First, our study provides a first systematic analysis of externalities arising from NPE patent litigations. In particular, we document that the decline in shareholder wealth due to NPE litigation is not limited

to the defendant firms but rather extends to their technology peers. The effects are both statistically and economically significant. Our evidence suggests that the set of firms affected by NPE litigation is broader than what has been identified in the existing NPE litigation literature.

Second, our results highlight the dichotomous reactions in R&D investments between defendant firms and their technology peers after NPE lawsuits. Cohen et al. (2016, 2019) show that defendant firms substantially reduce their R&D investments after NPE litigations, consistent with the notion that legal and settlement costs crowd out innovation activities at targeted firms. In contrast, our study provides large sample evidence supporting the survey evidence (e.g., Chien 2014) and theoretical predictions (Reitzig et al. 2007; Henkel and Reitz 2010) of the "chilling effects" of NPE lawsuits in that peers increase their R&D investments in response to the NPE litigation risk. Such an increase in R&D investments, however, is less efficient in generating valuable and impactful patents.

Overall, assessing the impacts of NPE litigations on different related parties is crucial to fully gauge their societal impacts. By identifying much broader wealth and real effects of NPE litigations on at-risk technology peers than what has been identified in the existing NPE litigation literature, our study could potentially inform the current regulatory and policy debate pertaining to NPEs. In particular, the insights of the study will assist policymakers in making a more thorough cost-benefit analysis with respect to NPE regulations.

The remainder of the paper is organized as follows. Section 2 discusses the institutional background of NPE litigations and why their impacts could spill over to defendants' technology peers. Section 3 describes the data, the sample, and our measure of at-risk technology peer firms. Section 4 analyzes the wealth effect of NPE litigations on defendants and their technology peers.

Section 5 examines the effects of NPE litigations on technology peers' R&D investment and operational performance. Section 6 concludes the paper.

2. Institutional background of NPE litigation

Prior research has documented the rise in patent litigation brought about by NPEs (e.g., Fischer and Heinkel 2012; Chien 2013; Leiponen and Delcamp 2019). Courts have been granting large monetary awards in patent-infringement lawsuits, even for ideas that make only small contributions to a product (Government Accountability Office 2013). Bessen et al. (2011) find that NPE lawsuits were associated with half a trillion dollars of lost wealth to defendants from 1990 through 2010. The potentially large costs associated with NPEs have prompted a number of scholars and policy commentators who urge policymakers to act to curtail NPEs' activities (e.g., Executive Office of the President 2013). Some states in the U.S. have passed laws to limit NPEs' ability to target local firms. U.S. Congress passed the America Invents Act (AIA) of 2011, which includes a provision that makes it more difficult to sue multiple defendants in the same patent-infringement suit (Bryant 2012); however, evidence suggests that the AIA has had limited effects on curbing abusive NPE litigation behavior (Council of Economic Advisers 2016).

As discussed in Section 1, there are two opposing views concerning the societal role played by NPEs. On the one hand, NPEs can perform the socially valuable function of facilitating markets for technology (Arora, Fosfuri, and Gambardella 2004; Shrestha 2011; Leiponen and Delcamp 2019). On the other hand, critics attribute the rapid growth in the number of patent suits to unclear or unpredictable technology boundaries (Bessen and Meurer 2008). To the extent that NPEs opportunistically assert "fuzzy patent boundaries" against technology firms, they decrease the incentives for these firms to innovate. The risk of inadvertent infringement reduces the rents innovator can expect to earn on their investment, thus decreasing innovators' willingness to invest

in R&D activities (Executive Office of the President 2013). Prior research also finds that NPE patent litigations substantially reduce innovation at targeted firms (Feldman and Lemley 2015; Cohen et al. 2016, 2019) and make it harder for targets to obtain venture capital funding (Kiebzak, Rafert, and Tucker 2016).

No prior empirical evidence has shown that NPE-initiated litigation has wealth contagion effects on technology peers as well as innovation responses by such technology peer firms. A number of factors related to NPEs' litigation strategies and patterns could make the spillover effects from NPE litigations much more pronounced than those from PE litigations. First, NPEs tend to take advantage of patents with "fuzzy boundaries" (Bessen et al. 2011), especially in the IT sector. Compared to PEs, "NPEs appear to bring frivolous or weak cases with significantly greater frequency than regular plaintiffs" (Hu 2014). NPEs also tend to assert their patent claims with little specific evidence of infringement. Prior studies show that in NPE litigations, the defendants in these lawsuits have rarely copied the patented technology (Bessen and Meurer 2008; Cotropia and Lemley 2009).

Second, patent litigation is expensive. Regardless of the court decision, total legal fees per case amount to $1—$25 million (American Intellectual Property Law Association 2013). According to a survey by RPX Corp. (2015), the mean combined legal and settlement costs per NPE litigation are $5.6 million, even if the defendant firm wins the case.[3] NPEs rely on the high cost of patent litigation to extort early settlements from the alleged infringing firms. Due to the costs of patent litigation, as well as the uncertainty and unpredictability of the outcome of jury trials, defendants may settle what they consider frivolous suits with NPEs (Lemley and Melamed

[3] The U.S. generally follows the American rule, under which each litigation party is responsible for paying its own attorney's fees.

2013). Hu (2014) estimates that 97% of NPE litigations eventually settle out-of-court instead of going through trials.

Third, since the business model of NPEs rests solely on patent litigation, NPEs are more likely to conduct aggressive, purely profit-seeking legal activities. Consistent with NPEs "casting a wide net," Cohen et al. (2019) report that NPEs are three times more likely to sue on a given patent than PEs are. For example, in 2001, NTP Inc., an NPE, brought an infringement action against Research in Motion (RIM). NTP claimed that RIM infringed its five patents involving email delivery via wireless systems. The jury ruled in favor of the plaintiff and granted an injunction. Shortly after, the U.S. Patent and Trademark Office (USPTO) made final determinations that essentially all of the claims in the five patents asserted against RIM were invalid. Nonetheless, in 2006, the parties settled the case for $612.5 million. The case, NTP Inc. v. Research in Motion, led industry observers to speculate that NTP intended to sue every telecommunication and IT firm. Consistent with NPEs "casting a wide net," NTP indeed sued a number of firms in the telecommunication and IT industries, including AT&T, Apple, Google, and Microsoft, between 2006 and 2010. NTP settled with these firms for undisclosed settlement terms in 2012.

Fourth, as observed by Reitzig et al. (2007), NPEs tend to wait patiently and allow alleged infringers to implement full-capacity manufacturing with the infringed technology before they sue alleged infringers. The strategic timing allows NPEs to put maximum pressure on the alleged infringing firm for outsized damage awards. With NPEs possessing such a latent litigation strategy, a rational at-risk technology peer firm would not stay put even though the firm has not been sued by NPEs yet. One measure that they could take is to develop workaround technologies.

Finally, compared to a PE litigant, the non-manufacturing status of an NPE has a strategic advantage in that the target defendant cannot file counterclaims of patent infringement. Additionally, a patent suit carries with it the threat of an injunction or mutual injunction, which could shut down manufacturing or other business operations. Since NPEs do not make, use, or sell patented technology, they are immune from "mutually assured destruction" (Sokol 2017). Thus, NPEs can afford to be aggressive in their patent claims and enforcement.

To summarize, the unique litigation strategy of NPEs exhibits not only "casting wide nets" but also aggressively and sequentially pursuing targets, both of which could create significant chilling effects among defendants' technology peers, affecting their valuations and operations.

3. Sample selection and data description

3.1 Litigation data and sample construction

Our sample selection procedures are conducted separately for two different tests: tests involving the likelihood of being sued and tests of the market reactions for at-risk peer firms. For the likelihood of being sued tests, we utilize the Compustat database between 2000 and 2017 with the North American Industry Classification System (NAICS) information. After merging with the Center for Research in Security Prices (CRSP) database, we are left with 106,784 observations. Furthermore, we remove observations with missing control variables and observations with which the associated NAICS industries do not have any patent litigation over the sample period. We thus end up with 76,175 observations for the likelihood of being sued tests.

For the market reaction tests, we start with proprietary patent-infringement litigation data from the RPX Corp. RPX data covers the complete universe of patent litigations from 2000 to 2017. RPX further categorizes all cases into five case types based on the plaintiff's identity: (1) patent asserters that earn revenue predominantly through asserting patents; (2) small inventors; (3)

non-competing entities (NCEs) that are operating companies that assert patents outside their areas of products or services; (4) universities and research institutions (UNIs); and (5) PEs. Following Cohen et al. (2019), we remove cases initiated by either NCEs or UNIs, each of which makes up 1% of all cases. We then define Types (1) and (2) cases as NPE lawsuits and Type (5) cases as PE lawsuits.[4] Furthermore, to avoid confounding events, we remove the cases for which multiple legal cases were filed on the same date against the same defendant, resulting in 32,576 observations. We then combine our patent-litigation data with the share price data from CRSP. We further impose the following three restrictions: requiring no other litigations within the estimation and event window [-135, +1]; removing observations with missing market-value and sales data; and removing immaterial loss cases by requiring a defendant firm's negative CAR at the [-1, +1] three-day window to be greater than -1.5%. Out of 6,380 total cases, 4,533 cases have an immaterial impact (i.e., less than 1.5% of market value losses), suggesting that for such cases, either the market reactions are anticipated, or the value implications are not substantive. We thus remove those cases and are left with 1,847 material patent-litigation cases.[5]

3.2 Identifying at-risk technology peer firms

Since our focus is on the wealth contagion effects of patent litigation, we need to first determine at-risk peer firms in our context. Unlike other contexts that connect defendant firms with peer firms through the same industry membership or the same supply chain, we identify at-risk peer firms through the concordance between patent classes and industry classification of at-risk peers. This identification strategy is motivated by industry practice, in which patent lawyers usually conduct "freedom to operate" (FTO) searches for clients before the clients proceed with

[4] The main results of our study are qualitatively similar when dropping small inventors (accounting for 3% of the sample) from the sample.
[5] Our inferences remain unaltered if we use -1% or -2% as alternative thresholds.

production (Bressler and Hu 2014). Aiming to prevent infringing an existing patent, an FTO search compares the client's planned product or process to classes of patents that have been granted by the USPTO.

[Figure 1 about here]

We show the detail of at-risk peer firm selection in Figure 1. Specifically, every patent litigation will involve one or more litigated patents for which a plaintiff firm sues the defendant firm asserting patent infringement. We then track down the patent class to which the litigated patent belongs. Based on the similarity of descriptions between NAICS industries and patent classes (CPC), each patent class is associated with several industries. Among all related industries, we select the industry that has the highest concordance score with the patent class.[6] Thus, if at least one operating segment of the firm belongs to a NAICS industry that uses technologies most related to the litigated patent, the firm is considered to be an at-risk technology peer with respect to the underlying defendant firm. Such peer firms are deemed to be at risk of being sued for patent infringement in the future, given that their operations involve related technologies.

An important feature of our technology peer measure is that it does not require defendant or peer firms to hold similar patents. As a matter of fact, NPEs assert their patent infringement claims against defendant firms irrespective of whether these defendant firms hold patents similar to the litigated patents or not. While our technology peer measure reflects industry practice in capturing at-risk peer firms that are most likely to be targeted in a subsequent patent lawsuit, we

[6] The concordance score linking NAICS industries and patent classes (CPC) is constructed using natural language processing (NLP) techniques. The details can be found at: https://commercedataservice.github.io/cpc-naics/#. Alternatively, instead of identifying peers from the industry with the highest concordance score, we identify peer firms to be from all those NAICS industries with a minimum concordance score of 30% or 50%. Untabulated results show that our main inferences do not change when we use the alternative identification.

will provide robustness test results by using an alternative technology peer measure based on patent citations across firms (see Section 6.1).

3.3 Descriptive statistics

Table 1 presents the descriptive statistics for the main sample of data used in the likelihood of being sued tests, for which the variables are defined in Appendix A. Among the 76,175 firm observations, 7.7% of the full sample were sued by NPEs, and only 4.6% of the full sample were sued by PEs. Moreover, among the full sample firms, average cash holdings are 24.3% of total assets, suggesting that many firms in the sample are cash-rich. On average, past-year stock returns for the full sample are 13.4%. The average book-to-market ratio is 1.882, while the median book-to-market ratio is 0.572. While the average R&D expense is 5.7% of total assets for the sample firms, more than 50% of sample firms do not report R&D expenses.

[Table 1 about here]

4. Wealth effect of NPE litigations on defendants' technology peers

4.1 Likelihood of being sued

As discussed earlier, NPEs are unlikely to sue all potential target firms in a "one-time deal" but instead tend to engage in sequential legal suits. If so, the defendants' technology peers would face higher probabilities of being sued by NPEs after defendants are sued. To examine whether at-risk peer firms are more likely to be sued in the year subsequent to a defendant firm being sued for patent litigation, we estimate the following logistic regression, following the specification of Cohen et al. (2019):

$$\begin{aligned}\Pr(Sued_{it}) = \text{logit}(&\gamma_0 + \gamma_1 Technologically\ Related\ Firm\ Sued_{it-1} + \gamma_2 Sued_{it-1} + Controls_{it-1} \\ &+ \sum Industry\ Fixed\ Effects + \sum Year\ Fixed\ Effects + \varepsilon_{it}).\end{aligned} \quad (1)$$

In the above model, $Sued_{it}$ is an indicator variable that equals 1 if firm i is sued by PEs or NPEs in year t. The key test variable is $Technologically\ Related\ Firm\ Sued_{it-1}$, which is an indicator

variable that equals 1 if a defendant firm, which is technologically related to firm *i*, is involved in patent litigation in year *t*-1. If litigations by NPEs are not one-time deal but rather sequential moves, we should observe a positive coefficient on *Technologically Related Firm Sued*$_{it-1}$. In addition, we include an indicator variable, *Sued*$_{it-1}$, which controls for whether the focal firm *i* is involved in patent litigation in the past year. We also control for several firm-specific variables in year *t*-1 as examined by Cohen et al. (2019), including firm cash levels and annual changes in cash levels, firm size (measured as the logarithm of total assets), book-to-market ratio, past-year stock returns, and R&D expense scaled by total assets. In particular, we control for firm size, as patent litigations could cause more harm to small firms. Alternatively, since large firms are quick to settle patent-infringement lawsuits and pay larger amounts, they are more likely to be sued (Bessen et al. 2011). Prior stock returns are shown to be related to the plaintiff's incentives to bring a lawsuit (Gande and Lewis 2009). In addition, we control for firm profitability (*ROA*, measured as return on assets at year *t*-1), which contains information incremental to cash holdings. Finally, we control for the fixed effects of industry and fiscal year, and cluster standard errors at the firm level.

[Table 2 about here]

Table 2 presents the logistic regression results. In Columns (1) and (2), we separately test for litigations by NPEs or PEs. Consistent with a "deep pocket" argument (Bessen et al. 2011), PEs and NPEs target large companies as defendants. Furthermore, consistent with Cohen et al. (2019), cash-rich and highly profitable firms (proxied by the return on assets in the past year) tend to fall prey to patent trolls. In addition, there is no statistically significant association between cash holdings and the likelihood of being sued by PEs. The positive and highly significant coefficient of 0.30 on *Technologically Related Firm Sued by NPE at t-1* in Column (1) indicates that at-risk technology peer firms are more likely to be sued in the year subsequent to a technologically related

defendant firm being sued by an NPE. The marginal effect of *Technologically Related Firm Sued by NPE at t-1* is 1.1% (untabulated). Thus, the probability of being sued by an NPE increases by 1.1% if there is a lawsuit involving a technologically related defendant firm in the prior year. Since Table 1 indicates that the unconditional probability of being sued by an NPE is 7.7%, the conditional probability represents an economically significant increase (1.1%/7.7% = 14%).

In contrast, as indicated in Column (2), the fact that the technologically related firms are sued by PEs in the past year has no statistically significant effect (the coefficient estimate is 0.08, which is not significant at the 10% level) on the at-risk peer's probability of being sued by a PE in the current year. Untabulated Chi-square tests reveal that the coefficients of *Technologically Related Firm Sued*$_{it-1}$ are significantly different at the 1% level between the NPE regression in Column (1) and the PE regression in Column (2).

These results show that NPE patent litigations exhibit a unique litigation strategy of aggressively and sequentially pursuing targets that are different from PE litigations. Such a strategy could significantly affect the market valuation of at-risk technology peers, which we now turn to.

4.2 Peer losses

We follow standard event study methodology and measure the share price response to the lawsuit filing as the CAR over the event time window [-1, +1], with day 0 being the lawsuit filing date, using the market model as the pricing benchmark. Daily abnormal return (*AR*) is computed as the actual return minus the predicted return from a market model:

$$AR_{jt} = R_{jt} - \alpha_j - \beta_j R_{mt} \qquad (2)$$

where R_{jt} is the stock return on firm *j* over day *t*, and R_{mt} is the stock return on the value-weighted index of NYSE, AMEX, and NASDAQ companies on the CRSP database over day *t*. α_j and β_j

are estimates from an ordinary least squares (OLS) regression of firm *j*'s market model over the period between days -135 and -11. The CARs for firm *j* are calculated as the sum of abnormal returns over the event window [-1, +1]:

$$CAR_{jt} = \sum_{t-1}^{t+1} AR_{js} \ . \tag{3}$$

As we discussed in the introduction, we focus on 1,847 material cases in our sample of defendant firms because material cases constitute salient events that were not anticipated by investors and could elevate the perceived litigation risk for the technology peers among investors.

[Table 3 about here]

Table 3 presents the filing date announcement effects. Panel A reports that, when defendant firms are sued by PEs (NPEs), the mean CAR is -4.719% (-4.382%). The CARs among NPE lawsuits are slightly less negative than among PE lawsuits, and the difference is marginally significant at the 10% level (see Panel A, bottom row).[7]

We also convert the daily abnormal returns into an estimate of the economic dollar effect for each event. Changes in market value are computed as market value at the beginning of the event window multiplied by CARs. We compute the wealth contagion effects in dollars by summing up the changes in market values of all at-risk peer firms, as well as by calculating the equal-weighted average of the changes in market values of such peer firms. As shown in Table 3, Panel B, a material patent lawsuit filed by NPEs will typically cause a defendant firm an average loss of $384.6 million in shareholder wealth. However, there is no statistically significant difference between the average loss for PE-initiated cases and that for NPE-initiated cases.

[7] To account for the impact of event date clustering among sample litigations, we adjust the t-statistics and evaluate the significance of CARs according to the methodology of Brown and Warner (1985).

To measure the wealth contagion effect, we calculate equal-weighted average CARs of all at-risk peers associated with a patent lawsuit, as well as average CARs weighted by market value and sales for a portfolio of peer firms.[8] Panel C presents the weighted average CARs for at-risk technology peers around the event period. The three methods of taking weights render similar statistics, so we focus on equal-weighted-average CARs. When defendant firms are sued by PEs (or NPEs), the mean equal-weighted-average CAR for at-risk technology peers stands at -0.337% (-1.490%). The market reaction for at-risk peers associated with NPE lawsuits is stronger than that associated with PE lawsuits, and the difference is highly significant (mean difference = -1.153, t-statistic = -3.73).

Panel D reports the aggregate market value loss for all at-risk peer firms in a specific case and then reports the average aggregate market value loss per defendant suit, in which the average is computed across all suits. As indicated in Panel D, shareholders of at-risk peers will on average incur an aggregate market value loss of $377.9 million per PE suit. In contrast, when the patent litigation is initiated by NPEs, shareholders of at-risk peers will on average incur an aggregate market value loss of $1,377.1 million per defendant suit. The average aggregate loss for at-risk peer firms is significantly higher if the case is initiated by NPEs.

Panel D also computes the average market value loss per peer firm in a specific case and then reports the average of such losses across all suits. It shows that shareholders of a typical at-risk peer firm will incur an average loss of $9.2 million per defendant suit if the patent litigation is initiated by PEs; when the patent litigation is initiated by NPEs, shareholders of a typical at-risk peer firm will incur an average loss of $29.8 million per defendant suit. Again, Panel D indicates that the average loss for an at-risk peer firm is significantly higher for an NPE-initiated case.

[8] Our sample indicates that, on average, there are 17.26 technology peers associated with a patent litigation suit (untabulated).

To summarize, the results in Table 3 document a significant wealth contagion effect involving NPE cases. While we do not observe a significant difference in economic dollar effects between NPE and PE cases involving defendant firms, the economic dollar effects for at-risk peer firms in NPE cases are more than three times as great as those in PE cases.[9]

4.3 Peer losses and the likelihood of being sued

If peer losses involving NPE litigation come from investors' anticipated risk of future lawsuit-related losses, the decline in stock prices of at-risk peer firms should increase with the anticipated risk of the likelihood of being sued by NPEs in the future. In this section, we check whether the conjecture holds by testing the association between the market reaction of at-risk technology peers and their projected likelihood of being sued. Specifically, we use the estimate of the likelihood of being sued from Eq. (1) as a key explanatory variable in the following OLS regression:

$$CAR_{cj}^{peer} = \theta_0 + \theta_1 \text{pr}(sued\ by\ NPE\ at\ t+1)_{cj} + Controls_{cj} + \sum Case\ Fixed\ Effects + \eta_{cj}, \quad (4)$$

where CAR_{cj}^{peer} is the cumulative abnormal returns of technology peers for case *c* and peer *j*. *Pr(sued by NPE at t+1)* is the predicted probability of being sued by an NPE at year *t*+1 based on the parameter estimates from Eq. (1). We compute this probability using both in-sample and out-of-sample approaches. In-sample estimates use all of the information during the entire sample period. The out-of-sample estimates use only the information prior to the NPE litigation to estimate the probability. For example, the likelihood of being sued for firm *i* in the year 2010 is based on firm *i*'s characteristics in the year 2009, and the parameter estimates of Eq. (1) are based on information prior to 2010. We include here some of the same explanatory variables that were used

[9] We observe no subsequent reversal of the negative market reactions over the post-event time window [+1, +10] among the portfolios of at-risk technology peers.

to estimate the likelihood of being sued because they are likely to be important determinants of shareholder losses as well. These explanatory variables include firm size, ROA, leverage, and book-to-market ratio.[10]

[Table 4 about here]

Table 4 presents the results for the in-sample and out-of-sample analyses. The *ex ante* probability that an at-risk peer firm will be involved in a follow-on NPE suit appears to generate more negative market reactions to the peer firm's stocks surrounding the dates when technologically related defendant firms are sued by NPEs. The coefficient estimates are -2.42 and -2.79, respectively (both significant at the 1% levels), in in-sample and out-of-sample tests. These results indicate that the higher the probability of being sued, the more negative the CARs for at-risk peer firms, suggesting that the likelihood of being sued is an important determinant of the market value losses of at-risk technology peers surrounding the filing date of a lawsuit against a defendant firm.

4.4 State-level anti-troll laws and spillover effects

In this section, we examine whether the passage of state anti-troll laws affects the NPE spillover effects that we documented in the previous sections. Since 2013, 33 states have adopted anti-troll laws that protect local businesses from bad-faith patent-infringement claims (Appel et al. 2019). If these state-level anti-troll laws are effective in combating aggressive tactics of NPEs' patent assertion, we should observe a smaller negative effect of NPE litigations on peer firms. Adoption states and their respective adoption dates are reported in Appendix IAB. In the sample, we exclude observations before 2011, which helps avoid potentially confounding effects introduced by the America Invents Act (AIA) of 2011. Moreover, most anti-troll laws were passed

[10] Note that there is considerable variation of *Pr(sued by NPE at t+1)* among at-risk peers in the same NAICS industry because we include various firm characteristics, such as *ROA* and *BM*, in Eq. (4).

around 2014. Our sample period from 2011 to 2017 ensures that we have approximately three years of data in each of the pre- and post-periods. We employ the following difference-in-differences specification to identify the effect of anti-troll laws:

$$CAR_{cj}^{peer} = \delta Post_{cj} + Controls_{cj} + \sum State\ Fixed\ Effects + \sum Year\ Fixed\ Effects + \eta_{cj} \quad (5)$$

where CAR_{cj}^{peer} is the cumulative abnormal returns of technology peer *j* around the filing of case *c*. *Post* is an indicator equal to 1 if case *c* is filed after the state in which peer *j* is headquartered has passed anti-troll legislation, and 0 otherwise. We also control for firm characteristics including firm size (*Size*), the return on total assets (*ROA*), leverage (*Lev*), and the book-to-market ratio (*BM*). The coefficient on *Post* essentially captures the change between the pre and post periods of treatment firms relative to the change of control firms, i.e., the difference in differences. In all specifications, we report robust standard errors clustered at the state level.

[Table 5 about here]

Table 5, Panel A shows that the mean CAR for technology peer firms over the time window [-1, +1] is -1.024%, which is consistent with the weighted-average statistics presented in Table 3, Panel C. Table 5, Panel B, presents the fixed-effects regression analyses with a difference-in-differences research design. The main test results are shown in Columns (1) and (2). Since both columns show similar results and Column (2) shows the multivariate regressions with the full specification, we focus on the results from Column (2). The coefficient on *Post* is positive (coefficient estimate = 2.76) and significant at the 1% level. The results indicate that, when compared to control firms, at-risk peer firms in those states that adopted anti-troll laws experience weaker spillover effects following NPE patent litigation. Regarding the control variables in Column (2), we only observe a significant and negative coefficient on *Size*, suggesting a more pronounced spillover effect for larger peer firms following NPE patent litigation.

Columns (3) and (4) report placebo tests for our difference-in-differences analyses. In both columns, we falsely assume that each state that passed an anti-troll law did so two years before the actual adoption date. The coefficients on *Post* are insignificant, thus confirming no expected results for pseudo-law-adoption events. Taken together, the results in Table 5 suggest that staggered adoptions of state-level anti-troll laws curb NPEs' aggressive litigation strategy of "casting a wide net," thus limiting the spillover effects for technology peers.

5. Real effects of NPE litigations on defendants' technology peers

5.1 R&D investments of technology peers

A higher probability of being sued increases the expected legal and settlement costs for at-risk technology peers, which might not be the only source of market value losses for at-risk technology peer firms. It is also possible that at-risk technology peers respond to higher NPE litigation risk by increasing R&D investments in developing workaround technologies that could potentially lead to lower operational performance, thereby resulting in lower market valuation. To identify the impact of NPE lawsuits on at-risk technology peers' R&D investments, we need to tease out the effect of increased legal and settlement costs in order to focus on costs arising from increased R&D investments in workaround technologies. Toward this end, we analyze at-risk technology peer firms that are not sued by NPEs in the previous or following five years for patent infringement related to the same patent class when a technologically related defendant is sued by an NPE (i.e., non-litigated peers).[11]

We first replicate the market reaction tests for non-litigated technology peers during the three-day window of material case filing announcements and present the results in internet appendices. The results in Table IA1, Panel A indicate significantly negative stock price reactions

[11] In our sample, a typical portfolio associated with a patent litigation on average consists of 14.40 non-litigated technology peers.

for the full sample of non-litigated peer firms. Moreover, the market reaction to non-litigated peers is significantly stronger among NPE lawsuits than that among PE lawsuits. In terms of market value losses, Table IA1, Panel B shows that shareholders of non-litigated peers on average incur $329.8 million of aggregate losses if the patent litigation is initiated by PEs, but the average aggregate loss for non-litigated peer firms rises to $950.3 million when the patent litigation is initiated by NPEs. Moreover, shareholders of a non-litigated peer firm incur an average loss of $25.5 million if the patent litigation is initiated by NPEs, which is significantly higher than an average loss of $8.6 million when the patent litigation is initiated by PEs. To summarize, we document significant wealth contagion effects for non-litigated technology peers associated with NPE litigation. The fact that such peer firms incur significant market value losses from NPE-initiated patent litigation confirms that costs associated with NPE litigations go well beyond existing and future defendant firms.

[Table 6 about here]

Table 6, Panel A reports the impact of NPE litigations on non-litigated technology peers' R&D. It shows that non-litigated peers associated with NPE litigation exhibit significantly increase in R&D expenses in the five-year period following the NPE case filing date. Our result differs from the one from Cohen et al. (2016, 2019), who show that defendant firms curtail R&D budget to pay for legal and settlement costs after settling with NPEs or losing to them in court.[12] It is also important to note that, as indicated in Table 6, Panel A, we do not observe significant R&D changes among non-litigated peers that are associated with PE-initiated litigations.

The increase in R&D activities of non-litigated peers is particularly interesting as it is consistent with the "chilling effect" of NPE lawsuits in that at-risk firms not yet sued take actions

[12] We also examine the real effect for defendant firms following NPE litigation. Consistent with Cohen et al. (2016, 2019), we do observe drops in defendant firms' R&D expenses after the settlement of NPE litigation.

to lower the likelihood of subsequent NPE lawsuits. For example, a survey by Chien (2014) finds that "among those who had not received a demand, some reported significant impacts from watching others receive them … and reported being very conscious of patent effects." It is also consistent with the game theory predictions of Reitzig et al. (2007) and Henkel and Reitz (2010). Both studies predict that a non-litigated peer may react to the NPE litigation risk by proactively replacing the NPE's technology with a non-infringing alternative ("workaround technology"), which enhances the bargaining position of the inadvertent infringer, since if future royalty negotiations ensue with the NPE, the infringer will agree to pay no more than the remaining R&D costs to develop the workaround technology.

5.2 R&D output and operational performance of technology peers

There are two possible types of workaround technologies: strategic technologies or original technologies. Strategic technologies are mainly for litigation purposes and have less intrinsic value. Abrams et al. (2013) find that patents with a high strategic value are actually characterized by lower quality, measured by the number of forward citations. Mezzanotti (2021) find that firms experience a reduction in the share of strategical defensive patents after the 2006 Supreme Court decision that reduced patent enforcement and effectively lowered the potential costs of patent litigation for defendants. If the increase in R&D is mainly for strategic purposes, we should expect to see that the increase in R&D is associated with lower quality patents. In contrast, if the increase in R&D is mainly to develop original technologies that have high intrinsic value, we should observe an increase in the quality of patents.

To differentiate these two types of R&D outcomes, we examine whether the documented increase in R&D is associated with a decline or increase in the quality of patents per dollar of R&D investment, i.e., innovation efficiency (Hirshleifer, Hsu, and Li 2013). We use two measures of

patent quality: a patent's market value, and a patent's citation. Specifically, we construct the following innovation efficiency measure based on patent market values:

$IE_{pre}^{value} = \frac{V_{-3}+V_{-2}+V_{-1}}{RD_{-5}+RD_{-4}+RD_{-3}}$, and $IE_{post}^{value} = \frac{V_{+3}+V_{+4}+V_{+5}}{RD_{+1}+RD_{+2}+RD_{+3}}$.

RD refers to R&D expenses (in dollar amounts) for each firm-year. Following Kogan, Papanikolaou, Seru, and Stoffman (2017), *V* is measured as the market values of all patents granted to a firm for a particular firm-year. Specifically, the market value of a particular patent is based on changes in the market values of the firm for the three days following the announcement of an issued patent (i.e., *t* to *t*+2). We then aggregate the market value of patents across all patents issued in a specific firm-year. See details of the estimation of patent market value in Internet Appendix IAA. Alternatively, similar to Hirshleifer et al. (2013), we construct a citation-based innovation efficiency measure:

$IE_{pre}^{cites} = \frac{C_{-3}+C_{-2}+C_{-1}}{RD_{-5}+RD_{-4}+RD_{-3}}$, and $IE_{post}^{cites} = \frac{C_{+3}+C_{+4}+C_{+5}}{RD_{+1}+RD_{+2}+RD_{+3}}$.

C is the number of citations within five years after the issuing date of patents granted to each firm. For both measures, we allow for a two-year gap between R&D investments and the issue date of the patent. Thus, for both measures, innovation efficiency in a five-year time frame is calculated as the innovation output in the most recent three years divided by the R&D expenses in a lagged three-year period. Changes in innovation efficiency are first computed as the innovation efficiency measure in the post-litigation period minus the corresponding measure in the pre-litigation period for each peer firm. In order to aggregate across all non-litigated peer firms for a particular case, a sales-weighted average of such changes is then calculated.

Our patent data comes from the Google Patent database. Google, in collaboration with IFI Claims, a global patent research company, has made a set of structured and searchable datasets of patents available to the public. However, company names in Google Patent need to be manually

linked to existing databases such as Compustat and CRSP. We first utilize a database kindly shared by Kogan et al. (2017). For patents issued up to November 2, 2010, the authors have managed to link the patents to U.S. public firms. For patents issued after that date, we manually match company names from the patent database with Compustat data. In particular, we follow a multi-step matching procedure as described by James Bessen, which is posted on the NBER website.[13] The ultimate parent information is extracted from the SDC Merger and Acquisition Database. We have managed to match 38% of new patents issued after November 2, 2010, which is comparable to a 40% success rate for patents issued between January 1, 2000 and November 2, 2010 as achieved by Kogan et al. (2017).

As indicated by Panel A of Table 6, the change in innovation efficiency for the five-year period following an NPE case filing compared to the corresponding five-year period prior to the case is negative and significant using both measures. For example, when the innovation efficiency is measured by patent market value, the decrease is -1.330, suggesting that the patent market value declines by 133 cents in response to a one-dollar investment in R&D activities. Similarly, when the innovation efficiency is measured by patent citations, the decrease is -0.282, suggesting that the patent citations decline by 28 percent in response to a one-dollar investment in R&D activities. We also compare the difference in innovation efficiency for non-litigated peers between PE and NPE-initiated cases. The results confirm that for both measures the decline in innovation efficiency is significantly greater following an NPE-initiated case, compared to a PE-initiated case.

We further explore the operational impacts on non-litigated technology peers. Table 6, Panel B shows that non-litigated peers report significantly negative changes in ROA and cash flow from operations in the five-year period following the NPE case filing date (-0.029 and -0.008, both

[13] See http://www.nber.org/~jbessen/matchdoc.pdf.

significant at the 1% level), pointing to negative operational impacts for non-litigated peers associated with NPE litigation. However, there is little impact of PE litigation as indicated by insignificant changes in ROA and cash flow from operations (-0.005 and 0.006, both insignificant at the conventional levels). The difference between NPE and PE litigations is again significantly different from zero.

Overall, the results for R&D investments and innovation outputs highlight real effects of NPE patent-infringement litigations. While NPE litigation could incentivize defendants' technology peers to increase R&D by developing workaround technologies, the patents generated from these R&D investments are less valuable or impactful, suggesting that at-risk peer firms are more likely to invest in strategic technologies instead of original technologies.

5.3 Management discussion on developing workaround technologies

To deepen our understanding of the development of workaround technologies for at-risk peers, we analyze the 10-K risk-factor disclosures by 100 at-risk peers randomly selected from our sample for the year when a technologically related defendant is sued. None of these 100 at-risk peers were sued by NPEs in the previous or following five years for patent infringement related to the same patent class (i.e., non-litigated peers). We find that 44% of the 100 firms specifically mentioned potential litigation threats from "third parties" (aside from their competitors) as a source of risk and uncertainty in their own operations. These firms also discussed the negative operational impacts arising from potential future patent litigation: 42% of the 100 firms mentioned the possible need for increased R&D (i.e., developing "workaround technologies") to modify or redesign an existing product or develop substitute technologies, and 60% of the firms mentioned the potential need to exit a product line. Further, 44% of the firms mentioned obtaining a license or paying royalties to the plaintiff for a patent-infringing product, while 22% of the firms mentioned the

possible need to obtain a license for a closely related patent. As additional evidence of potential negative consequences, 30% of the firms mentioned that they had indemnified their customers for third-party patent-infringement claims, and 6% of firms mentioned a decrease in competitive advantage as a result of non-exclusive use of the allegedly infringed patent. We include in Appendix B the excerpts of representative 10-K disclosure by an at-risk peer firm.

Given that firms only discuss major risk factors in their annual reports, the evidence from inspecting annual reports shows that developing workaround technologies is pervasive among technology peers. More importantly, managements of at-risk peer firms view NPE litigation risk as a significant risk factor that investors should be informed of when they invest in the firms. The results also provide an explanation for the negative market reactions observed for non-litigated peers when their technologically related defendant firms are sued by NPEs. In other words, investors are well informed of peer firms' attempts to develope "workaround technologies" and rationally anticipate the negative operational impacts arising from actions taken by such at-risk peer firms.

6. Alternative way of identifying at-risk technology peer firms

In a robustness check, we repeat our main analyses using an alternative way to identify at-risk technology peer firms based on citations to litigated patents. This alternative approach of identifying technology peers is premised on the notion that as knowledge flows from a firm with a cited patent to another firm that files a citing patent (Almeida and Kogut 1999; Kuhn, Younge, and Marco 2020), patent litigation will likely follow suit. In particular, for each patent litigation, we track the litigated patents for which a plaintiff firm sues the defendant firm asserting patent infringement. Specifically, for a case involving the litigated patent P1, we search another patent P2 that (1) cited the litigated patent P1 and (2) was filed at the USPTO before the initiation of the

case involving the patent P1. Then we look up the owner firm of the patent P2 at the case initiation date, which is deemed a peer firm related to the patent-infringement lawsuit involving the litigated patent P1. This citation-based technology peer measure stems from the idea that firms which cite the litigated patents are likely to use the underlying technology covered by the litigated patents and are therefore likely to be affected by the litigation. Tabakovic (2015) confirms that NPEs tend to target those firms whose patents cite the NPEs' patents.

We present the results from the alternative citation-based technology peer measure in the internet appendix (see Table IA2). The results are consistent with our main results. In particular, the market reaction for at-risk peers associated with NPE lawsuits is much stronger than that associated with PE lawsuits. For instance, in Table IA2, Panel C, when defendant firms are sued by PEs (or NPEs), the mean equal-weighted-average CAR for at-risk technology peers stands at -0.567% (-1.865%), and the mean CAR difference between PE and NPE litigations is significant at the 5% level (mean difference = -1.298, t-statistic = -2.08). As shown in Table IA2, Panel D, we also observe economically significant market value losses for at-risk peer firms among NPE litigations ($596.0 million and $25.1 million for aggregate and average losses, respectively) while the market value losses are insignificant among PE litigations. Moreover, in Table IA3, Panel B, we continue to find that the impact of NPE litigation on non-litigated peers' operating performance is significantly different from the impact of PE litigations on non-litigated peers. Most importantly, non-litigated peers associated with NPE litigation exhibit significantly positive changes in R&D expense (0.007 and significant at the 1% level), but no statistically significant changes are observed among their PE counterparts. Lastly, results in Table IA3, Panel A show that non-litigated peers experience declines in innovation efficiency after the NPE litigation (-0.667 and -

0.488 for two measures, respectively). The decline is significantly greater following an NPE-initiated case, compared to a PE-initiated case.

Overall, the results in this section indicate that our main inferences are robust to the alternative way of identifying peer firms. We do note, however, that the citation-based technology peer measure excludes potential at-risk peer firms that use the litigated technology in their products but have not applied for any related patents.

7. Conclusions

In this study, we analyze the impact of NPE litigation on the market value and innovation strategies of defendants' technology peer firms. We find that the likelihood of a technology peer being sued by NPEs increases significantly in the year subsequent to a technologically related defendant firm being sued by an NPE, suggesting that NPE patent litigations exhibit a unique litigation strategy of sequentially pursuing targets while eventually "casting wide nets." We further document economically large negative stock price reactions for peer firms after defendants are sued by NPEs. Furthermore, adverse stock price reactions for peer firms are related to the likelihood of being subject to an NPE's follow-on suit. NPE litigations affect not only market values but also innovation strategies of defendants' peers. We find that nonlitigated peer firms exhibit significant increases in R&D activities in the five-year period after an NPE sues a technologically related defendant firm. However, the increase in R&D is associated with declines in both the ratio of patent citations to R&D and the ratio of patent values to R&D. Peer firms also experience a drop in operational performance subsequent to NPE litigations. The results are consistent with management narratives in peer firms' annual reports that NPE litigations create chilling effects incentivizing peer firms to increase R&D in developing workaround technologies.

Our findings are particularly relevant for policymakers pertaining to NPE regulations as they provide the first evidence showing that the set of firms affected by NPE litigation is broader than what has been identified in the existing NPE litigation literature, thus allowing for a more thorough cost-benefit analysis for NPE regulations. Our study focuses on publicly traded firms which typically are large. With the availability of data, an interesting direction for future research is to investigate whether NPE litigations help small private firms to enforce their intellectual properties and therefore increase their innovations. Overall, assessing the impacts of NPE litigations on different related parties is crucial to fully gauge their societal impacts. Our paper takes the first step in this direction.

References

Abrams, D. S., U. Akcigit, and J. Popadak. 2013. Patent value and citations: Creative destruction or strategic disruption? National Bureau of Economic Research (NBER) Working Paper 19647.

Almeida, P., and B. Kogut. 1999. Localization of knowledge and the mobility of engineers in regional networks. *Management Science* 45 (7): 905–917.

American Intellectual Property Law Association. 2013. *2013 Report of the Economic Survey*.

Appel, I., J. Farre-Mensa, and E. Simintzi. 2019. Patent trolls and startup employment. *Journal of Financial Economics* 133 (3): 708-725.

Arora, A., A. Fosfuri, and A. Gambardella. 2004. *Markets for Technology: The Economics of Innovation and Corporate Strategy*. Cambridge, MA: MIT Press.

Bessen, J. E., and M. J. Meurer. 2008. *Patent Failure: How Judges, Bureaucrats and Lawyers Put Innovators at Risk*. Princeton, NJ: Princeton University Press.

Bessen, J. E., J. Ford, and M. J. Meurer 2011. The private and social costs of patent trolls. *Regulation* 34 (4): 26–35.

Brown, S. J., and J. B. Warner. 1985. Using daily stock returns: The case of event studies. *Journal of Financial Economics* 14 (1): 3-31.

Bryant, T. L. 2012. The America Invents Act: Slaying trolls, limited joinder. *Harvard Journal of Law and Technology* 25: 674-695.

Chien, C. V. 2013. Patent trolls by the numbers. Working Paper, Santa Clara University.

Chien, C. V. 2014. Startups and patent trolls. *Stanford Technology Law Review* 17: 461-506.

Cohen, L., U. G. Guran, and S. D. Kominers. 2016. The growing problem of patent trolling. *Science* 352 (6285): 521–522.

Cohen, L., U. G. Guran, and S. D. Kominers. 2019. Patent trolls: Evidence from targeted firms. *Management Science* 65 (12): 5449-5956.

Cotropia, C. A., and M. A. Lemley. 2009. Copying in patent law. *North Carolina Law Review* 87: 1421-1466.

Council of Economic Advisers. 2016. *The Patent Litigation Landscape: Recent Research and Developments.*

Executive Office of the President. 2013. *Patent Assertion and U.S. Innovation*. White Report, prepared by the President's Council of Economic Advisers, the National Economic Council, and the Office of Science & Technology Policy.

Federal Trade Commission. 2011. *The Evolving IP Marketplace: Aligning Patent Notice and Remedies with Competition.*

Feldman, R., and M. A. Lemley. 2015. Do patent licensing demands mean innovation? *Iowa Law Review* 101: 137-189.

Fischer, T., and J. Henkel. 2012. Patent trolls on markets for technology – An empirical analysis of NPEs' patent acquisitions. *Research Policy* 41: 1519-1533.

Gande, A., and C. M. Lewis. 2009. Shareholder-initiated class action lawsuits: Shareholder wealth effects and industry spillovers. *Journal of Financial and Quantitative Analysis* 44 (4): 823-850.

Government Accountability Office. 2013. *Assessing Factors That Affect Patent Infringement Litigation Could Help Improve Patent Quality*. Report to Congressional Committees. GAO Report GAO-13-465.

Henkel, J., and M. Reitzig. 2010. Patent trolls, the sustainability of 'locking-in-to-extort' strategies, and implications for innovating firms. Working Paper, Technical University of Munich and University of Vienna.

Hirshleifer, D., P. H. Hsu, and D. Li. 2013. Innovative efficiency and stock returns. *Journal of Financial Economics* 107: 632-654.

Hu, C. 2014. Some observations on the patent troll litigation problem. *Intellectual Property & Technology Law Journal* 26 (8): 10-19.

Kiebzak, S., G. Rafert, and C. E. Tucker. 2016. The effect of patent litigation and patent assertion entities on entrepreneurial activity. *Research Policy* 45 (1): 218–231.

Kogan, L., D. Papanikolaou, A. Seru, and N. Stoffman. 2017. Technological innovation, resource allocation, and growth. *Quarterly Journal of Economics* 132 (2): 665-712.

Kuhn, J. M., K. Younge, and A. Marco. 2020. Patent citations reexamined. *RAND Journal of Economics* 51 (1): 109-132.

Leiponen, A., and H. Delcamp. 2019. The anatomy of a troll? Patent licensing business models in the light of patent reassignment data. *Research Policy* 48: 298-311.

Lemley, M. A., and A. D. Melamed. 2013. Missing the forest for the trolls. *Columbia Law Review* 113: 2117-2190.

Mezzanotti, F. 2021. Roadblock to innovation: The role of patent litigation in corporate R&D. Forthcoming, *Management Science*.

Reitzig, M., J. Henkel, and C. Heath. 2007. On sharks, trolls, and their patent prey—Unrealistic damage awards and firms' strategies of "being infringed". *Research Policy* 36 (1): 134–154.

RPX. 2014. *2014 NPE Cost Report: High-Level Findings*. White Report, RPX Corp.

RPX. 2015. *2015 Report: NPE Litigation, Patent Marketplace, and NPE Cost*. White Report, RPX Corp.

Shrestha, S. K. 2011. Trolls or market-makers? An empirical analysis of non-practicing entities. *Columbia Law Review* 110: 114-160.

Sokol, D. D. 2017. Introduction. In D. D. Sokol (Ed.), *Patent Assertion Entities and Competition Policy*, 1-8. Cambridge: Cambridge University Press.

Tabakovic, H. 2015. Essays on innovation, strategy and competition. Doctoral Dissertation, Harvard Business School.

Appendix A
Variable Definitions

Variable	Definition
Sued by NPE	An indicator that equals 1 if a firm is sued by an NPE in year *t*, and 0 otherwise
Sued by PE	An indicator that equals 1 if a firm is sued by a PE in year *t*, and 0 otherwise
Technologically Related Firm Sued by NPE at t-1	An indicator that equals 1 if one or more technologically related firms are sued by NPEs in year *t*–1, and 0 otherwise
Technologically Related Firm Sued by PE at t-1	An indicator that equals 1 if one or more technologically related firms are sued by PEs in year *t*–1, and 0 otherwise
ROA	The ratio of earnings before extraordinary items divided by total assets at the beginning of the year
Cash	The ratio of cash holdings divided by total assets at the beginning of the year
Size	The logarithm of total assets
BM	The book-to-market ratio of equity
Ret	The buy-and-hold stock return over the past 12 months
R&D	The ratio of R&D expenditure divided by total assets at the beginning of the year
Change in Cash	Annual change in cash holdings divided by total assets at the beginning of the year
CAR	The cumulative abnormal returns over the [-1, +1] three-day window around the case filing date
CAR^{peer}	The cumulative abnormal returns of peer firms over the [-1, +1] three-day window around the case filing date
Post	An indicator that equals 1 if the peer firm is headquartered in a state that has passed anti-troll legislation before the filing date of the patent litigation, and 0 otherwise
Lev	The ratio of long-term debt to the book value of equity
OCF	Operating cash flow deflated by total assets at the beginning of the year

Appendix B
Management Discussion on Developing Workaround Technologies

Excerpts of Coherent Inc.'s 2010 10-K:

"In recent years, there has been significant litigation in the United States involving patents and other intellectual property rights. This has also been seen in our industry as well, for example in the litigation brought by IMRA America, Inc. against IPG Photonics Corporation. … In the future, we may be a party to litigation to protect our intellectual property or as a result of an alleged infringement of others' intellectual property whether through direct claims or by way of indemnification claims of our customers, as, in some cases, we contractually agree to indemnify our customers against third-party infringement claims relating to our products. These claims and any resulting lawsuit, if successful, could subject us to significant liability for damages or invalidation of our proprietary rights. These lawsuits, regardless of their success, would likely be time-consuming and expensive to resolve and would divert management time and attention. Any **potential** intellectual property litigation could also force us to do one or more of the following: (bold emphasis ours)

- stop manufacturing, selling or using our products that use the infringed intellectual property;
- obtain from the owner of the infringed intellectual property right a license to sell or use the relevant technology, although such license may not be available on reasonable terms, or at all; or
- redesign the products that use the technology.

If we are forced to take any of these actions or are otherwise a party to lawsuits of this nature, we may incur significant losses for which we do not have insurance and our business may be seriously harmed. We do not have insurance to cover potential claims of this type."

Figure 1
Selection of Technology Peer Firms

This figure shows how a group of firms (A1, A2, A3…) are selected as peer firms to a defendant firm (D) that is sued in a patent litigation (L) involving an asserted patent (P) that belongs to a patent class (CPC). Among all related NAICS industries, we select the industry that has the highest concordance score with the patent class. Firms in the same NAICS industry are selected as peers if no corresponding NAICS industry can be identified.

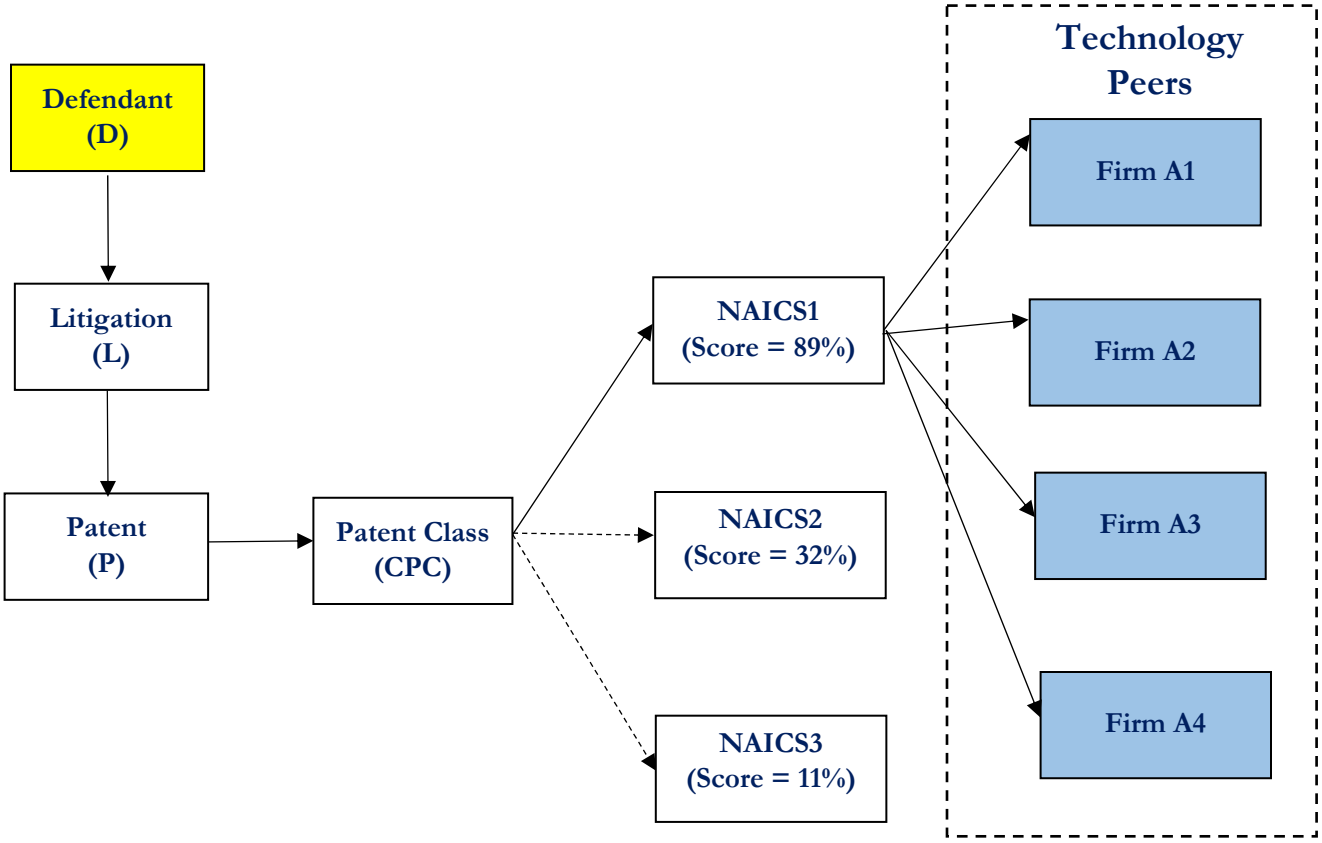

Table 1
Summary Statistics for Variables Used in the Likelihood of Being Sued Tests

This table presents descriptive statistics for variables employed in the likelihood of being sued tests. The sample period is from 2000 to 2017. All variables are defined in Appendix A.

Variable	N	Mean	S.D.	P25	Median	P75
Sued by NPE	76,175	0.077	0.267	0	0	0
Sued by PE	76,175	0.046	0.209	0	0	0
Technologically Related Firm Sued by NPE at t–1	76,175	0.126	0.331	0	0	0
Technologically Related Firm Sued by PE at t–1	76,175	0.220	0.414	0	0	0
ROA	76,175	-0.039	0.277	-0.032	0.016	0.067
Cash	76,175	0.243	0.366	0.036	0.108	0.307
Size	76,175	0.992	1.207	0.128	0.512	1.402
BM	76,175	1.882	8.039	0.305	0.572	0.970
Ret	76,175	0.134	0.627	-0.211	0.063	0.336
R&D	76,175	0.057	0.135	0.000	0.000	0.054
Change in Cash	76,175	-0.047	0.629	-0.037	0.001	0.042

Table 2
Likelihood of Being Sued by NPEs/PEs

This table presents the logit regression estimates that investigate the likelihood of being sued by a PE/NPE in a subsequent year. The sample period is from 2000 to 2017. The dependent variable in Column 1 (2) is an indicator variable that equals 1 if a firm is involved in one or more patent litigations initiated by an NPE (PE), and 0 otherwise. Firm year observations that involve both PE and NPE cases are excluded in Columns 1 and 2. Some observations are omitted in the logit analyses due to collinearity. All variables are defined in Appendix A. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	[1]	[2]
Dep. Var. =	*Sued by NPE at t*	*Sued by PE at t*
Technologically Related Firm Sued by NPE at t–1	0.30***	
	[4.33]	
Technologically Related Firm Sued by PE at t–1		0.08
		[1.29]
ROA	0.97***	0.95***
	[5.34]	[4.48]
Cash	0.24**	-0.09
	[2.56]	[-0.78]
Size	0.60***	0.29***
	[21.54]	[5.83]
BM	-0.02***	-0.03***
	[-3.76]	[-3.03]
Ret	0.09**	-0.05
	[2.08]	[-1.14]
R&D	2.01***	-0.47
	[6.43]	[-1.24]
Change in Cash	0.08	0.16***
	[1.17]	[2.66]
Sued by NPE/PE at t–1	2.14***	1.64***
	[27.63]	[19.24]
Year Fixed Effects	YES	YES
Industry Fixed Effects	YES	YES
Clustered by firm, year	YES	YES
Pseudo R^2	0.33	0.17
N	73,040	73,051

Table 3
Market Reactions for Technology Peers Around Material Case Filing Dates

This table presents the cumulative abnormal returns (CARs) and changes in the market values for defendant firms and their peer firms over the window [-1, +1] around case filing dates during the period between 2000 and 2017. The abnormal return is computed as the actual return minus the return predicted by the market model. The market model is estimated over the pre-event window [-135, -11]. Technology peer firms are identified based on the NAICS industry that has the highest concordance score with the litigated patent. Procedures for peer-firm selection are displayed in Figure 1. Panel A reports the CARs for defendant firms involved in material cases. Material cases are defined as cases with defendants' CARs over the window [-1, +1] lower than -1.5%. Panel B reports changes in market values for defendant firms involved in material cases. Changes in market value are computed as the market value at the beginning of the event widow multiplied by CARs. Panel C reports weighted-average CARs for the portfolio of technology peer firms in each material case. Specifically, weighted-average CARs refer to equal-weighted-average CARs, CARs weighted by the market value of equity, or CARs weighted by net sales. Panel D reports changes in market values for technology peer firms. Specifically, we compute the aggregate market value loss for all peer firms in a case ("Aggregate"), as well as the sales-weighted-average change across all peer firms in a case ("Average").

Panel A: CARs for Defendant Firms Around the Material Case Filing Dates [-1, +1]

Sample	N	Mean (%)	t-stat.	p-value
NPE	1,124	-4.382	-42.35	0.00
PE	723	-4.719	-32.55	0.00
Difference (NPE-PE)		0.337	1.89	0.06

Panel B: Changes in Market Values for Defendant Firms Around the Material Case Filing Dates [-1, +1]

Sample	N	Mean (MM$)	t-stat.	p-value
NPE	1,124	-384.6	-10.51	0.00
PE	723	-462.6	-2.62	0.01
Difference (NPE-PE)		78.0	0.43	0.67

Panel C: Weighted-Average CARs for Technology Peers Around the Material Case Filing Dates [-1, +1]

Sample	Weight	Mean (%)	t-stat.	p-value
NPE	Equally Weighted	-1.490	-5.61	0.00
PE	Equally Weighted	-0.337	-2.12	0.03
Difference (NPE-PE)	Equally Weighted	-1.153	-3.73	0.00
NPE	Weighted by MV	-0.427	-2.72	0.01
PE	Weighted by MV	-1.616	-6.79	0.00
Difference (NPE-PE)	Weighted by MV	-1.189	-4.17	0.00
NPE	Weighted by Sales	-0.422	-2.82	0.00
PE	Weighted by Sales	-1.516	-6.55	0.00
Difference (NPE-PE)	Weighted by Sales	-1.094	-3.97	0.00

Panel D: Changes in Market Values for Technology Peers Around the Material Case Filing Dates [-1, +1]

Sample	Stat.	Mean (MM$)	t-stat.	p-value
NPE	Aggregate	-1377.1	-5.72	0.00
PE	Aggregate	-377.9	-1.95	0.05
Difference (NPE-PE)	Aggregate	-999.2	-3.23	0.00
NPE	Average	-29.8	-5.47	0.00
PE	Average	-9.2	-2.47	0.01
Difference (NPE-PE)	Average	-20.6	-3.12	0.00

Table 4
Peer Losses and the Likelihood of Being Sued

This table presents the fixed-effects regression estimates that investigate whether the market value losses of technology peer firms are associated with peer firms' likelihood of being sued by NPEs in the subsequent year, as predicted in the likelihood of being sued analyses from Table 2. The sample consists of 17,411 case peers, in which peers are associated with material NPE cases (i.e., when a defendant firm experiences a CAR lower than -1.5%). *Pr(Sued by NPE at t+1)* is the predicted probability of being sued by NPEs based on the logit model estimates from Table 2. The predicted probability is also computed using an out-of-sample approach, where only the information prior to the litigation is used to estimate the logit model. All other variables are defined in Appendix A. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

	[1]	[2]
	In-Sample	Out-of-Sample
Dep. Var. =	CAR^{peer}	CAR^{peer}
Pr(Sued by NPE at t+1)	-2.42***	-2.79***
	[-2.58]	[-2.72]
Size	-0.01	-0.00
	[-0.06]	[-0.04]
ROA	-0.00	0.00
	[-0.07]	[0.02]
Lev	0.00	-0.00
	[-0.97]	[-0.97]
BM	-0.00	-0.00
	[-0.79]	[-0.68]
Case FE	YES	YES
Clustered by	Case	Case
Adj. R^2	0.09	0.09
N	17,411	16,816

Table 5
Peer Losses and Staggered Adoptions of State Anti-Troll Laws

This table presents the fixed-effects regression estimates that investigate whether the passage of state anti-troll laws affects the market value losses of technology peers surrounding NPE litigations using the following difference-in-differences specification: $CAR_{cj}^{peer} = \delta Post_{cj} + Controls_{cj} + \sum State\ Fixed\ Effects + \sum Year\ Fixed\ Effects + \eta_{cj}$, where CAR_{cj}^{peer} is the cumulative abnormal returns of technology peer *j* around the filing of case *c*. *Post* is an indicator equal to 1 if case *c* is filed after the state in which peer *j* is headquartered has passed anti-troll legislation, and 0 otherwise. See Internet Appendix IAB for states that adopted anti-troll laws and their respective adoption dates. We also control for firm characteristics, including firm size (*Size*), the return on total assets (*ROA*), leverage (*Lev*), and the book-to-market ratio (*BM*). The coefficient on *Post* essentially captures the change between the pre and post periods of treatment firms relative to the change of control firms, i.e., the difference in differences. Since most anti-troll laws were passed after 2014, we exclude cases filed before 2011, which allows approximately three years before and three years after adoption and also ensures that all cases were filed after the passage of the America Invents Act. The sample consists of 14,693 case peers, in which peers are associated with material NPE cases (i.e., when a defendant firm experiences a CAR lower than -1.5%). We further remove peer firms without headquarter information in their 10-Ks. In the placebo tests, we change the adoption year of the anti-troll laws by falsely assuming that each state that passed an anti-troll law did so two years before the actual adoption date. The placebo-test sample thus goes from 2009 to 2015 to be consistent with the sample duration for the main tests. All variables are defined in Appendix A. Panel A presents the descriptive statistics of all variables employed in this analysis. Panel B reports the results of fixed-effects regressions that facilitate difference-in-differences analyses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Summary Statistics

Variable	N	Mean	S.D.	0.25	Median	0.75
CAR^peer (%)	14,603	-1.024	11.024	-3.693	-0.380	2.622
Post	14,603	0.099	0.299	0.000	0.000	0.000
Size	14,603	5.596	1.855	4.218	5.443	6.858
ROA	14,603	0.025	4.312	-0.116	0.006	0.056
Lev	14,603	6.152	150.423	0.000	0.017	0.379
BM	14,603	0.564	2.033	0.251	0.492	0.795

Panel B: Fixed-Effects Regression Analyses

	[1]	[2]	[3]	[4]
	Main Tests		Placebo Tests	
Dep. Var. =	CAR^{peer}	CAR^{peer}	CAR^{peer}	CAR^{peer}
Post	2.67***	2.76***	-0.71	-0.56
	[3.90]	[4.02]	[-0.56]	[-0.43]
Size		-0.13**		-0.13**
		[-2.53]		[-2.45]
ROA		-0.01		-0.01
		[-0.64]		[-0.64]
Lev		-0.00		-0.00
		[-1.16]		[-1.15]
BM		0.07		0.06
		[1.26]		[1.08]
State Fixed Effects	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Clustered by	State	State	State	State
Adj. R^2	0.041	0.041	0.053	0.054
N	14,603	14,603	14,540	14,540

Table 6
The impact of NPE litigations on R&D and Operational Performance of Non-litigated Technology Peer Firms

This table presents changes in R&D, R&D efficiency, and operating performance for non-litigated peer firms over the years [-5, +5] around the date when a defendant is sued in a patent litigation. The sample includes material cases with CARs lower than -1.5%. Panel A presents changes in R&D and R&D innovation efficiency for non-litigated peer firms. The sample period for the tests of patent market value ends in 2012 because we need data for the five-year period following a defendant lawsuit. The sample period for the tests of citations ends in 2007 because we need data for the five-year period following a defendant lawsuit, and we need another five years to compute patent citations. For each non-litigated peer, we measure R&D innovation efficiency based on either patent market values or patent citations, as follows: $IE_{pre}^{value} = \frac{V_{-3}+V_{-2}+V_{-1}}{RD_{-5}+RD_{-4}+RD_{-3}}$, $IE_{post}^{value} = \frac{V_{+3}+V_{+4}+V_{+5}}{RD_{+1}+RD_{+2}+RD_{+3}}$, $IE_{pre}^{cites} = \frac{C_{-3}+C_{-2}+C_{-1}}{RD_{-5}+RD_{-4}+RD_{-3}}$, and $IE_{post}^{cites} = \frac{C_{+3}+C_{+4}+C_{+5}}{RD_{+1}+RD_{+2}+RD_{+3}}$. V is the market value of all patents granted to a firm for a particular firm-year using the measure developed in Kogan et al. (2017) (see details in Appendix IAA); C is the number of citations within five years after the issuing date of patents granted in each firm-year; and RD refers to R&D expenses (in dollar amounts) for each firm-year. Changes in innovation efficiency (ΔIE^{value} and ΔIE^{cites}) are first computed as the innovation efficiency measure in the post-litigation period minus the corresponding measure in the pre-litigation period for each peer firm. In order to aggregate across all non-litigated peer firms for a particular case, a sales-weighted average of such changes is then calculated. Panel B presents changes in operating performance for non-litigated peer firms. The sample size varies for each variable according to its availability in Compustat. Changes in operating performance measures, including ΔROA and ΔOCF, are first computed as the average value in the post-litigation period minus the average value in the pre-litigation period for each peer firm. A sales-weighted average is then calculated for the portfolio of non-litigated peer firms in each material case. All other variables are defined in Appendix A.

Panel A: Changes in R&D and R&D Efficiency for Non-Litigated Peers Around Years [-5, +5]

Sample	N	Mean	t-stat.	p-value
		$\Delta R\&D$		
NPE	619	0.005	3.45	0.00
PE	320	-0.002	-0.76	0.45
Difference (NPE-PE)		0.006	2.58	0.00
		ΔIE^{value}		
NPE	599	-1.330	-15.60	0.00
PE	293	-1.041	-11.35	0.00
Difference (NPE-PE)		-0.289	-2.31	0.02
		ΔIE^{cites}		
NPE	325	-0.282	-3.37	0.00
PE	178	-0.163	-3.16	0.00
Difference (NPE-PE)		-0.119	-3.89	0.00

Panel B: Changes in Operating Performance for Non-Litigated Peers Around Years [-5, +5]

Sample	N	Mean	t-stat.	p-value
		ΔROA		

NPE	692	-0.029	-9.52	0.00
PE	356	-0.005	-1.06	0.29
Difference (NPE-PE)		-0.024	-4.06	0.00
		ΔOCF		
NPE	692	-0.008	-2.84	0.00
PE	366	0.006	1.49	0.14
Difference (NPE-PE)		0.013	-2.87	0.00

Chilling Effects of Patent Trolls

Internet Appendices

Appendix IAA
Estimation of the Patent Market Value

Following Kogan et al. (2017), the market value of patent j (V_j) is estimated by the following equations:

$$V_j = (1-\pi)^{-1}\frac{1}{N_j}E\left[v_j\middle|R_j\right]M_j, \text{ and } E\left[v_j\middle|R_j\right] = \delta_{ft}R_j + \sqrt{\delta_{ft}}\sigma_{\epsilon ft}\frac{\phi(-\sqrt{\delta_{ft}}\frac{R_j}{\sigma_{\epsilon ft}})}{1-\Phi(-\sqrt{\delta_{ft}}\frac{R_j}{\sigma_{\epsilon ft}})},$$

where π is the unconditional success rate of a patent application, assumed to be 56%; N_j is the number of patents issued on the issuing date; M_j is the market value of the firm that is issued patent j on the day prior to the announcement of the patent issuance; $E\left[v_j\middle|R_j\right]$ is a function of idiosyncratic stock return (R_j) during the three-day window around the issuing day (i.e., t to t+2); ϕ and Φ are standard normal pdf and cdf, respectively, and δ_{ft} is the signal-to-noise ratio. Following Kogan et al. (2017), we assume that δ_{ft} is constant across firms and time as estimated as follows:

$$log\left(R_{fd}\right)^2 = \gamma I_{fd} + cZ_{fd} + u_{fd},$$

where R_{fd} is the daily idiosyncratic return. I_{fd} is an indicator for the three-day window around the issuing day. Z_{fd} controls for the day of week. To account for time-varying fluctuation, firm interacted with year fixed effects are included. The signal-to-noise $\hat{\delta}$ is estimated using $\hat{\delta} = 1 - e^{-\hat{\gamma}}$.

$\sigma_{\epsilon ft}$ is the variance of the measurement error estimated as follows:

$$\sigma^2_{\epsilon ft} = 3\sigma^2_{ft}(1 + 3d_{ft}(e^{-\gamma} - 1)),$$

where σ^2_{ft} is the annual realized mean idiosyncratic squared returns; d_{ft} is the fraction of the trading days of the announcement days. Finally, we deflate the dollar amount to 1982 using the CPI index downloaded from the Bureau of Economic Analysis (https://www.bea.gov/).

We first replicate Kogan et al. (2017) for their sample period (i.e., between 1926 and 2010) and our estimates are similar to theirs. In particular, the mean of our estimated patent value is 10.60 million dollars, which is close to 10.36 million dollars as Kogan et al. (2017) reported in their Table 1. The other statistics are also similar to those in their Table 1. We then expand our sample period to 2017 and estimate the patent values for our tests as reported in our Table 6.

Appendix IAB
Adoption Dates of State Anti-Troll Laws

This table lists the 33 states with anti-troll laws in our sample period along with the corresponding adoption dates.

State	Adoption Date
AL	4/02/14
AZ	3/24/16
CO	6/05/15
FL	6/02/15
GA	4/15/14
ID	3/26/14
IL	8/26/14
IN	5/05/15
KS	5/20/15
LA	5/28/14
ME	4/14/14
MD	5/05/14
MI	10/01/17
MN	4/29/16
MS	3/28/15
MO	7/08/14
MT	4/02/15
NH	7/11/14
NC	8/06/14
ND	3/26/15
OK	5/16/14
OR	3/03/14
RI	6/04/16
SC	6/09/16
SD	3/26/14
TN	5/01/14
TX	6/17/15
UT	4/01/14
VT	5/22/13
VA	5/23/14
WA	4/25/15
WI	4/24/14
WY	3/11/16

Table IA1
Market Reactions for Non-Litigated Technology Peers Around Material Case Filing Dates

This table replicates the results in Table 3 by focusing on non-litigated technology peer firms only. In particular, we remove peer firms that are sued by NPEs (involving patents in the same patent class) in the previous or following five years when a defendant is sued by an NPE. Sample attrition is due to non-existence of non-litigated peer firms in a few cases. Panel A reports the CARs for defendant firms involved in material cases. Material cases are defined as cases with defendants' CARs over the window [-1, +1] lower than -1.5%. Panel B reports changes in market values for defendant firms involved in material cases. Changes in market value are computed as the market value at the beginning of the event widow multiplied by CARs. Panel C reports weighted-average CARs for the portfolio of technology peer firms in each material case. Specifically, weighted-average CARs refer to equal-weighted-average CARs, CARs weighted by the market value of equity, or CARs weighted by net sales. Panel D reports changes in market values for technology peer firms. Specifically, we compute the aggregate market value loss for all peer firms in a case ("Aggregate"), as well as the sales-weighted-average change across all peer firms in a case ("Average").

Panel A: CARs for Defendant Firms Around the Material Case Filing Dates [-1, +1]

Sample	N	Mean (%)	t-stat.	p-value
NPE	1,112	-4.326	-45.29	0.00
PE	720	-4.640	-34.70	0.00
Difference (NPE-PE)		0.313	1.91	0.06

Panel B: Changes in Market Values for Defendant Firms Around the Material Case Filing Dates [-1, +1]

Sample	N	Mean (MM$)	t-stat.	p-value
NPE	1,112	-386.4	-10.46	0.00
PE	720	-463.8	-2.62	0.01
Difference (NPE-PE)		77.4	0.43	0.67

Panel C: Weighted-Average CARs for Technology Peers Around the Material Case Filing Dates [-1, +1]

Sample	Weight	Mean (%)	t-stat.	p-value
NPE	Equally Weighted	-1.076	-5.99	0.00
PE	Equally Weighted	-0.320	-2.24	0.03
Difference (NPE-PE)	Equally Weighted	-0.756	-3.30	0.00
NPE	Weighted by MV	-0.956	-6.62	0.00
PE	Weighted by MV	-0.405	-2.99	0.00
Difference (NPE-PE)	Weighted by MV	-0.551	-2.78	0.01
NPE	Weighted by Sales	-0.965	-7.51	0.00
PE	Weighted by Sales	-0.439	-3.71	0.00
Difference (NPE-PE)	Weighted by Sales	-0.527	-3.01	0.00

Panel D: Changes in Market Values for Technology Peers Around the Material Case Filing Dates [-1, +1]

Sample	Stat.	Mean (MM$)	t-stat.	p-value
NPE	Aggregate	-950.3	-5.50	0.00
PE	Aggregate	-329.8	-1.79	0.07
Difference (NPE-PE)	Aggregate	-620.5	-2.45	0.01
NPE	Average	-25.5	-4.99	0.00
PE	Average	-8.6	-2.46	0.01
Difference (NPE-PE)	Average	-16.9	-2.72	0.01

Table IA2
Market Reactions for Technology Peers Around Material Case Filing Dates: Using an Alternative Measure of Technology Peers

This table replicates the results in Table 3 by using an alternative measure of technology peers. Specifically, technology peer firms are identified based on the citations of litigated patents. The procedures of peer firm selection are described in Section 5.1. Panel A reports the CARs for defendant firms involved in material cases. Material cases are defined as cases with defendants' CARs over the window [-1, +1] lower than -1.5%. Panel B reports changes in market values for defendant firms involved in material cases. Changes in market value are computed as the market value at the beginning of the event widow multiplied by CARs. Panel C reports weighted-average CARs for the portfolio of technology peer firms in each material case. Specifically, weighted-average CARs refer to equal-weighted-average CARs, CARs weighted by the market value of equity, or CARs weighted by net sales. Panel D reports changes in market values for technology peer firms. Specifically, we compute the aggregate market value loss for all peer firms in a case ("Aggregate"), as well as the sales-weighted-average change across all peer firms in a case ("Average").

Panel A: CARs for Defendant Firms Around the Material Case Filing Dates [-1, +1]

Sample	N	Mean (%)	t-stat.	p-value
NPE	643	-4.344	-32.222	0.00
PE	501	-4.641	-27.975	0.00
Difference (NPE-PE)		0.298	0.93	0.35

Panel B: Changes in Market Values for Defendant Firms Around the Material Case Filing Dates [-1, +1]

Sample	N	Mean (MM$)	t-stat.	p-value
NPE	643	-525.6	-4.98	0.00
PE	501	-596.7	-4.58	0.00
Difference (NPE-PE)		71.1	0.42	0.67

Panel C: Weighted-Average CARs for Technology Peers Around the Material Case Filing Dates [-1, +1]

Sample	Weight	Mean (%)	t-stat.	p-value
NPE	Equally Weighted	-1.865	-3.22	0.00
PE	Equally Weighted	-0.567	-2.46	0.01
Difference (NPE-PE)	Equally Weighted	-1.298	-2.08	0.04
NPE	Weighted by MV	-1.719	-2.56	0.01
PE	Weighted by MV	-0.238	-0.63	0.53
Difference (NPE-PE)	Weighted by MV	-1.481	-1.92	0.06
NPE	Weighted by Sales	-2.295	-2.82	0.01
PE	Weighted by Sales	0.225	0.55	0.58
Difference (NPE-PE)	Weighted by Sales	-2.520	-2.77	0.01

Panel D: Changes in Market Values for Technology Peers Around the Material Case Filing Dates [-1, +1]

Sample	Stat.	Mean (MM$)	t-stat.	p-value
NPE	Aggregate	-596.0	-3.95	0.00
PE	Aggregate	-19.8	-0.02	0.98
Difference (NPE-PE)	Aggregate	-576.3	-1.84	0.06
NPE	Average	-25.1	-3.36	0.00
PE	Average	88.1	0.63	0.53
Difference (NPE-PE)	Average	-113.2	-1.93	0.05

Table IA3
The impact of NPE litigations on R&D and Operational Performance of Non-litigated Technology Peer Firms: Using an Alternative Measure of Technology Peers

This table replicates the results in Table 6 by using an alternative measure of technology peers. Specifically, technology peer firms are identified based on the citations of litigated patents. The procedures of peer firm selection are described in Section 5.1. Panel A presents changes in R&D and R&D innovation efficiency for non-litigated peer firms. Panel B presents changes in operating performance for non-litigated peer firms.

Panel A: Changes in R&D and R&D Efficiency for Non-Litigated Peers Around Years [-5, +5]

Sample	N	Mean	t-stat.	p-value
		ΔR&D		
NPE	279	0.007	3.50	0.00
PE	188	-0.001	-0.50	0.62
Difference (NPE-PE)		0.009	2.73	0.01
		ΔIE^{value}		
NPE	279	-0.667	-5.04	0.00
PE	188	-0.314	-2.61	0.01
Difference (NPE-PE)		-0.353	-1.97	0.05
		ΔIE^{cites}		
NPE	199	-0.488	-2.81	0.01
PE	95	0.141	0.54	0.59
Difference (NPE-PE)		-0.630	-2.02	0.05

Panel B: Changes in Operating Performance for Non-Litigated Peers Around Years [-5, +5]

Sample	N	Mean	t-stat.	p-value
		ΔROA		
NPE	292	-0.015	-2.68	0.01
PE	198	0.014	2.70	0.01
Difference (NPE-PE)		-0.029	-3.80	0.00
		ΔOCF		
NPE	292	-0.019	-3.54	0.00
PE	198	0.009	1.86	0.06
Difference (NPE-PE)		-0.027	-3.88	0.00