An Empirical Analysis of the Patent Troll Hypothesis: Evidence from Publicly-Traded Firms

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Do firms that earn revenues from licensing patent portfolios, rather than producing physical products—often called patent assertion entities (PAEs)—frustrate or facilitate innovation? Using a sample of 17 years of SEC filings by all 26 publicly-traded firms that an expert (RPX Corporation) categorized as PAEs, we estimate spending on, patent acquisition, and litigation; and their revenues, rates of return, and risk-return ratios. We also estimate an upper bound of the transfer from operating companies to those 26 firms, including the cost of defending against their lawsuits. We find that sample firms spent twice as much on R&D (as a percentage of revenues) than the average for large high technology companies. We also find that most sample firms lost money. Finally, we find that the magnitude of the transfer from operating companies (including legal defense costs), represents only 0.28% of the revenues of the U.S. high technology market. These findings are inconsistent with the characterization of the PAE business model in an influential policy and academic literature.

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1. Introduction

Do firms that earn revenues from licensing their patent portfolios, rather than producing physical products—often referred to as patent assertion entities (PAEs)—frustrate or facilitate innovation?

According to one view, PAEs purchase specious intellectual property and then file frivolous lawsuits in order to extort revenues from operating companies that would rather settle than go through the expense of litigation. The assumption underpinning this view is that patents held by PAEs have little or no value.[1] The revenues earned by PAEs are therefore a tax on innovation: dollars that would be spent on R&D by operating companies are diverted to non-productive uses (Merges 2009; FTC 2011, 2016; Bessen, Ford, and Meurer 2011; Executive Office of the President 2013; Bessen and Meurer 2014; Kiebzak, Rafert and Tucker 2016.) PAEs are therefore like the trolls in Scandinavian folktales: unsuspecting companies on their way to the meadow of commercial success are gobbled up by monsters lurking under a bridge — hence PAEs are often referred to pejoratively as "patent trolls." A business model based on using low value patents to file frivolous lawsuits for their nuisance value, with little risk of being countersued, should yield easy returns—and a high yield, low risk business model that is not characterized by barriers to entry should proliferate rapidly. It follows, accordingly, that PAEs are a systemic problem in need of a policy solution.

This view of PAEs, which we hereinafter refer to as the "patent troll hypothesis," has proved influential among government officials. The 2013 White House report on *Patent Assertion and U.S. Innovation*, for example, makes the following claim: "PAEs assert broad patent claims against an unusually large set of potential defendants; these assertions are often not based on any evidence of infringement by an individual defendant, but are instead an attempt to find

[1] As Hovenkamp (2015) puts it, the patents "are likely invalid and ought not to have been granted in the first place." This view of PAE patents is the basis for the claim that PAEs do not simply give rise to a transfer, but produce a "social loss" (Bessen and Meurer 2014: 392).

companies that will seek to settle the PAE's claims rather than risk a trial." The report goes on to say, "Given this situation, many patent owners and users prefer to settle out of court for amounts that have not so much to do with the economic value of their patents or the probability that they have infringed." (Executive Office of the President, 2013). The Federal Trade Commission (FTC, 2016: 16) makes a broadly similar claim, quoting its 2011 report, *The Evolving IP Marketplace*: "[f]or the most part, PAEs purchase patents, and then sell or license them as assets whose values are based on the amount of licensing fees that can be extracted from operating companies already using and marketing the technology, or they facilitate others who make the assertions." The FTC's view of PAEs has reached the Supreme Court.[2] In Commil USA, v. Cisco Systems Inc, a 6-2 majority wrote: "Some companies may use patents as a sword to go after defendants for money, even when their claims are frivolous." The decision went on to quote FTC officials to argue that demand letters asserting infringement "may be sent very broadly and without prior investigation, may assert vague claims of infringement, and may be designed to obtain payments that are based more on the costs of defending litigation than on the merit of the patent claims," which can impose a "harmful tax on innovation."[3]

The policy implication of the patent troll hypothesis is straightforward; PAEs are a threat to innovation, economic growth, and consumer welfare, and thus Congress should reform the laws governing patents and civil procedure so as to make their business model unsustainable. This view of PAEs was the impetus for the 2011 America Invents Act, as well as the (failed) 2015 Innovation Act.

An alternative view of PAEs is that they create value by developing or purchasing patents which they then license to operating companies. They therefore provide a mechanism by which

[2] The FTC's claims have also influenced the academic literature. Bessen and Meurer (2014: 394), for example, cite FTC (2011) as the source for their claim that: "Rather than transferring technology and aiding R&D, it appears that NPEs usually arrive on the scene after the targeted innovator has already commercialized some new technology."

[3] *Commil USA, LLC v. Cisco Systems, Inc.,* 575 U.S. (2015).

inventors can appropriate the returns to their investments, which allows the stock of new technologies to expand, increasing innovation, economic growth, and consumer welfare. (McDonough 2006; Geradin, Layne-Farrar, and Padilla 2008; Beron and Kinsella 2011; Risch 2012). This view of PAEs is consistent with the results from survey experiments (Haber and Werfel 2016), as well as the U.S. economic history literature. Lamoreaux and Sokoloff (2003), Lamoreaux, Sokoloff, and Sutthiphisal (2013), Khan (2014), and Mossoff (2015) all find that at earlier points in U.S. history specialized firms emerged that acquired patents in order to seek licensing revenues and litigated aggressively when their patents were infringed. Those intermediaries were derided by the firms they sued.

We refer to this view of PAEs hereinafter as the "intermediation hypothesis." The logic underpinning this hypothesis is that a firm that develops a new technology can choose among four possible options in order to appropriate the value of that technology: (1) commercialize the patented technology itself; (2) sell the patented technology to an operating company; (3) license the patented technology to an operating company, thereby becoming a PAE; or (4) sell the patented technology to an already established PAE. The first option—become an operating company—is expensive, requiring large amounts of capital and marketing talent. The second option—sell the patent to an operating company—entails the risk that the operating company will infringe the patent rather than purchase it, and use its superior financial resources to fight any lawsuit that comes along — a strategy known as "efficient infringement" or "patent holdout." (See, for example, Ball and Kesan 2009; Heiden and Petit 2018.) The third option — become a PAE — is only viable if the inventive firm can mobilize the capital and talent necessary to build a successful licensing business. The fourth option — selling the patented technology to an established PAE—removes the risk inherent in the other options and provides the inventive firm with liquidity that can be deployed in further rounds of inventive activity. The policy implication of

the "intermediation hypothesis" is that reforms designed to make the PAE business model unsustainable will hinder innovation; if there are no intermediaries, then there will be fewer inventive firms creating pioneer technologies.

The question of whether PAEs are harmful trolls, useful intermediaries, or something else cannot be adjudicated based on the intensity of the opposition to them by operating companies. If patents are to have value they must be defended against infringement—but nobody likes to be sued. Thus, PAEs might be harmful, helpful, or irrelevant to the U.S. economy, but regardless they are not going to be popular with operating companies.

Our goal in this paper is to bring analytic clarity to a debate whose terms remain unclear. As Allison, Lemley, and Schwartz (2017: 240) point out, there is "a lack of clarity regarding whom exactly we are talking about. The pejorative term 'troll' is used by some to refer to any party that doesn't actually produce goods or services. Indeed, some use 'troll' to refer to anyone who is suing them, even practicing entities." Obviously, it cannot be the case that any firm that sues another firm for patent infringement, or that earns revenue by licensing patents, does harm to the U.S. economy. How, then, how are researchers and policy makers to figure out whether business models that focus on licensing patents rather than producing products are consistent with the "patent troll hypothesis," the "intermediation hypothesis," or some other hypothesis yet to be specified? The same can be asked about the criteria by which scholars and policy makers should determine the extent to which PAE activities—either harmful or helpful—matter for the rest of the economy. Any statement about the magnitude of the impact of PAEs is necessarily relative. The question is, relative to what?

There is no consensus definition in the literature about the criteria by which a firm should be identified as a PAE. According to Bessen and Meurer (2014: 388), for example: "Colleen Chien coined the term 'Patent Assertion Entities' (PAEs) to specifically identify NPEs [Non-

Practicing Entities] who assert patents rather than play some other intermediary role in the market for patent rights or the market for technology." The crucial distinction is therefore "assertion" versus "intermediation," though it is unclear how a firm can play an "intermediary role" if it does not assert its patents.

The Federal Trade Commission (2016: 15) defines a PAE based not on assertion versus intermediation, but on the basis of whether the patents were created in-house or were purchased in the market. "The term 'patent assertion entity,' or PAE, as used by the Commission in this report and elsewhere, refers to a firm that primarily acquires patents and seeks to generate revenue by asserting them against accused infringers. As the term underscores, PAE business models focus on asserting patents that the firm has acquired from third parties, rather than obtained from the U.S. Patent and Trademark Office (USPTO) through prosecution." The crucial distinction is therefore whether a firm acquires patented technologies by hiring scientists and engineers, or acquires patented technologies by purchasing them from scientists and engineers — though, as a matter of economic theory, it is unclear why this distinction should matter. Regardless, it follows that a firm that invests in R&D, patents the resulting inventions, and then asserts its patents against infringers is not a PAE according to the FTC.

The defensive patent aggregator and patent litigation insurer RPX defines a PAE based on the type of entity that asserts a patent. According to RPX (2015b: 82) a PAE is an entity "believed to earn revenue predominantly through asserting patents" and does not fall into one of the following three groups: "(1) Universities and research institutions; (2) Individual inventors; (3) Non-competing entities (NCEs)—operating companies asserting patents outside their areas of products or services." RPX classifies those three groups, plus PAEs, as Non-Practicing Entities (NPEs). Thus, in the RPX definition of a PAE what matters is neither whether a firm asserts or

intermediates patents, nor the source of its patents, but that a firm is an NPE that is *not* a university, an inventor, or an operating company. RPX identifies NPEs through its own expert review process.[4]

We address the lack of analytic clarity in the debate about PAEs in three stages. First, we draw on the Executive Office of the President, (2013), the FTC (2011, 2016), and the academic literature to define the features of a harmful PAE (a "patent troll") so that we can operationalize claims about them as testable hypotheses. We then let an external expert (the RPX Corporation, a defensive patent aggregator and patent litigation insurer that has a strong incentive to identify PAEs in order to build its business model) demarcate the universe of publicly-traded PAEs based on its "Public PAE Reports."[5] Those reports denote 26 firms as publicly-traded PAEs, and we refer to them hereinafter as "RPX-identified public PAEs." Readers may wonder why we rely on the categorization of the RPX Corporation. The reason, as we discuss above, is that the academic and policy literatures do not provide a consensus definition of a PAE. Rather than come up with our own definition, and therefore categorization, which might induce selection bias, we tie our hands by letting an external expert identify the universe of firms under study.

[4] See https://www.rpxcorp.com/reports/, accessed July 26, 2018. "RPX identifies NPEs through a manual review process performed by experienced employees with sophisticated knowledge of the patent industry. The process includes, among other things, searching for evidence of operating or patent monetization activities on the Internet including company websites; reviewing complaints, with a focus on accused products and allegations regarding products and/ or services sold by the patent owner; considering the outside counsel employed by the entity (e.g. whether outside counsel has a history of representing NPEs); reviewing public filings; reviewing corporate disclosure statements filed in litigation; and soliciting market intelligence from patent professionals. While there are elements of subjectivity in this approach, we believe that the process is robust based on feedback from other patent professionals."

[5] RPX Corporation (2016: 5), explains its process as follows: "RPX identifies public PAEs through a manual review process performed by experienced employees with knowledge of the patent industry. The process includes, among other things, reviewing public filings; searching for evidence of operating or patent monetization activities on the Internet, including company websites; reviewing complaints, with a focus on accused products and allegations regarding products and/or services sold by the patent owner; considering the outside counsel employed by the entity (e.g. whether outside counsel has a history of representing public PAEs); reviewing corporate disclosure statements filed in litigation; and soliciting market intelligence from patent professionals. The public PAEs for this particular report represent the largest, most established public PAEs as well as several recently formed public PAEs that have become public via reverse mergers. While there are elements of subjectivity in this approach, RPX believes that the process is robust based on feedback from other patent professionals."

We then test the predictions of the patent troll hypothesis by building and analyzing a dataset that we have built covering the RPX-identified public PAEs based upon publicly available sources—most particularly their Securities and Exchange (SEC) 10K filings and their share price data. The dataset documents each firm's annual revenues, net income, spending on R&D, spending on patent acquisitions, spending on litigation, return on assets, and share returns covering the period 2000 through 2016.[6] We have placed the dataset online so that it may be used, critiqued, or improved upon by other researchers.[7]

The basic findings of the first stage of our analysis is that as a group the RPX-identified public PAEs do not appear to operate in a manner consistent with the patent troll hypothesis. The defining characteristics of a harmful PAE, according to the FTC (2011, 2016) and a related academic literature, is a business model characterized by negligible spending on R&D and the filing of frivolous lawsuits designed to earn easy returns. The data show, however, that as a group the RPX-identified public PAEs spent nearly twice as much on R&D (as a percentage of revenues) than the weighted average of the 153 largest American high technology companies over the period 2011-16. In fact, 17 of the 26 RPX-identified public PAEs spent the same share, or more, of their revenues on R&D as Apple and Hewlett Packard.

Our analysis also finds that the RPX-identified public PAEs as a group do not appear to earn easy returns from filing nuisance lawsuits. If they were filing nuisance lawsuits using valueless intellectual property, then they would be highly profitable. The data indicate, however, that most of the RPX-identified public PAEs lose money—so much so that, as a group, they lost $3.1 billion over the period 2000-16. Only six of the 26 firms yielded profits on an accounting basis

[6] A potential source of bias is that RPX's "Public PAE Reports" began to be published in 2014, and thus we might be missing publicly-traded PAEs that went out of business or were taken private prior to 2014. Given that failed firms are, by definition, not profitable, and that unprofitable firms tend not to grow, we think that selection effects are likely biased in favor of finding more profitable, larger firms.

[7] The dataset may be downloaded as an excel workbook at: https://hooverip2.org/wp-content/uploads/Dataset-for-Maurer_Haber_An-Empirical-Examination.xlsx

over that period. Only six of the 26 firms yielded positive returns for their shareholders over that period, and the evidence indicates that they did so by accepting considerable risk.

Our analysis finds, in addition, that the RPX-identified public PAEs are modest-sized enterprises by the standards of the U.S economy, most of them with revenues lower than a typical Safeway supermarket. This is not what we would expect from a business model that poses a systemic threat to the U.S. economy. In short, when we take the evidence about R&D spending, profitability, risk versus returns, and size together, we find that the testable predictions of the patent troll hypothesis do not match the facts.

It is a basic principle of science that researchers should be skeptical about their results. Thus, as a second stage of analysis, we set aside our findings about R&D spending, profitability, investment risk, and firm sizes, and estimate the magnitude of the "innovation tax" that would be produced if all 26 RPX-identified public PAEs were actually harmful PAEs (patent trolls). We define the market where PAEs operate based on information in FTC (2016) and various RPX reports. There is broad agreement across these sources that PAEs concentrate in high technology markets. We ascertain that the RPX-identified public PAEs operate in those markets based on information in their SEC 10-K filings. We then estimate the size of the U.S. high technology market by aggregating firm-level revenue data for 153 large high technology firms from the 2017 Global Innovation 1000 study by PricewaterhouseCoopers (hereinafter PwC 2017), covering the years 2011-16.[8] We next estimate the total annual revenues of the 26 RPX-identified public PAEs from their SEC 10Ks over the same period. We also estimate the litigation costs that the

[8] PwC 2017 examines the biggest 1,000 global companies in terms of R&D spending. Of those, 357 firms were American. Of those, 153 were in high-technology industries, which we identify as firms whose primary industry is identified by PwC 2017 as Communications Equipment (e.g., Cisco); Electronic Components (e.g., Corning); Electronic Equipment and Instruments (e.g., Fitbit); Internet and Direct Marketing Retail (e.g., Amazon); Internet Software and Services (e.g., Alphabet); IT Consulting and other Services (e.g., IBM); Data Processing and Outsourced Services (e.g., Paypal) Semiconductors (e.g., Intel); Semiconductor Equipment (e.g., Teradyne); Technology Hardware, Storage and Peripherals (e.g., Apple); Application Software (e.g., Adobe); Systems Software (e.g, Microsoft); and Home Entertainment Software (e.g., Electronic Arts). For the PwC data on high-technology firms, see Tab 3.14 "PwC Data US High Tech Firms" in the online dataset. The PwC study and dataset were accessed at https://www.strategyand.pwc.com/innovation1000.

RPX-identified public PAEs might have imposed on other firms. We stress test our litigation cost estimate against those of Bessen and Meurer (2014) and RPX, and find that our estimates are likely upward biased. We have placed the data for all of these estimates in our online dataset so that it may be used, critiqued, or improved upon by other researchers.

The finding of the second stage of our analysis is that the RPX-identified public PAEs as a group are too small to have much effect—either positive or negative—on the U.S. high technology sector. The total size of the transfer from the U.S. high technology sector to the RPX-identified public PAEs (their revenues, plus our estimate of the litigation costs they might impose on other companies) averaged only 0.28 percent of the high technology sector's revenues over the period 2011-16. There is, of course a difference between a transfer and a dead weight loss; the transfer is the total tax (in this case, the PAE's "tax on innovation"), and the dead weight loss is the effect of the tax on consumer and producer surplus—it is the deals that never happen because of the tax. Given standard assumptions about elasticities of supply and demand in consumer products, the deadweight loss imposed by the RPX-identified public PAEs would be on the order of 0.003 percent of the revenues of the U.S. high technology sector.[9] In short, even if the results from the first stage of our analysis about R&D spending and profitability are flawed, we cannot reject the hypothesis that the innovation tax they impose is too small to have any meaningful effect on the U.S. high technology sector. The small size of the RPX-identified public PAEs as a group also implies that we cannot reject the hypothesis that any intermediation they perform for the U.S. high technology sector is too small to have any meaningful effect.

The scientific method does not just allow researchers to winnow out hypotheses that are not supported by logic and evidence, it also allows them to identify the facts that, if true, should cause them to change their minds. Thus, as a third stage in our analysis we ask, what facts about

[9] The standard formulas for these calculations can be found in Maurer and Yu (2010), p. 368.

privately-held PAEs would cause us to think that the results from the first two stages of our analysis lack external validity? As regards the first stage of our analysis, privately-held PAEs would have to behave and perform very differently from the RPX-identified public PAEs, and, in addition, they would also have to be large and numerous. Unless privately-held PAEs spent much less on R&D or patent acquisitions than the average high technology company identified in PwC (2017), then their inclusion could not counterbalance the high R&D intensity of the RPX-identified public PAEs. Unless privately-held PAEs were profitable, low risk enterprises, then their inclusion could not counterbalance the record of low profitability and high risk of the RPX-identified public PAEs. Even if both of these facts about privately-held PAEs proved to be true, the privately-held PAEs as a group would have to approach the size of the RPX-identified public PAEs as a group; otherwise their inclusion would have little material effect on any re-analysis of our R&D and profitability estimates. As regards the second stage of our analysis, unless the privately-held PAEs as a group approached the size of the RPX-identified public PAEs as a group, then their inclusion would have little effect on our estimate of the gross transfer from operating companies, and hence have little effect our estimate on the magnitude of any potential deadweight loss.

We invite other researchers to conduct a thorough analysis of the performance and behavior privately-held PAEs, as well as an analysis of the size of the privately-held PAE sector. As a step in that direction, we assess publicly-available evidence about three large, privately-held patent licensing firms that are often referred to as NPEs, PAEs, and/or patent trolls: Rockstar Consortium, Intellectual Ventures, and Conversant IP.[10] We find that their behavior and performance is not unlike the RPX-identified public PAEs. We also find that the addition of the estimated revenues of these three firms, plus an estimate of the litigation costs they might impose on operating

[10] See, for example, Fuchs (2012), Levy (2014), Yoshida (2017).

companies, would not substantially change our estimates of the transfer and litigation costs imposed by the RPX-identified public PAEs—and hence would not substantially change the magnitude of any potential deadweight loss if these firms were, in fact, levying an innovation tax.

Let us be clear about the inferences that we draw from our three-stage analysis. We are not claiming that there are no patent trolls. The question is not, however, whether one can point to a firm that operates in the manner described by Executive Office of the President (2013), FTC (2011, 2016), and a related academic literature, but whether such firms are large and numerous enough to constitute a systemic problem. We are also not claiming that the RPX-identified public PAEs are helpful intermediaries in the market for innovation. Finding that the evidence about this set of firms is inconsistent with the "patent troll hypothesis" does not necessarily mean that the "intermediation hypothesis" holds. One would have to specify the testable implications of that hypothesis, and then assess it systematically. Indeed, one might easily imagine other hypotheses that should be subjected to tests against evidence—such as, PAEs are specialized technology development companies, or PAEs are failed operating companies that license their legacy IP, or PAEs are so heterogenous that the term is not analytically meaningful.

What we are saying is: (1) we have operationalized the characteristics of harmful PAEs based on claims made by in Executive Office of the President (2013), FTC (2011, 2016), and the associated academic literature, so as to yield testable predictions; (2) we have built and analyzed a dataset about a group of firms that an external expert has identified as PAEs; and (3) we find that the testable predictions of the patent troll hypothesis are inconsistent with the data. We are also saying that, even if we set aside the results of our analysis of the firm-level data, any deadweight loss that the RPX-identified public PAEs might impose on the U.S. high technology sector is trivially small. Finally, we are specifying the evidence that would render our analyses externally invalid, in order to provide a guide for future research.

The rest of this paper proceeds as follows. Section 2 presents the first stage of our analysis. It analyzes the data on R&D spending, profitability, and risk versus returns of the RPX-identified public PAEs. Section 3 presents robustness tests. Section 4 presents the second stage of our analysis. It estimates the magnitude of the transfer, and hence the potential dead weight loss, that the RPX-identified public PAEs might impose on the U.S. high technology market. Section 5 examines publicly-available information about three large, privately-held patent licensing firms that are often referred to as patent trolls, PAEs, and/or NPEs. Section 6 concludes.

2. Stage 1: Evaluating Potentially Negative Impacts

Calling firms "patent trolls" is a shorthand way of saying that they extort payments from operating companies for low-value intellectual property by threatening expensive litigation. There are therefore three testable implications of the patent troll hypothesis. The first is that patents held by trolls have little value other than as a means by which they can extract payments from operating companies. The second is that patent trolls are high-return, low risk enterprises. The third is that such firms are large and numerous. Let us explore each in turn.

If the patent troll business model is to extract settlements that have little relationship to the economic value of their patents, then patent trolls have weak incentives to purchase patents with actual commercial value. As Hovenkamp (2015) puts it, the patents "are likely invalid and ought not to have been granted in the first place." It follows that patent trolls will have spent little to develop or purchase their patents. Patents held by non-trolls, on the other hand, had to be purchased in a competitive market: their inventors could have commercialized the patented technology themselves, licensed them directly to operating companies, or sold them to other firms. As a matter of logic, it follows that we can reject the hypothesis that a group of firms is engaged in patent trolling if they spend a high proportion of their revenues to acquire or develop intellectual property (IP). The FTC (2016:15) claims, in fact, that PAEs do not file patents, which implies that their internal R&D spending should be negligible: "As the term [PAE] underscores,

PAE business models focus on asserting patents that the firm has acquired from third parties, rather than obtained from the U.S. Patent and Trademark Office (USPTO) through prosecution." This claim is echoed in the academic literature. As Lemus and Temnyalov (2017: 1004) put it: "Patent Assertion Entities (PAEs) are companies that typically neither invest in R&D nor use their acquired patents to make new products."

We therefore need to know the how much of their revenues the RPX-identified public PAEs spend on R&D or on the acquisition of patented technologies from third parties. We retrieve the data from their SEC 10Ks. We also need to establish a benchmark by which to judge whether the R&D expenses of these firms are large or small. The obvious benchmark is the R&D spending by other firms in the same high technology markets in which the RPX-identified public PAEs operate. We therefore retrieved the data on R&D spending as a percent of revenues for the 153 largest American high-technology companies identified in PwC (2017) covering the period 2011-16.

The second testable implication of the patent troll hypothesis is that trolling is a high-return, low-risk business model. Filing frivolous lawsuits in order to extract nuisance-value settlements is not characterized by a high level of risk: there is little sunk capital, the marginal cost of production is low, and defendants cannot countersue.[11] We therefore need to know whether the central tendency of the RPX-identified public PAEs is to make or lose money. We also need to know the returns earned by the investors in those firms, as well as the volatility of those returns, because the definition of risk is uncertainty about the future stream of income from an investment. Finally, we need to establish a benchmark by which we can judge whether the return and risk to investors is high or low. The standard benchmark for a low-risk investment is the S&P 500.

[11] While a defendant cannot countersue for infringement, the defendant can challenge the validity of the PAE's patent.

The third testable implication of the patent troll hypothesis follows from the first two, and is in fact the basis for the claim that patent trolls represent a systemic problem for the U.S. economy in need of a policy solution: patent trolling should be a widespread. A high yield, low risk business model that is not characterized by barriers to entry should attract investment dollars. We therefore need to know the size of the RPX-identified public PAEs, relative to the market in which they operate.

The patent troll hypothesis therefore fails a test against evidence if we observe the following: (1) The central tendency of the RPX-identified public PAEs is to spend at least as much on R&D and/or patent licensing as America's large, high technology companies; (2) The central tendency of the RPX-identified public PAEs is that they lose money, and those that earn money do so by taking on risk; and (3) The central tendency of the RPX-identified public PAEs is that they are small.

2.1 Spending on Innovation

We estimate spending on R&D and patent acquisitions for the RPX-identified public PAEs over the period 2000-16. The data we have obtained on R&D spending by America's largest high technology firms only cover 2011-16. Thus, in order to make the results from the two samples comparable, in Table 1 we constrain the data about the RPX-identified public PAEs to the period 2011-2016.[12]

As Table 1 shows, the weighted average spending on R&D and patent acquisition of the RPX-identified public PAEs over the period 2011-16 was 28 percent of revenues. Surprisingly, most spending consisted of internal R&D expenses: 19 percent of revenues, compared to nine percent on the acquisition of patents from outside sources. We note that the nine percent figure is

[12] For data disaggregated by firm and year see Tabs 3.54 "R&D Spending as % of Revenues" and 3.64 "Patent Acquisition Spending as % of Revenues," in the online dataset.

likely a lower-bound estimate, because it does not include patents acquired as a result of mergers with, and acquisitions of, other firms.

TABLE 1 AROUND HERE

Determining whether spending a weighted average of 19 percent of revenues on R&D and nine percent on outside patent acquisition is a lot or a little requires us to ask, "as compared to what? A reasonable comparison is to the large operating companies in the same markets as the RPX-identified public PAEs, which is to say high technology manufacturing, software, and services. Operating companies generally do not report the amounts spent on patent acquisition in their SEC 10K filings, but they report their internal R&D spending. On that basis, R&D spending of 19 percent of revenues is quite a large number indeed. To get a sense of relative magnitudes consider that from 2011 through 2016, Juniper Networks spent, on average, 23 percent of its revenues on R&D, Intel spent 19 percent, Google/Alphabet spent 15 percent, Cisco, Motorola and Microsoft each spent 13 percent, Texas Instruments spent 12 percent, IBM spent 6 percent, and Apple and Hewlett-Packard each spent 3 percent. Overall, R&D spending for the 153 large American high-technology companies in PwC (2017) averaged 10 percent over the period 2011-16—which is to say that they spent roughly half as much as the RPX-identified public PAEs.[13]

It is worth discussing the implications of high R&D spending by the RPX-identified public PAEs for claims made by FTC (2011, 2016) and the academic literature informed by those studies. FTC (2016:15) defines a PAE as a firm that asserts patents acquired from third parties, instead of obtaining them from the U.S. Patent and Trademark Office (USPTO) through prosecution. Unless one were to maintain that the RPX-identified public PAEs spent $2.3 billion on R&D during 2011-16, but then did not patent the resulting inventions, one would have to conclude that many of those firms would not meet the FTC's definition of a PAE. How many would depend on where one set the threshold for R&D spending. If the threshold were set at the R&D

[13] See Tab 3.14 "PwC Data US High Tech Firms" in the online dataset.

spending ratio of Apple and Hewlett Packard (three percent of revenues), then 17 of the 26 firms would not meet the FTC definition of a PAE. If the threshold were set higher—at the weighted average of 10 percent for the 153 high tech firms identified in PwC 2017—then 12 of the 26 firms would not meet the FTC definition of a PAE.

A skeptical reader might argue that the period over which we can draw comparisons to large high tech companies (2011-16), might bias the results upwards, against the patent troll hypothesis. We therefore extend the analysis of R&D spending to cover the entire period over which we have data (2000-16). As Table 2 shows, R&D spending as a percent of revenues was actually higher over the entire 2000-16 period than over the 2011-16 subperiod; 23 percent of revenues, as opposed to 19 percent.

TABLE 2 AROUND HERE

A defining characteristic of the patent troll business model, as we discuss above, is low spending on R&D and patent acquisition. Using the average R&D spending of the large-firm, high-tech sector as a benchmark, we ask how many of the 26 RPX-identified public PAEs spent less than 10 percent of their revenues on R&D, and also spent less than 10 percent of their revenues on outside patent acquisitions, over the period 2011-16 (See Table 1). We apply the 10 percent benchmark to both categories because internal R&D and patent acquisitions are substitutes: firms can do their own R&D or buy someone else's. Only seven of the 26 firms in our sample fall below this 10 percent benchmark. To the degree that these seven firms have a common feature, it is their small size: the largest of them, Network-1, had revenues of only $118 million over the period 2011-16, roughly $20 million per year.[14] To put that figure into perspective, the average Safeway supermarket has annual revenues of $23 million per store (eMarketerRetail, 2017).

2.2 PROFITABILITY

[14] If we push this analysis back to 2000, the results do not materially change. Seven firms meet the criteria. See Table 2.

Patent trolls are alleged to file specious lawsuits for their nuisance value. Thus, a second testable implication of the patent troll hypothesis is that the firms in question are high-profit, low-risk enterprises. We start with a straightforward calculation of returns on assets. This measure shows how effective the RPX-identified public PAEs have been in translating the assets under their control into profits. We calculate this ratio using data in their 10-K and 20-F filings with the SEC.

The results, presented in Table 3, are not consistent with the patent troll hypothesis—for the simple reason that the vast majority of the 26 RPX-identified public PAEs consistently lost money. As a first pass, we look at the data over the same period as our comparative analysis of R&D, the years 2011 through 2016. During this six year period the RPX-identified public PAEs as a group *lost* $469 million; and their weighted average annual rate of return on assets was *negative* one percent. Only six of the 26 firms had positive earnings over the six-year period.[15]

One might be concerned that focusing on the years 2011-16 might be biasing the results downwards, against the patent troll hypothesis. We therefore extend the analysis of earnings and average annual rates of return back to 2000. The data show that the RPX-identified public PAEs as a group *lost* $3.1 billion over the period 2000-2016, and their weighted average annual rate of return was *negative* four percent. Only seven of the 26 had positive earnings over the 17 year period.[16]

TABLE 3 AROUND HERE

A skeptical reader might be tempted to argue that low absolute ROAs are not informative because companies often lose money when they begin operation. Such a reader would argue that investors believe the companies in Table 3 to be solid long-term investments. This hypothesis is

[15] For data disaggregated by company and year back to 2000 see Tabs 3.21 "Earnings" and 3.71 "Returns on Assets" in the online dataset.

[16] Some of the RPX-identified public PAEs sustained astonishingly high losses. This happens when companies with small asset bases burn through a lot of investor money to cover their operating costs. As long as investors are willing to fund their operations, those losses can be sustained. For the underlying data, see tabs 3.21 "Earnings," 3.31 "Assets," and 3.71 "Returns on Assets" in the online dataset.

testable. If investors believe that a publicly-traded firm is a solid long-term investment, then that will be reflected in its share price, even if the company loses money on an accounting basis. Amazon is the quintessential example of such a company. It has generated high returns for shareholders since 1997, but it did not turn a full-year profit on an accounting basis until 2004 and promptly returned to losing money in most years since.

The standard way to measure whether an investment yields a high return is to examine the performance of its shares against the S&P 500 index. We compare the end-of-year share prices for the RPX-identified public PAEs against the S&P 500 by creating an index in which each firm's share price, as well as the S&P 500, is set at 1.00 on the last trading day of 2000.[17] We show the results in Table 4. Only six of the 26 RPX-identified public PAEs earned positive returns for their shareholders (an index value of greater than 1.00 in 2016). Only five of those six outperformed the S&P 500 (an index value of greater than 1.70 in 2016). That is to say, 20 of the firms saw declines in their share prices *in absolute terms*, not just relative to the S&P 500.[18]

TABLE 4 AROUND HERE

Did any of the five firms that out-performed the S&P 500 do so without exposing their investors to more risk than would have been the case had they simply invested in the S&P 500? In order to answer this question, we graph each of the five firms' share price index values in Figure 1. The volatility of the share price indices relative to the S&P 500 index suggests that these were not low risk investments. Table 5 then presents each of the five firm's average monthly market rate of return and its standard deviation (a measure of volatility) compared to the returns

[17] If a firm went public after 2001 we assigned them an index value equal to the S&P 500's index value on the date they began trading. Their performance can therefore be directly compared to the index value for the S&P 500. Figure 1also follows this practice. ITUS was named Copytele until 2014. It traded over the counter. Verizon bought Straight Path Communications in May 2017. All indications are that Verizon wanted Straight Path's wireless spectrum licenses rather than its patent portfolio. See, for example, Ray (2017). Unwired Planet changed its name to the Great Elm Capital Group in June 2016 and delisted in October; the index value for 2016 is its value on October 31. TiVo temporarily ceased trading in September 2016 when Rovi acquired it. The index value for 2016 is its value on August 31.

[18] Two of the 19 firms have no observation for 2016, but the latest observations (2011 for Quest; and 2015 for Revolutionary Concepts) indicate substantial absolute losses to shareholders.

and standard deviation of the S&P 500 over the same periods for which we have share price data. We then divide each firm's share return by that of the S&P 500 for the same period that we have that firm's share price data. We do the same with each firms' standard deviation of its share price. Table 5 tells the same story as Figure 1 investors in the five high-return firms earned two to 10 times more than had they invested in S&P 500, but their investors bore three to nine times more risk.

TABLE 5 AND FIGURE 1 AROUND HERE

How many of the 26 RPX-identified public PAEs meet the combination of low spending on innovation, high returns, and low investment risk that would be consistent with the patent troll hypothesis? Answering this question requires that we establish benchmarks by which can judge what constitutes "high" or "low. Let us bias in favor of the patent troll hypothesis by setting a high benchmark for R&D spending: the weighted average of the 153 large high technology companies in PwC (2017) over the period 2011-16, which is to say 10 percent of revenues. Let us also bias in favor of the patent troll hypothesis by treating firms that do not report R&D spending as having R&D expenditures of less than 10 percent of revenues. Let us also set the benchmark for outside patent acquisition at 10 percent of revenues, because internal R&D and outside patent acquisitions are substitutes, and again treat missing values as spending less than 10 percent. Finally, let us set the benchmark for being a "high return, low risk" investment as a positive return to investors higher than the S&P 500 (an index of 1.70 or more in 2016 in Table 4), and the ratio of the average monthly return over the comparable S&P 500 period is higher than the ratio of the standard deviation of monthly returns over the S&P 500 for the comparable period, as in Table 5.

The results are inconsistent with the testable predictions of the patent troll hypothesis. Twelve of the 26 RPX-identified public PAEs spent 10 percent or more of their revenues on R&D over the period 2011-16. Of the remaining 14 firms, only seven spent less than 10 percent of their revenues on patent acquisition (see Table 1). Of those seven, only two outperformed the

S&P 500 (see Tables 4 and 5). Both of those firms—Network-1, and Straight Path—were extremely small enterprises: Network-1 had average annual revenues from 2011 through 2016 of $20 million; and Straight Path had average annual revenues of $4 million.

What happens if we relax these benchmarks, so as to bias the results even more in favor of the patent troll hypothesis? Let us then ignore all spending on outside patent acquisition, even though the data indicates that a number of firms spent more than half of their revenues on the purchase of patents from inventors or other firms. Let us also ignore risk-return ratios, even though doing so implies that returns to investors were not compensation for bearing risk. Of the 26 RPX-identified firms, 14 spent less than 10 percent of their revenues on R&D in 2011-16. Of those 14, only three outperformed the S&P: the two firms discussed above, plus Acacia. These three account for only nine percent of the revenues of the RPX-identified public PAEs as a group.

Lest these results be misunderstood, misinterpreted, or mis-represented we are not drawing the inference that these three firms are "patent trolls." Rather, we have operationalized the characteristics of harmful PAEs according to claims made in Executive Office of the President (2013), FTC (2011, 2016), and a related academic literature. We refer to this body of claims as the patent troll hypothesis. We then gather the publicly-available data about a group of firms that an external expert has identified as "Public PAEs." Regardless of where we draw benchmarks, we find that the central tendency of the data about these firms is inconsistent with the predictions of the patent troll hypothesis.

The small size of three firms discussed above also points to an additional test of the patent troll hypothesis. Recall that a central part of the hypothesis is that patent trolls pose a systemic threat to the U.S. economy. In order for that to be true, patent trolls would have to be large and numerous. The data indicate, however, that the entire group of RPX-identified public PAEs

is of modest scale, and many of the firms are stunningly small. As Table 1 shows, over the period 2011-16, the 26 RPX-identified PAEs earned a total of $12.1 billion in revenues—on average, roughly $78 million per year each—which is to say that, by the standards of the American economy, they are of modestly-sized enterprises.[19] To give a sense of how small they are, the average annual revenues of the 153 U.S. high tech companies in PwC (2017) over the same period was $7 billion—close to 100 times the average of the RPX-identified public PAEs.[20] Eighteen of the 26 RPX-identified public PAEs had average revenues of less than $20 million per year, which is to say that they were smaller than a Safeway supermarket (eMarketerRetail, 2017). Even the largest RPX-identified PAE had average annual revenues of only $577 million, making it one-twelth the size of the average large high technology company.

3. Robustness Tests

One possible concern is that using weighted averages to compute R&D spending ratios and rates of return on assets might permit a few large firms to drive our results. We have already addressed this concern by looking at the characteristics of individual firms regarding R&D, profitability, risk and returns, and size, but in order to leave no stone unturned let us consider what happens if we remove potentially influential observations from the aggregate estimates.

One possible influential observation is TiVo (Rovi prior to 2016), which accounted for 29 percent of the revenues of the RPX-identified public PAEs over the period 2011-16 (see Table 1). We therefore exclude TiVo from our analysis as a robustness check. As Table 1 shows, the weighted average percentage of spending on R&D by the RPX-identified public PAEs is the same without TiVo (19 percent). Excluding TiVo makes the RPX-identified public PAEs appear somewhat more profitable: total *losses* for 2011-16 fall from $469 million to $383 million, but

[19] For data disaggregated by company and year back to 2000 see tab 3.11, "Revenues" in the online dataset.
[20] See Tab 3.14 ,"PwC Data US High Tech Firms," in the online dataset for the revenue data of the U.S. high tech firms.

the rate of return falls from *negative* one percent to *negative* two percent. In short, we find that excluding TiVo does not materially change the results.

Another potentially influential observation is InterDigital, which accounted for 23 percent of the revenues of the RPX-identified public PAEs over the period 2011-16 (see Table 1). It is also been a contributor to the research group that one of us directs, and we think it good practice to report whether the results of a study are strengthened or weakened by the inclusion of data that refer to a donor.[21] We therefore exclude InterDigital from the analysis as a robustness check. As Table 1 shows, doing so makes our results even less consistent with the patent troll hypothesis. The weighted average percentage of spending on R&D by the RPX-identified public PAEs increases slightly, growing from 19 percent (including InterDigital) to 20 percent (without InterDigital) over the period 2011-16. Excluding InterDigital also makes the RPX-identified public PAEs as a group appear less profitable, because it was one of the six firms that earned a positive rate of return on assets during 2011-16 (see Table 3) and one of the five firms that out-performed the S&P 500 over the period 2000-2016 (see Table 4).

4. Transfers and Dead-Weight Losses

4.1. ESTIMATING DEADWEIGHT COSTS

Perhaps our tests of the patent troll hypothesis based on R&D spending, patent acquisition spending, rates of return, investment risk, and size are inaccurate? We therefore need to consider the hypothesis that the RPX-identified public PAEs do in fact impose a tax on innovation, and estimate the magnitude and effect of that tax.

The logic of an "innovation tax" is that when an operating company pays a licensing royalty (or a settlement for past royalties) to a PAE it is transferring part of its revenues to that PAE.

[21] See the footnote identifying the authors of this paper for the statement of that research group regarding contributions only in the form of unrestricted gifts in order to maintain academic freedom and independence, as well as the identification of corporate donors.

When an operating company defends against an infringement claim, it transfers part of its revenues to an outside law firm or to inside counsel. If those payments are a "tax on innovation," rather than the rental rate on valuable intellectual property, then they can be analyzed using the same methods that one would use to analyze the partial equilibrium impact of any tax: the tax raises the cost of production to firms and increases the prices paid by consumers, causing output and sales to fall. The resulting shrinkage of the market — the deadweight loss — is captured by the well-known Harberger triangle.[22] We therefore need to estimate the deadweight loss—the deals that are never made—because of the "innovation tax" levied by the RPX-identified public PAEs.

We cannot stress strongly enough that deadweight losses are the product of deals that do not happen and thus they cannot be directly observed. A deadweight loss can only be inferred based on (1) the magnitude of the tax—in this case the transfer from operating companies to allegedly harmful PAEs plus the legal defense costs imposed on operating companies by those PAEs; and (2) the elasticities of supply and demand for the final products. Given standard assumptions about supply and demand elasticities in high technology markets, one would expect the deadweight loss to be a very small fraction of the transfer.[23]

The empirical implication is straightforward: in order for the deadweight losses created by the RPX-identified public PAEs to be large one of two things must be true: (1) The royalty payments from operating companies to those firms, as a percentage of the market in which the

[22] For a discussion of Harberger's contribution, and subsequent research which tended to show that Computable General Equilibrium models provided roughly similar results to Harberger triangles, see Hines 1999.

[23] The more an industry is characterized by highly elastic supply and demand curves, the higher the ratio of the dead weight loss to the size of the transfer. That is, if a small increase in prices induces a big decline in the amount consumers are willing to buy and a big increase in the amount producers are willing to sell, then the magnitude of the deadweight loss can approach, or even exceed, the size of the transfer. The industries characterized by highly elastic supply and demand are composed of large numbers of small firms with few constraints on entry, in which producers take prices as given, and in which consumers do not differentiate among producers based on branding or perceived differences in quality. Dry cleaning is a textbook case of such an industry. These conditions do not obtain in high technology manufacturing, which are textbook examples of imperfect competition and supply constraints. See Comino and Manenti 2014, 90; and Klein 2015, 52-53. Harberger assumed that the elasticity of the demand curves was equal to 1 in his classic 1954 monopoly paper. If we assume a similar elasticity of demand, as well as of supply, then the dead weight loss would be equal to roughly one percent of the transfer.

RPX-identified PAEs operate, must be large; or (2) the costs of defending against their infringement lawsuits, as a percentage of the market, must be large. We therefore need to know: the magnitude of the payments from operating companies to the RPX-identified public PAEs; the legal costs incurred by operating companies in defending against lawsuits initiated by those firms; and the size of the market serviced by the operating companies.

If we observe that the transfer from operating companies (the revenues of the RPX-identified public PAEs, plus the expenses incurred by operating companies in defending against their lawsuits) is a small number relative to the size of the relevant market, then the claim that those firms impose a tax on innovation that significantly reduces consumer and producer surplus is not tenable. To stick with the monster lurking under a bridge metaphor, a troll is not much of a threat to passersby if it is the size of a gnat.

4.2. How Big is the Transfer?

We have already found, in Section 2, that over the period 2011-16 the RPX-identified PAEs earned a total of $12.1 billion in revenues—on average, roughly $78 million per year per firm. Since every dollar earned by a firm that licenses patents, rather than produces a product, must come from a firm further along the production chain (Galetovic, Haber, and Zaretzki 2018) the $12.1 billion represents the direct transfer from operating companies to the RPX-identified public PAEs.

4.3. Litigation Costs

A crucial component of the patent troll hypothesis is that the innovation tax imposed by PAEs also includes the litigation costs they impose on operating companies. We assume that operating companies as a group spend 50 percent of the cost of the payments they make to the RPX-identified public PAEs on legal defense—the logic being that a rationally-run operating company will only litigate lawsuits that it thinks it has a chance of winning, and it will spend up

to 50 percent of the cost of settling on litigation if it thinks it has a 50 percent chance of winning. We then stress test this estimate by calculating the actual expenditures of the RPX-identified public PAEs on litigation from their SEC 10K's and 20F's.[24] Between 2000 and 2016, the RPX-identified public PAEs spent a weighted average of 17 percent of their total revenues on litigation or litigation-related expenses.[25] Thus, our estimate of average operating company litigation costs is higher than the average of the RPX-identified public PAEs by a factor of three. We then conduct a second stress test of our estimate of litigation spending by operating companies by comparing it against per case estimates made by RPX and by Bessen and Meurer (2014). We find that even we attribute all of the lawsuits documented in those sources to the RPX-identified public PAEs, our estimates of defendant costs per case are higher than theirs, suggesting that our estimate is likely an upper bound.[26]

4.4 Identifying the Relevant Market

[24] Six of the 26 firms did not report litigation expenses (or licensing expenses, which we take as an upper bound approximation of litigation expenses). See Tab 3.41 "Litigation Spending" for the firm level data. A few firms have outsized litigation expenses, relative to their revenues. Examples include Finjan (78 percent), Patriot (54 percent), VirnetX (56 percent), and Vringo (187 percent). See Tab 3.44 "Litigation Spending as % Revenues." As Table 1 shows, the common characteristic of these firms is their small revenue bases.

[25] See Tab 3.44, Litigation Expenses as a Percent of Revenues, in the online dataset.

[26] We stress-tested the 50 percent figure against data on the total number of lawsuits filed by publicly-traded PAEs in 2009, 2010, 2013, 2014, and 2015. The 2009 and 2010 data came from Bessen and Meurer (2014: 403), where they estimated a total number of 1,450 cases filed over five years, for an average of 290 cases per year. We estimated the total litigation cost imposed by the 26 RPX-identified public PAEs on defending firms to be $402 million in 2009 and $523 million in 2010. (See Tab 3.41 "Litigation Spending" in the online dataset). Dividing those annual numbers by 290 cases results in an average spending per case of $1.4 million in 2009 and $1.8 million in 2010. Our estimates are therefore in line with Bessen and Meurer's estimate of $1.4 million per defense. (Page 399.) Note that their estimate is of the total litigation cost per case, which could stretch over multiple years, whereas our estimate is an upper-bound for annual litigation expenses. We then made the same calculation for 2013, 2014, and 2015, using RPX's data on the number of new cases filed by publicly-traded PAEs. That gave us an average annual litigation cost per case filed of $2.4 million in 2013, $2.7 million in 2014, and $4.6 million in 2015. These numbers are high enough to suggest that our estimate is indeed an upper bound, particularly for the most recent year available. RPX's reports can be found at https://www.rpxcorp.com/reports/; our data came from Chart 24 in "Q4 2014 Public PAE Report" and Chart 24 in "Q1 2016 Public PAE Report." An alternative approach to the RPX litigation cost data would come from using the average number of active lawsuits in Chart 25 of RPX's "Q4 2014 Public PAE Report" and Chart 25 of "Q1 2015 Public PAE Report." Using that data for 2013 and 2014 (2015 is not available), and our estimate of total litigation costs imposed by the RPX-identified public PAEs, implies an average annual cost per case of $2.2 million in 2013 and $1.7 million in 2014, which is still above the Bessen and Meurer estimate of $1.4 million. We therefore believe that we have a reasonable upper bound for the total litigation costs imposed by the RPX-identified public PAEs.

How large are the transfers to the RPX-identified public PAEs relative to the size of the market in which they operate?[27] The firms identify the markets in which they operate in their SEC 10K filings. Though some of the firms have some patent assets in sectors such as medical devices, for the most part they tend to operate in high technology markets.[28] We confirm this by consulting RPX reports on litigation activity. As Table 6 shows, those reports indicate the NPE-related lawsuits occurred in high technology manufacturing, software, and related service industries. We also consulted the FTC (2016: 57), which states that "… the vast majority of patents held by Study PAEs were Information and Communications Technology (ICT) patents: 88% were in the Computers & Communications or Other Electrical & Electronic technology categories, and more than 75% of the Study PAEs' overall holdings were categorized as software-related patents."

TABLE 6 AROUND HERE

We therefore measure the size of the relevant market based on the sales revenues of the 153 large high technology operating companies identified in PwC (2017).[29] We present the revenues of these 153 high tech firms, the revenues of the RPX-identified public PAEs, our estimate of the litigation costs those 26 firms might impose, and the estimated transfer from high technology companies to those 26 firms, both in absolute amounts and in percentages, in Table 7.[30]

[27] We cannot use the commonly-cited North American Industry Classification System (NAICS) census data to estimate market sizes because such data excludes firms which manufacture their products outside the United States. Consider Communications Equipment (NAICS code 3342). Total shipments of Communications Equipment in 2016 according to NAICS 3342 was $36 billion. NAICS 3342 includes cellphones, which means that Apple is a contributor to the $36 billion in reported NAICs revenues—but Apple's mobile device revenues in 2016 were $159 billion, more than four times the total value of Communications Equipment recorded in NAICS. Including other U.S. firms that produce communications equipment expands the gap even further: Cisco's product revenue came to $37 billion; more than the value of the entire NAICS code.

[28] Acacia, for example, reported in its 2013 SEC 10Ks (p. 25-26) that in 2011 and 2012 it earned some revenues from patents on medical devices. "In fiscal year 2012, $41.2 million, or 16.5%, of revenues were generated from our patent portfolios in the medical technology industry sector, as compared to $8.6 million, or 4.7%, in fiscal year 2011. In fiscal year 2013, $9.9 million, or 7.6%, of revenues were generated from our patent portfolios in the medical technology industry sector."

[29] See tab 3.14 "PwC Data US High Tech Firms" in the online dataset.

[30] A case can be made that we should also include the $19.5 billion market for the rental of set-top boxes in 2016, since TiVo's main *bête noire* in patent litigation is Comcast. See the Senate inquiry by Senators Ed Markey and Dick Blumenthal. (See Molla 2016 and Locklear 2018.) The inclusion of this $19.5 billion would not, however, materially affect our results.

TABLE 7 AROUND HERE

Relative to the size of the relevant market, how large are the transfers to the RPX-identified public PAEs? The answer is: exceedingly small. The RPX-identified public PAEs are minnows compared to the sea in which they swim. Over the six-year period 2011-16 the total revenues of the RPX-identified public PAEs came to only $12.1 billion, compared to high technology revenues of $6.4 trillion. If we factor into our estimate the litigation costs imposed by the RPX-identified public PAEs, then the total transfer from the high technology sector over the six-year period 2011-16 would have been on the order of $18.1 billion, which is to say that it would have accounted for only 0.28 percent of total high tech revenues over that same period. If we assume standard elasticities of supply and demand of 1, then the deadweight loss would be roughly $1/100^{th}$ of the transfer, which is to say that it would be on the order of 0.003 percent of high technology revenues.

4.5 DISCUSSION

Taking all the evidence together, we find that the data are not consistent with the testable implications of the patent troll hypothesis. As a group, the RPX-identified public PAEs are simply too small to impose a large deadweight loss. Even if the business model of the RPX-identified public PAEs is to extract settlements for low quality IP on the basis of nuisance lawsuits—a claim that we assessed in Section Two and found to be inconsistent with the evidence—a more apt moniker for them might be patent lawn gnomes, rather than patent trolls.

The small size of the RPX-identified public PAEs, relative to the market in which they operate, fits with one of the main findings in Section Two: over the period 2000-16, the RPX-identified public PAEs *lost* $3.1 billion. Even if we focus only on the period after the Great Recession (2011-16), as a group the RPX-identified public PAEs *lost* $469 million (See Table 3). Most also lost money for their shareholders (see Table 4), and the few that did make money appear to have done so by taking on considerable risk (Table 5). It is therefore not a mystery why, as a group,

these firms are so small: one would not expect a business model in which there is a high probability of net losses to grow very large.

5. Privately-Held PAEs

Do privately-held PAEs behave and perform differently from the RPX-identified public PAEs we have analyzed? If so, are they large and numerous enough to have a significant impact on our findings? The assessment of the size, performance, and behavior of privately-held PAEs is an area that has not garnered as much empirical research as one might hope. We offer some partial evidence, drawing on publicly available information, about three large privately-held licensing firms that are often referred to as PAEs, patent trolls, or NPEs; Rockstar Consortium, Intellectual Ventures, and Conversant IP.

Rockstar Bidco was set up by Apple, Microsoft, BlackBerry, Ericsson, and Sony in 2011 to purchase 6,000 patents owned by bankrupt Nortel Networks for $4.5 billion. Two thousand of the patents were distributed among the consortium members. The remaining 4,000 patents were then allocated to a new entity, Rockstar Consortium, whose shares were held by some of the original Rockstar Bidco founding firms. The consortium soon found, however, that other firms were reluctant to license its portfolio, forcing Rockstar to begin litigation in October 2013 against Google, Cisco, Samsung, LG Electronics, HTC, Asustek Computer, Pantech, ZTE, and Huawei. It settled with Google and Cisco in 2014, and though the details were not made public Cisco revealed that it took a charge of $188 million to cover the settlement. At the end of 2014, Rockstar agreed to sell its patent portfolio to RPX for $900 million. All remaining lawsuits were dropped and Rockstar concluded its operations on February 3, 2015 (Jones 2014; Vehling 2015; and Rockstar 2015). In short, the evidence suggests that Rockstar was not unlike the RPX-identified public PAEs we have analyzed in the sections above. The fact that RPX was willing to pay $900 million for its patent portfolio suggests that Rockstar invested in IP of considerable value.

The fact that it went out of business two years after it was founded suggests that it did not yield easy returns for its shareholders.

Intellectual Ventures (IV) was founded in 2000 by the former Chief Technology Officer of Microsoft, the former Chief Architect and Advisor to Executive Staff of Microsoft, the former Assistant General Counsel of Intel, and a partner at the law firm, Perkins Cole LLP. According to court filings that IV made in 2011, its investors included some of the world's largest operating companies, universities, and foundations.[31]

Information on IV's current and past websites, along with other information in the public domain, allows us to estimate its revenues. In 2009, the *Seattle Times* reported that IV had earned roughly $1 billion in licensing revenue since its inception, which is to say roughly $100 million per year from 2000 through 2009 (Dudley 2009.) The following year, CEO Nathan Myhrvold, responding to investor unrest over the firm's disappointing performance, reported that the company earned $700 million in licensing revenue in 2010 (Wild 2011, Letzing 2011). Myhrvold's statements are consistent with reports that IV received $120 million from Intuit and $350 million from Verizon in various licensing deals in 2010 (Wild 2012). As of September 2017, the firm's website reported that it had earned "cumulative licensing revenues exceeding $4.3 billion." In order to bias our estimate of IV's annual revenues upwards, so as to bias in favor of the patent troll hypothesis, we assume that none of this revenue was booked in 2017. We also assume that the post-2010 revenue was booked evenly from 2011 through 2016. The implication is that IV had revenues of $2.6 billion from 2011 through 2016 ($4.3 billion, sans the $700 million earned in 2010 and the $1 billion earned before 2010) which is to say an average of

[31] In 2011 a declaration was filed listing companies and individuals with a stake in I.V. funds as part of *Xilinx, Inc v Invention Investment Fund I Lp, Invention Investment Fund II LLC, Intellectual Ventures LLC, Intellectual Ventures Management LLC, Intellectual Ventures I LLC, and Intellectual Ventures II LLC*. The relevant document is the "Defendants' Certificate of Interested Entities or Persons Pursuant to Civil Local Rule 3-16 and F.R.C.P. 7.1. United States District Court for the Northern District of California, San Francisco Division, Case Number 11-cv-0671-SI, May 16, 2011." Retrieved from https://patentlyo.com/media/docs/2011/05/financial-interest-in-iv.pdf, September 29, 2017. One of the authors of this paper is a faculty member at one of the universities listed as having a stake in I.V.

$433 million per year.[32] IV claims to have "raised more than $7.3 billion in investor capital," implying a revenue flow against capital of six percent per year over the period 2011-2016.

The implication of a six percent revenue flow against capital is that IV has not been highly profitable—and that implication is consistent with several other pieces of information. First, according to Reuters, from 2008 through 2012, one of IV's major funds earned only 2.5 percent per year for its investors (Levine 2014). Second, The University of Texas is an investor in two of IV's major funds, and by law U.T. needs to publish figures on their investments, including estimates of their current value and cumulative returns. Between 2008 and 2015, U.T. invested approximately $48 million in two IV funds. Over the same period, those funds returned approximately $17 million to the University of Texas Investment Management Company (UTIMCO). As of February 2015, however, UTIMCO valued its stake in both funds at only $19 million. That is to say, UTIMCO invested $48 million in IV funds and received $17 million in income, for a net investment of $31 million in two funds that it revalued at only $19 million. The net *loss* to U.T. was therefore $12 million (UTIMCO 2015.) The U.T. reports are consistent with reporting from *Forbes* which estimated that IV's $2.3 billion Invention Investment Fund II posted an annual return of *negative* 12.6 percent while its $590 million Invention Development Fund returned *negative* 36.7 percent per year (Vardi 2016).

Third, in 2014, IV carried out two rounds of layoffs — 5 percent of its workforce in February and then another 19 percent in August — reportedly because a number of big technology firms, such as Google, Cisco, and Hewlett-Packard refused to invest in a fund that would have given them access to and protection from IV's pool of patents. Finally, lawsuits that IV launched against firms that it claimed were infringing its patents did not go well (Goldman 2014; Temple

[32] As of 2015, Intellectual Ventures claimed to have earned a cumulative $3.9 billion. Using the same calculation as in the text, we estimate that for the five years between 2011 and 2015 the firm earned $2.2bn = ($3.9bn through 2015) – ($700m in 2010) — ($1bn before 2010). That implies an average annual revenue of $440 per year during that period.

2014; Levine 2014). The facts suggest, in short, that IV was not unlike the RPX-identified public PAEs we have analyzed in the sections above.

Conversant IP was a Canadian public company (MOSAID) before it went private in 2011, renaming itself in 2014. MOSAID began in 1975 as a semiconductor company specializing in memory modules. Competition from Japanese memory firms, however, drove its products out of the market, and thus it turned to licensing its designs. In 1999, it signed its first patent licensing agreement; in 2007, it began to acquire patents from third parties.[33] In its last year as a publicly-traded company (2011), MOSAID earned gross revenues of $80.9 million.[34] In 2013, the (now private) company claimed annual revenues on the order of $100 million. (See Conversant IP 2013.) In 2000-11, when Conversant IP was still MOSAID and a public company, it spent roughly 4% of its revenues on R&D and 16% on "patent licensing and litigation." It earned an average return on assets of 3.3 percent per year. Shareholders who held onto to the stock from 2001 until the day Sterling Partners bought the firm (at a 45 percent premium) to take it private in August 2011 would have earned an annual return of 1.9 percent against 4.4 percent for the Toronto Stock Exchange composite index. In short, the evidence suggests that Conversant IP was not unlike the RPX-identified public PAEs we have analyzed in the sections above.

What would happen if we added the revenues of these three privately-held firms to our estimate of the transfer to the RPX-identified public PAEs, added in 50 percent to account for litigation costs imposed on operating companies, and biased the results upwards by picking the year of the highest combined revenues of the RPX-identified firms? In 2016, the RPX-identified public PAEs as a group earned their highest annual revenues, $2.4 billion.[35] If we then include an

[33] The date of MOSAID's first patent licensing agreement can be found on page 2 of its 2011 Annual Report, which can be found by accessing the System for Electronic Document Analysis and Retrieval (SEDAR), used for electronically filing securities related information with the Canadian securities regulatory authorities, and searching on "MOSAID." SEDAR can be searched at https://www.sedar.com/search/search_form_pc_en.htm. The date that the company began to acquire patents can be found at http://www.conversantip.com/about/history/, February 28, 2018.
[34] We converted Canadian dollars to U.S. dollars at an exchange rate of C$0.99 per U.S. dollar.
[35] See Tab 3.11 "Revenues" in the online dataset.

additional 50 percent as an estimate of the costs of defending against patent infringement lawsuits, then the transfer from operating companies would have been $3.6 billion. The addition of Rockstar would have no impact on the results, as Rockstar ceased to exist in February of 2015. Including IV would push up the total transfer by $650 million ($433 in estimated revenues, plus 50 percent of those revenues in estimated litigation costs). If we make the assumption that Conversant IP had the same revenues in 2016 as in 2013, then we need to add another $150 million ($100 million in revenues plus 50 percent of those revenues in estimated litigation costs). Adding all of those costs together yields $4.4 billion. In 2016, the 153 U.S. high technology firms in PwC (2017) had revenues of $1.25 trillion.[36] Thus, the transfer would have been on the order of 0.35 percent of the revenues of the high tech market, and the deadweight loss from this transfer would be on the order of 0.004 percent.

6. Conclusions and Implications

Let us be clear about our claims. We are not saying that there are no patent trolls.-We are also not claiming that no firm that licenses patents, rather than produces a product, has ever frustrated the development of a downstream firm. The question is not, however, whether one can point to a firm that operates in the manner described by Executive Office of the President (2013), FTC (2011, 2016), and a related academic literature, but whether such firms are large and numerous enough to constitute a systemic problem.

What, then, are we claiming? The first takeaway of our study is that the magnitude of the transfers to the RPX-identified public PAEs plus the legal costs that might be associated with them are small compared to the size of the market in which they operate. This fact is not consistent with the hypothesis that they impose a significant "innovation tax" that causes a

[36] See Tab 3.14 "PwC Data US High Tech Firms" in the online dataset.

deadweight loss. The small size of these firms as a group is also inconsistent, however, with the hypothesis that they are important intermediaries in the market for innovation.

The second takeaway is that the RPX-identified public PAEs, as a group, do not seem to be earning economic rents. Most of them lose money, both on an accounting basis and as investments for their shareholders. It is hard to reconcile these findings with the claim that PAEs assert low value IP against defendants for nuisance-value settlements. This finding also explains why the revenues of these firms, as a group, are small compared to the market in which they operate: if there are no rents, there is little entry.

The third takeaway of our study is that the RPX-identified public PAEs tend to spend heavily on R&D. It follows that the claims made in FTC (2011 and 2016), as well as some of the academic literature that has drawn on those reports, about the business model of PAEs require revision. Unless it is the case that there are numerous, large privately-held PAEs that operate very differently from the RPX-identified public PAEs, the high R&D intensity of the RPX-identified firms may imply that PAE, as a category of analysis, is not meaningful. If a core characteristic of a group of firms is to invest heavily in research and development, then focusing on the fact that they need to use the legal system to enforce their intellectual property rights, may cause us to misunderstand, and hence mischaracterize, their role in the economy. Whether or not this implication holds is a question for additional research.

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TABLE 1: R&D AND PATENT ACQUISITION SPENDING, 2011-16

			As percent of revenues (weighted averages)*		
	Period	Total Revenues	R&D	Patent acquisition	Combined**
Acacia	2011-16	$974,602	2%	29%	31%
Crossroads	2011-16	$41,993	102%	12%	114%
DSS	2011-16	$102,921	2%	12%	14%
Endeavor IP	2011-16	$3,041	0%	30%	30%
Finjan	2013-16	$30,816	3%	0%	3%
InterDigital	2011-16	$2,813,276	15%	3%	18%
Inventergy	2011-16	$72,055	1%	34%	35%
ITUS	2011-16	$15,554	51%	na	51%
Marathon	2011-16	$80,430	0%	19%	19%
Network-1	2011-16	$118,075	0%	5%	5%
OPTi	2011-12	$4,075	1026%	93%	1119%
Parkervision	2011-16	$25,360	6%	na	6%
Patriot	2011-16	$194,611	1038%	46%	1085%
Pendrell	2011-16	$3,363	0%	89%	89%
Quest	2011-16	$1,747,348	42%	1%	42%
Rambus	2011-16	$0	na	na	na
Revolutionary	2011-13	$70,815	3%	2%	5%
SITO Mobile	2011-16	$20,869	11%	10%	21%
Spherix	2011-16	$21,875	6%	2%	8%
Straight Path	2012-16	$1,428,987	14%	9%	23%
Tessera	2011-16	$3,462,134	20%	1%	21%
TIVO	2011-16	$170,717	27%	7%	33%
Unwired Planet	2011-16	$29,983	39%	na	39%
VirnetX	2011-16	$44,286	11%	54%	65%
Vringo	2011-16	$43,935	na	3%	3%
Walker	2013-16	$576,020	3%	24%	27%
Wi-Lan	2011-16	$974,602	2%	29%	31%
ALL FIRMS		$12,097,142	19%	9%	28%
ALL EXCEPT TIVO		$8,635,008	19%	11%	29%
ALL EXCEPT INTERDIGITAL		$9,283,866	20%	10%	31%

* Includes data only for those firm-years that report R&D or patent acquisition spending.
** Combined may not add to R&D plus Patent Acquisitions because of rounding.

TABLE 2: R&D AND PATENT ACQUISITION SPENDING, 2000-16

			As percent of revenues (weighted averages)*		
	Period	Total Revenues	R&D	Patent acquisition	Combined**
Acacia	2000-16	$1,387,675	7%	23%	29%
Crossroads	2000-16	$208,196	57%	19%	76%
DSS	2003-16	$147,982	3%	19%	22%
Endeavor IP	2011-16	$3,041	0%	30%	30%
Finjan	2013-16	$30,816	3%	0%	3%
InterDigital	2000-16	$5,027,111	21%	2%	24%
Inventergy	2000-16	$225,801	11%	34%	45%
ITUS	2000-16	$29,927	134%	NA	134%
Marathon	2011-16	$80,430	0%	19%	19%
Network-1	2007-16	$152,504	0%	5%	5%
Parkervision	2000-16	$43,139	402%	41%	443%
Patriot	2001-16	$49,818	15%	na	15%
Pendrell	2002-16	$194,611	1038%	46%	1085%
Quest	2008-16	$4,241	1%	71%	72%
Rambus	2000-16	$3,408,654	38%	2%	41%
Revolutionary	2008-13	$0	na	na	na
SITO Mobile	2007-16	$76,524	3%	3%	6%
Spherix	2000-16	$165,264	16%	1%	18%
Straight Path	2012-16	$21,875	6%	2%	8%
Tessera	2003-16	$2,843,920	15%	6%	21%
TIVO	2000-16	$5,637,679	18%	2%	20%
Unwired Planet	2000-16	$3,310,199	29%	0%	29%
VirnetX	2007-16	$230,286	7%	na	7%
Vringo	2009-16	$44,517	21%	54%	75%
Walker	2013-16	$43,935	na	3%	3%
Wi-Lan	2007-16	$748,515	3%	38%	41%
ALL FIRMS		$24,116,660	23%	7%	30%
ALL EXCEPT TIVO		$18,478,981	24%	8%	32%
ALL EXCEPT INTERDIGITAL		$19,089,549	23%	9%	31%

* Includes data only for those firm-years that report R&D or patent acquisition spending.
** Combined may not add to R&D plus Patent Acquisitions because of rounding.

TABLE 3: EARNINGS AND RETURNS ON ASSETS, 2000-16, THOUSAND DOLLARS

	Combined earnings		Annual return on assets	
	2011-16	2000-16	Average 2011-16*	Average 2000-16*
Acacia	($256,007)	($456,037)	-9%	-12%
Crossroads	($46,026)	($193,802)	-61%	-47%
DSS	($61,326)	($96,131)	-39%	-42%
Endeavor IP	($3,109)	($3,109)	-104%	-104%
Finjan	($28,803)	($28,803)	-38%	-38%
InterDigital	$554,039	$1,143,968	7%	9%
Inventergy	($45,057)	($89,696)	-35%	-27%
ITUS	($37,713)	($101,005)	-86%	-61%
Marathon	($56,697)	($56,697)	-40%	-40%
Network-1	$41,231	$62,505	21%	26%
Parkervision	($124,921)	($325,414)	-124%	-70%
Patriot	($19,511)	$4,387	-44%	2%
Pendrell	$160,963	$160,963	9%	9%
Quest	($3,315)	($5,498)	-63%	-101%
Rambus	$33,272	($146,437)	1%	-2%
Revolutionary	($11,080)	($13,005)	-2679%	-2565%
SITO Mobile	($26,833)	($79,271)	-40%	-100%
Spherix	($110,275)	($138,412)	-67%	-45%
Straight Path	($7,048)	($7,048)	-9%	-9%
Tessera	$108,479	$440,432	3%	6%
TiVo	($86,173)	$132,277	-1%	0%
Unwired Planet	($100,198)	($2,996,359)	-16%	-33%
VirnetX	($139,633)	($132,063)	-53%	-37%
Vringo	($220,979)	($237,070)	-48%	-50%
Walker	($12,227)	($12,227)	-15%	-15%
Wi-Lan	$29,983	$25,134	1%	1%
ALL FIRMS	($468,964)	($3,148,419)	-1%	-4%
ALL EXCEPT TIVO	($382,791)	($3,280,696)	-2%	-7%
ALL EXCEPT INTER-DIGITAL	($1,023,003)	($4,292,387)	-3%	-7%

* Years of coverage vary by firm. For the underlying data see tabs 3.21 “Earnings” and 3.72 “Returns on Assets” in the online dataset.

TABLE 4: END OF YEAR SHARE PRICE INDEX, RELATIVE TO S&P 500, 2000-16
Last day of trading, 2000 = 1.00

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Acacia	-	-	0.67	1.51	1.47	1.91	3.70	2.48	0.84	2.52	7.17	10.10	7.10	4.02	4.68	1.19	1.80
Crossroads	1.00	0.92	0.18	0.58	0.31	0.18	-	-	-	-	-	0.87	0.47	0.39	0.41	0.17	0.03
DSS	-	-	-	-	0.92	1.63	1.43	0.84	0.24	0.32	0.70	0.33	0.28	0.27	0.06	0.02	0.02
Endeavor IP	-	-	-	-	-	-	-	-	-	-	-	0.95	17.66	71.79	1.78	0.03	0.01
Finjan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.75	0.33	0.33
InterDigital	1.00	1.79	2.69	3.81	4.09	3.39	6.21	4.32	5.09	4.91	7.70	8.06	7.60	5.45	9.78	9.07	16.90
Inventergy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.37	0.85	0.40
ITUS	1.00	0.63	0.28	0.75	1.17	1.09	1.34	2.02	0.65	0.93	0.29	0.15	0.24	0.27	0.18	0.17	0.30
Marathon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.05	0.20	0.21
Network-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.59	1.51	2.45
Parkervision	1.00	0.57	0.22	0.27	0.24	0.25	0.30	0.43	0.07	0.05	0.01	0.02	0.06	0.12	0.02	0.01	0.01
Patriot	1.00	0.26	0.11	0.09	0.16	0.18	1.21	1.17	0.24	0.31	0.16	0.10	0.22	0.19	0.06	0.01	0.01
Pendrell	-	-	-	-	-	-	-	-	-	-	-	0.89	0.44	0.70	0.48	0.18	0.25
Quest	1.00	0.81	0.19	0.10	0.05	0.10	0.05	0.19	0.29	0.10	0.05	0.07	-	-	-	-	-
Rambus	1.00	0.22	0.19	0.85	0.64	0.45	0.52	0.58	0.44	0.68	0.57	0.21	0.13	0.26	0.31	0.32	0.38
Revolutionary	-	-	-	-	-	-	-	-	-	-	1.77	0.04	0.01	0.01	0.00	0.00	-
SITO Mobile	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.80	1.42
Spherix	1.00	1.90	1.50	1.29	0.65	0.69	0.45	0.22	0.09	0.23	0.14	0.23	0.07	0.08	0.01	0.00	0.00
Straight Path	-	-	-	-	-	-	-	-	-	-	-	-	-	1.97	4.56	4.12	8.16
Tessera	-	-	-	0.83	1.63	1.14	1.77	1.83	0.52	1.02	0.97	0.74	0.72	0.88	1.50	1.40	1.74
TiVo/Rovi	1.00	0.48	0.22	0.31	0.35	0.23	0.38	0.25	0.17	0.43	0.84	0.33	0.21	0.27	0.31	0.23	0.28
Unwired Planet	1.00	0.20	0.04	0.23	0.32	0.36	0.19	0.05	0.01	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.01
VirnetX	-	-	-	-	-	-	-	1.11	0.28	0.56	2.81	4.72	5.54	3.67	1.04	0.49	0.42
Vringo	-	-	-	-	-	-	-	-	-	-	0.79	0.33	0.96	0.99	0.18	0.08	0.07
Walker	-	-	-	-	-	1.02	0.64	0.10	0.08	0.08	0.14	0.14	0.13	0.19	0.12	0.01	0.03
Wi-Lan	-	-	-	-	-	-	-	-	-	-	-	0.71	0.56	0.42	0.37	0.16	0.20
S&P 500	1.00	0.87	0.67	0.84	0.92	0.95	1.07	1.11	0.68	0.84	0.95	0.95	1.08	1.40	1.56	1.55	1.70

TABLE 5: AVERAGE MONTHLY SHARE RETURNS AND STANDARD DEVIATION FOR FIRMS THAT OUTPERFORMED THE S&P 500 OVER THE LONG RUN

	Period of analysis	Average monthly return	Monthly standard deviation	S&P500 monthly return	S&P500 monthly standard deviation	Average monthly return/ S&P 500 monthly return	Firm standard deviation/ S&P 500 standard deviation
Acacia	2003-16	2.2%	18.9%	0.6%	3.9%	3.4	4.8
InterDigital	2000-16	2.9%	18.7%	0.4%	4.2%	7.8	4.4
Network-1	2014-16	2.3%	9.6%	0.5%	3.3%	5.0	2.9
Straight Path	2013-16	8.3%	26.9%	0.8%	3.0%	9.9	8.9
Tessera	2004-16	1.3%	12.7%	0.6%	4.0%	2.3	3.2

FIGURE 1: SHARE PRICE PERFORMANCE AGAINST THE S&P 500, MONTHLY DATA (JAN 2001 = 1.00)

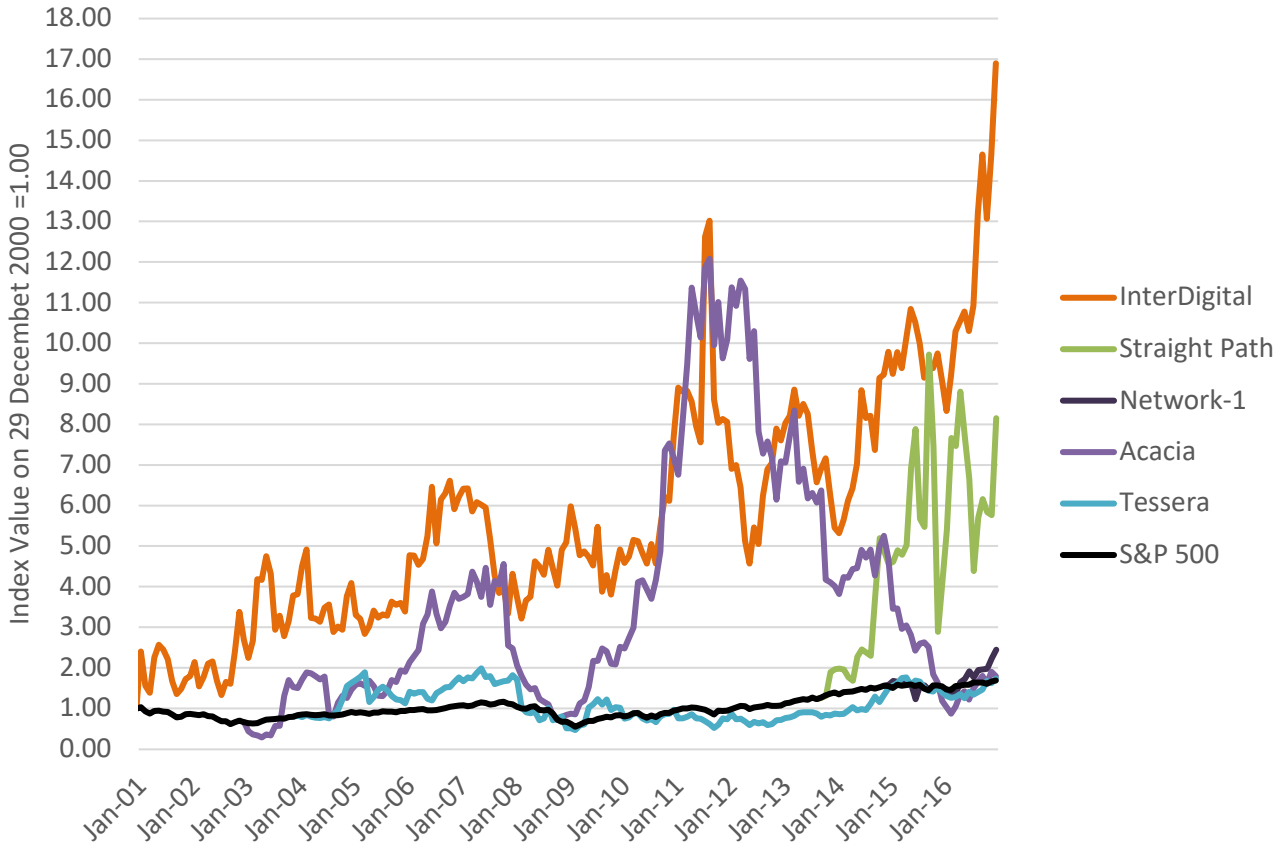

TABLE 6: NPE LITIGATION ACTIVITY BY SUBMARKET

	2012	2013	2014
E-commerce and software	34%	28%	32%
Consumer electronics and PCs	12%	12%	11%
Networking	11%	10%	7%
Mobile Communications and Devices	7%	10%	10%
Media Content and Distribution	6%	7%	5%
Consumer Products	6%	8%	12%
Semiconductors	3%	4%	3%
TOTALS	79%	78%	81%

Source: RPX, *2012 NPE Activity Report*, p. 19; *2014 NPE Activity Report*, p. 25; and *2016 NPE Activity Report*, p. 26.

TABLE 7: ESTIMATED TRANSFER IMPOSED ON LARGE, HIGH-TECHNOLOGY FIRMS (THOUSAND $)

	Revenues of RPX-identified public PAES	Estimated litigation costs	Estimated transfer from high-tech firms	Revenues of large high-tech firms	Transfer as % of large high tech revenues
2011	$2,035,720	$1,017,860	$3,053,580	$816,841,284	0.37%
2012	$2,145,849	$1,072,924	$3,218,773	$947,169,607	0.34%
2013	$1,626,393	$813,196	$2,439,589	$1,101,842,533	0.22%
2014	$1,929,409	$964,705	$2,894,114	$1,142,697,336	0.25%
2015	$1,937,998	$968,999	$2,906,997	$1,160,958,754	0.25%
2016	$2,421,773	$1,210,886	$3,632,659	$1,252,003,612	0.29%
2011-16	$12,097,142	$6,048,571	$18,145,713	$6,421,513,126	0.28%