# ESSAYS ON PATENT LITIGATION, PATENT MONETIZATION, AND ENTREPRENEURIAL FIRMS

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To my parents and Ni.

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# ABBREVIATIONS

| | |
|---|---|
| PE | Practicing Entity |
| NPE | Non-Practicing Entity |
| PAE | Patent Assertion Entity |
| SEPs | Standard Essential Patents |
| AIA | America Invents Act |
| PTAB | Patent Trial and Appeal Board |
| PGR | Post-Grant Review |
| IPR | Inter Partes Review |
| CBM | Covered Business Methods |
| USPTO | United States Patent and Trademark Office |
| CPC | Cooperative Patent Classification |
| IPC | International Patent Classification |
| FTC | Federal Trade Commission |
| SFM | Strategic Factor Market |
| VC | Venture Capital |
| CVC | Corporate Venture Capital |

# GLOSSARY

| | |
|---|---|
| PAEs | Patent Assertion Entities, also known as patent trolls, "*are businesses that acquire patents from third parties and seek to generate revenue by asserting them against alleged infringers.*" (Quote from Federal Trade Commission (2016)) |
| NPE | a Non-Practicing Entity, as opposed to an PE (practicing entity), owns and claims rights on patents but does not practice the patented technology to produce and offer products and services. |
| BMPs | Business method patents, a category of patents that do not cover concrete inventions, but a new way of doing business, usually combined with technology. |
| AIA | America Invents Act, an act passed in 2011 and enacted in 2012 and 2013 that reforms the US patent system, established PTAB, and changes the US patent system from first-to-invent to first inventor-to-file. |
| PGR | Post-Grant Review, a proceeding at PTAB that allows patents to be challenged within nine months of its grant, the case must be completed within 12 months from institution. |
| IPR | Inter Partes Review, a proceeding at PTAB that allows a third party to challenge the validity of patents that were granted more than nine months prior, the case must be completed within 12 months from institution. |

| | |
|---|---|
| CBM | Covered Business Methods, a transitional proceeding at PTAB that specifically allows accused infringers of certain covered business method patents to challenge the validity of patents, this program is available until September 15, 2020. The case must be completed within 12 months from institution. |
| CPC | Cooperative Patent Classification is a patent classification system cooperatively developed by the USPTO and the EPO (European Patent Office) |
| Alice | Alice Corp. v. CLS Bank International, 573 U.S. 208 (2014), was a decision announced in June 2014 by the United States Supreme Court on eligibility of software patents. |

# ABSTRACT

Xu, Mingtao PhD, Purdue University, August 2020. Essays on Patent Litigation, Patent Monetization, and Entrepreneurial Firms. Major Professor: Richard Makadok.

This dissertation studies how patents are monetized via legal actions without practicing the technology and the implications to firms. In recent years, scholars in other fields have extensively studied patent monetization and litigation regime, given the importance of technological innovation and commercialization to the strategy field, strategy scholars have been underrepresented on the topic of patent litigation and monetization. In this dissertation, I develop a theory on how heterogeneity in firms' business models monetizing resources determine firms' heterogeneity in valuation and acquisition of resources. Using a context of patents, we study two primary business models monetizing patents, namely, the practicing monetization and litigating monetization, which differ fundamentally in their value appropriation mechanisms. On the one hand, the value appropriation mechanism for practicing monetization relies on the value created by the firm's deployment of the patented technology in the product market, and from the restraint of rivalry via excluding competitors from accessing the patented technology. On the other hand, litigating monetization depends on the strength of legal actions and the ability to collect payments from target firms to the patent-owning firm, in forms such as settlement fees and damages awarded by the court. The theorization reclarifies the two types of patent heterogeneity: innovativeness and exclusivity, and theorize that differences in patents' innovativeness and exclusivity lead to differences in the expected profit from practicing and litigating monetization, thus leading to a difference in optimal monetization strategy and firms' different preferences for resource acquisition.

In Essay 1, we develop the aforementioned theory of patent monetization using formal models to understand the relationships among firms' business models, patent characteristics, and the optimal monetization strategy. We show the situations where litigating monetization can prevail and be the method that maximizes patents' value. We further predict that compared to patents that are practiced to produce products or services, patents monetized in a litigating manner are ones that are relatively less technologically innovative. Then, in Essay 2, I use the patent monetization context to investigate how firms' business models affect their resource acquisition behavior in the factor market, i.e., the market of patents. Exploiting recent institutional changes such as the enactment of the American Invents Act (AIA) that asymmetrically influenced different business models, I show that firms specialize in litigating monetization disproportionately acquire highly cited but old patents and patents that were litigated before. Then Essay 3, rooted in the literature that patents are essential signals from entrepreneurial firms to investors, I examine how disputes in patents in the form of litigations affect entrepreneurial firms' obtaining of external financing.

# CHAPTER 1 INTRODUCTION

## 1.1 The Value of Resources is in the Eye of the Beholder

A firm's ability to earn superior returns on resources purchased in the factor market may depend upon the firm's private information about the resource's value (Barney, 1986), but it also depends upon whether the firm can use the resource to create value in a way that competing bidders cannot. Thus, resources, even as mundane as product inventory, may be valued differently by firms, if they obtain different synergies by monetizing that inventory in different ways, such as sales, rentals, leases, or subscriptions. For example, movie DVDs may be valued differently by RedBox, Netflix, and Walmart, since their different monetization methods create different synergies. More generally, resource-market competition between firms from different product markets (Markman et al., 2009) or with different business models (Casadesus-Masanell and Zhu, 2010, 2013) can affect the valuation of any productive resource, the identity of the firm that ultimately acquires the resource, and the amount of value the acquiring firm can both create with and appropriate from that resource.

## 1.2 The Multiplicity of Business Models Surrounding Intellectual Properties

Patents are yet another type of resource where different firms may seek to obtain different synergies, according to each firm's capabilities and appropriation/monetization strategy (Hsu and Ziedonis, 2013; Steensma et al., 2016). Research on the market for technology views the external acquisition of patents as a substitute for firms' internal development of technologies (Arora and Gambardella, 2010). Following this logic, the value of the patent, represented in licensing, self-commercializing, or other commercialization methods, primarily depends on the technical value of the patent (Arora and Gambardella, 1994, 2010; Marx and Hsu, 2015) and its resulting value as a signal of quality to external stakeholders (Hsu and Ziedonis, 2013). Using a patent in this way not only requires that the implementation of the patent's technology, but also that the firm must prevent competitors from doing so as well (Capron and Chatain, 2008). Therefore, a crucial intention for acquiring patents is to prevent rivals from accessing the technology (Bessen and Maskin, 2009). The exclusionary value of patents makes the idiosyncrasy of resource valuation more prominent in the market for patents (Grimpe and Hussinger, 2014). Firms that monetize patents in this conventional way are often called practicing entities (PEs). However, a firm can also monetize patents without implementing the technology, or even without participating in the product market. In particular, patent assertion entities (PAEs) or non-practicing entities (NPEs), often labeled derisively as patent trolls in public policy discourse, represent a relatively new form of business (Steensma et al., 2016) that monetize patents purely through litigation, with no intention of either entering the product market or using their patents as a quality signal (Cohen et al., 2016).

So far, research on patent litigation and PAEs has explored such predatory methods (Cohen et al., 2020), as well as their impact on social welfare and their implications for intellectual property policy (Appel et al., 2020). Little has studied the factor-market competition between PEs and PAEs as they both seek to acquire patents. Consequently, many questions remain unanswered, such as: How does the competition between PE and PAE business models affect the market valuation of patents? How much value can be appropriated from a patent by either PEs or PAEs? What factors determine the amount of value that PEs or PAEs can appropriate from a patent? Under what conditions would one expect PAEs to outbid PEs for a patent, and vice versa? What are the consequences of lawsuits by PEs and PAEs?

As a starting point on the path toward answering these questions, in this dissertation, we develop a formal model and then empirically test differences in the practicing (PEs') and the litigating (PAEs') methods for patent monetization. On the one hand, the value appropriation mechanism for practicing monetization relies on the extra value created by the PE's deployment of the patented technology in the product market, and from the restraint of rivalry via excluding rivals from the patented technology. On the other hand, the value appropriation mechanism for litigating monetization depends on the payment of the litigating target, in forms of either settlement fee or licensing fee. We re-clarify the two types of differences in patents: innovativeness and exclusivity, and theorize that differences in patents' innovativeness and exclusivity lead to differences in the expected profit from practicing and litigating monetization, and deduce from the profit differential the optimal monetization methods for patents. We show the situations where litigating monetization can prevail and be the method that maximizes patents' value. We further predict that compared to patents that are practiced to produce products or services, patents monetized in a litigating manner are ones that are exclusive but less innovative.

## 1.3 Significance of the Context

Because of the assertive nature of their business model, this relatively new type of organization that specializes in the litigating monetization of patents is often called Patent Assertion Entities (PAEs), Non-Practicing Entities (NPEs), or patent trolls. PAEs' business model for patents is different from that of practicing entities (PEs) or practicing firms in that PAEs have no stake in the product market (Choi and Gerlach, 2018). Because PAEs do not produce any products or services using the patented technologies, they are much less susceptible to counter lawsuits. Without much to lose, PAEs exploit the judicial system aggressively to capture value from patents via legal actions against other firms. Those actions bring extensive controversies and criticisms (Cohen et al., 2016; Leiponen and Delcamp, 2019). Figure 1.1 shows quarterly numbers of patent lawsuits initiated by PAEs and other entities at US Federal District Courts from 2000 to 2018. As shown, most of the recent increase in the number of patent litigations came from PAE plaintiffs. In some peak years, PAEs make up more than 60% of all patent litigations filed in a year.

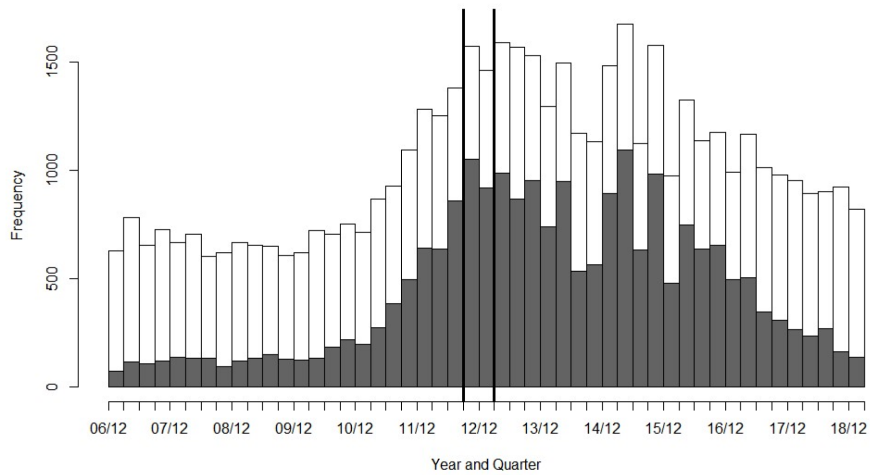



Figure 1.1.: Number of Patent Litigations by Quarter before and after AIA

Notes: (1) The x-axis is Year-Quarter that covers quarters from 2007 Q1 to 2018 Q4. The y-axis is the count of patent litigations in each quarter with the shaded histograms indicate patent litigations initiated by PAEs. (2) Two vertical lines mark 2012 Q4 and 2013 Q2, which are the times when two batches of the AIA statutes took effect. The AIA provisions that changed post-grant oppositions went effective on Sept. 16th, 2012. (3) The graph shows the fast-increasing PAE litigations before the AIA, and its decline in the post-AIA period.

PAEs' litigating monetization is also controversial at the policy level. The intention for building a strong patent system is to encourage innovation, to lower the transaction cost, to help the development of the market for technology (Arora and Fosfuri, 2003), and to facilitate technology commercialization (Dechenaux et al., 2008). PAEs' activities of exploiting a strong patent system, however, could hurt innovation (Abrams et al., 2019). Firms' innovation can be harmed as frivolous litigations initiated by PAEs divert substantial resources of practicing firms to handling lawsuits and threats. Such distractions deprive firms' capabilities to innovate (Leiponen and Delcamp, 2019). The negative consequences of legal actions by PAEs are especially severe for small entrepreneurial firms, which consist of more than half of PAEs' defendants (Chien, 2013). As startups usually lack resources, the extra burden from PAE activities slows the growth of startups and hurts startup employment (Smeets, 2014).

In recent years, scholars in economics, law, finance, public policy, and political science have invested significant effort in studying patent monetization and PAEs who exploit patent litigations. PAEs account for more than 60% of all patent infringement litigations, and bring a total of nearly $10 billion litigation and settlement cost to firms, 60% of the targeted firms had annual revenue below $100 million. Several large PAEs are already publicly traded and some of them have accumulated huge patent portfolios. In addition, such trolling behavior has been found in other industries of intellectual properties, such as copyright trolls in the music industry (Simcoe and Watson, 2019). With the significance of PAEs, scholars in other fields study PAEs trying to figure out their role in the market for technology, and the future for the development of intellectual property right (IPR). Extant studies have shown that PAE activities negatively affect regional venture capital investment (Kiebzak et al., 2016), small business employment (Appel et al., 2020), and firms corporate R&D investment (Smeets, 2014). However, studies presented mixed findings regarding whether PAEs acquire high or low-quality patents (Abrams et al., 2019; Feng and Jaravel, 2020)

Given the importance and interest of technological innovation and commercialization to the field, strategy scholars have been surprisingly silent on issues surrounding PAEs and patent litigations. Thus, we join the current discussion and shed light on PAEs patent acquisition behavior and the impact of patent litigations on ventures. To solve the puzzling mixture of findings regarding patent acquisitions, we propose that the value of technology is only reflecting one facet of patent quality, and PAEs make their acquisition based on the exclusionary value of patents, which may not necessarily be related to the technical value. For instance, a valuable technology that is written poorly into a patent may still be highly valuable for practicing monetization, but it may have no value in the eyes of PAEs for litigating monetization. This dissertation deepens our understanding of patents and patent litigations and calls for the attention to the exclusionary value of patents presented in patent acquisitions and litigations.

## 1.4 Outline of Essays

Essay 1 develops a theory of patent monetization to understand how heterogeneity in firms and patents determines the optimal monetization strategy of patents. In particular, we compare two methods of patent monetization: the practicing method, with which value appropriation comes from the product market, and the litigating method, with which firms appropriate value from litigations. We show that differences in the innovativeness of the patented technology and the exclusivity of the patent lead to differences in the value that firms can appropriate from practicing and litigating monetization. While litigating monetization can maximize value for patents with medium innovativeness but medium to high exclusivity, highly innovative patents are always best monetized via practicing monetization. Patents with low innovativeness and exclusivity will stay in dormancy and are not actively practiced or used in litigations. Comparing value appropriation from different monetization methods, this paper sheds light on the question of how heterogeneity in firms' value appropriation mechanism determine their value the same patent, and how the valuation affect their patent acquisition. We contribute to the strategy theory by studying how firms' different value appropriation mechanisms can affect their valuations of resources. While extant literature has not yet formally modeled how firms' different resource valuations emerge from value appropriation mechanisms, we show that resource characteristics, together with firms' heterogeneity in monetizing resources determine the optimal monetization methods of resources, and the best ownership and allocation of resources among different firms.

Essay 2 empirically tests the relationship between firms value appropriation and their factor market behavior by exploiting institutional changes aiming to restrain patent assertion such as the enactment of the American Invents Act (AIA) and patents' different exposure to such changes. In September 2011, the AIA was passed by Congress and was signed by President Obama. The provisions took effect in September 2012 and March 2013. In general, AIA made it easier for other entities to challenge the validity of granted patents, thus weakening the threat that the plaintiff posts to the defendant. While AIA weakened the complementary resources and the business model of PAEs by regressing their aggressive patent litigations; AIA did not significantly affect the value of PEs practicing-related complementary capabilities and their value appropriation through practicing. The asymmetric impacts allow us to test our theory and examine how AIA, via changing the value appropriation from litigation, affect the dynamics in the market of patents. I find that PAEs disproportionately acquire highly cited but old patents and patents that have a medium exclusivity, as well as patents that were litigated before. Patents of the best and newest technologies and patents that have the broadest scope, however, are rarely acquired by PAEs.

In Essay 3, we examine the impact of patent litigation to firms obtaining external financing. A large proportion of the recent surge of patent litigations has involved entrepreneurial firms. While extant research mostly focuses on examining the impact of patent litigations on firms internal development of technological capabilities, it is understudied how litigations may also affect their acquiring of external resources. This paper contributes to the literature on patent litigation and entrepreneurial financing by examining how patent litigations affect ventures financing from venture capital (VC). Using a carefully constructed matched sample linking patent litigations to VC-backed firms and exploiting variations in practices among district courts, we find that litigations reduce an entrepreneurial firms probability of receiving VC investment as well as the amount of investment received. Besides, we find that the negative impacts are less prominent when the startup has more quality signals, and the litigations is a less negative signal.

# CHAPTER 2 TROLLING FOR DOLLARS: A THEORY OF PATENT MONETIZATION, COMPETING BUSINESS MODELS, AND NON-PRACTICING ENTITIES [1]

## 2.1 Introduction

### 2.1.1 Impact of competing business models on strategic factor markets

One of the most interesting strategic phenomena in the twenty-first century economy is competition between firms with different business models (Casadesus-Masanell and Zhu, 2010, 2013) – e.g., between Amazon and Wal-Mart, or between Craigslist and newspapers. Technologies like mobile computing and artificial intelligence have increased the frequency of disruptive innovations (Bower and Christensen, 1995) that pit a conventional business model against a new upstart business model. So far, research on this phenomenon has focused primarily on how it affects competition in the product market, although it is clear that competing business models may also affect the resource market as well (Markman et al., 2009). Existing research provides few clues about how competing business models can affect the valuation of a productive resource, the identity of the firm that ultimately acquires the resource, and the amount of value the acquiring firm can both create with and appropriate from that resource.

In principle, a firm's ability to earn superior returns on acquired resources may depend upon whether the firm can use the resource to create value in a way that competitors cannot. This reality has long been recognized in market for corporate acquisitions, where "only when bidding firms enjoy private and uniquely valuable

[1] Co-authored with Richard Makadok.

synergistic cash flows with targets, inimitable and uniquely valuable synergistic cash flows with targets, or unexpected synergistic cash flows, will acquiring a related firm result in abnormal returns for the shareholders of bidding firms" (Barney, 1988). For example, "financial buyers" like private equity firms, whose business model creates value by exercising their own superior skills to improve an acquired business and then sell it within a few years, often must bid against "strategic buyers" like the business's competitors, suppliers, or distributors, who create value by keeping the business indefinitely and integrating it into their own operations in order to exploit synergies (Blomkvist and Korkeamaki, 2017). A similar type of competition occurs in the market for startup equity, where independent venture capital funds play the role of the financial buyers, while corporate venture capital funds play the role of the strategic buyers (Dushnitsky and Shaver, 2009). Indeed, even among strategic buyers, there can be stark differences in the types of synergies that different acquirers seek to obtain. For example, in 1999, Comcast and AT&T engaged in a bidding war for cable television operator MediaOne, with very different synergies in mind. Comcast sought MediaOne as a horizontal merger in order to broaden its geographic scope and thereby increase scale economies in its existing business model, while AT&T sought to create a new business model by vertically integrating with MediaOne in order to reestablish the "last mile" connection that it had lost in the 1982 forced divestiture of its regional operating companies.[2] Even resources as mundane as product inventory may be valued differently by firms, if they obtain different synergies by monetizing that inventory in different ways, such as sales, rentals, leases, or subscriptions. For example, movie DVDs may be valued differently by RedBox, Netflix, and Walmart, since their business models monetize them differently.[3]

[2] Such differences in the types of synergies sought from an acquired resource also occur in the labor market, where some firms pursue an exploration strategy of hiring new employees to initiate new activities, while other firms pursue an exploitation strategy of hiring new employees to expand or enhance its existing activities, and these differences have been shown to affect the amount and type of value created (Groysberg and Lee, 2009).

[3] Similarly, commercial real estate is valued differently by companies according to the type of synergies they can obtain from a property, as evidenced by the recent trend of U.S. shopping malls replacing defunct department stores with hotels (Frankel, 2018; Gose, 2018).

### 2.1.2 Business models and patent monetization methods

Patents are another type of resource where firms with different business models may seek to obtain different synergies, according to each firm's capabilities and appropriation/monetization strategy (Steensma et al., 2016; Hsu and Ziedonis, 2013). Most research on the market for technology views external acquisition of patents as a substitute for firms' internal development of technologies (Arora and Gambardella, 2010; Arora and Nandkumar, 2012). Following this logic, the value of the patent, represented in licensing, self-commercializing, or other commercialization methods, primarily depends on the technological strength of the patent (Arora and Gambardella, 1994, 2010; Marx and Hsu, 2015) and its resulting value as a signal of quality to external stakeholders (Hsu and Ziedonis, 2013).

This conventional use of a patent for competitive advantage not only requires that the firm must implement the patent's technology to increase its own economic value creation, but also that it must prevent competitors from doing so as well (Capron and Chatain, 2008). So, an important purpose of acquiring patents can be to prevent rivals from using the technology (Bessen and Maskin, 2009; Cunningham et al., 2018). Firms that monetize patents in this conventional way are often called "practicing entities" (PEs).

However, a firm can also monetize patents in other ways that do not require it to implement the technology, or even to compete in the product market at all. In particular, "non-practicing entities" (NPEs) or "patent assertion entities" (PAEs), often labeled derisively as "patent trolls" in public policy discourse, represent a relatively new business model (Steensma et al., 2016) that monetize patents purely through litigation, with no intention of either entering the product market themselves or using their patents as a quality signal (Cohen et al., 2016).

So far, research on NPE's has focused on their predatory methods (Cohen et al., 2020), and their implications for public welfare, technology diffusion, and intellectual property policy (Appel et al., 2020; Tucker, 2014). Little if any research has studied the factor-market competition between PEs and NPEs as they both seek to acquire patents. Consequently, many questions remain unanswered, such as: How does the competition between PE and NPE business models affect the market valuation of patents? How much value can be appropriated from a patent by either PEs or NPEs? What factors determine the amount of value that PEs or NPEs can appropriate from a patent? Under what conditions would one expect NPEs to outbid PEs for a patent, and vice versa?

These questions have economic, strategic, and public policy implications: From an economic perspective, answering them may illuminate how markets for technology work, including how PEs and NPEs differ in the types of patents they trade, and the conditions under which NPEs may acquire patents from PEs, or vice versa. From a strategic perspective, answering these questions may illuminate how factor market competition differs when rival firms pursue different business models. From a public policy perspective, these questions may help to craft targeted policies that would be most effective at reducing the incentive for NPEs to acquire patents in the first place by focusing on the particular types of patents that are most vulnerable to predatory exploitation.

### 2.1.3 Technological versus exclusionary strength and relative valuation by PEs and NPEs

As a starting point on the path toward answering these questions, this study develops a formal model to analyze the practicing (PE) and the litigating (NPE) methods for patent monetization, comparing the value that each of these methods can capture from a patent with a given set of characteristics. Although patents vary on many characteristics, our model focuses especially on two important ones: their technological strength for creating value, and their exclusionary strength for appropriating value. While the value that a PE derives from a patent depends upon both of these characteristics, the value that a NPE derives from it depends only on its exclusionary strength. After all, the NPE does not actually use the patent's technology, so the technology's strength matters little, if at all, to the NPE's valuation of the patent. Hence, it has been observed that NPEs tend to buy lower quality "junk patents" with negligible technological value but high litigation value (Choi and Gerlach, 2018; Lemus and Temnyalov, 2017; Cohen et al., 2016). Thus, it seems obvious that a PE's valuation for a patent would exceed a NPE's valuation when the patent's technological strength is sufficiently high, while a NPE's valuation would exceed a PE's when the patent's technological strength is sufficiently low. So, between these two extremes, there must be some intermediate "boundary" level of technological strength at which PE's and NPE's would value the patent equally.

What is less obvious, however, is the role of exclusionary strength: How does a patent's exclusionary strength affect its valuation by PEs versus NPEs? How do exclusionary strength and technological strength interact to jointly affect a patent's valuation by PEs and NPEs? Does a patent's exclusionary strength affect the "boundary" level of technological strength where PEs and NPEs share the same valuation of the patent? If so, how? To answer these questions, our model starts with the observation that, although greater exclusionary strength increases a patent's value to both PEs and NPEs, it increases at an increasing rate for PEs (i.e., convex) but increases at a decreasing rate for NPEs (i.e., concave). Why this difference? Increasing a PE's ability to exclude competitors from using its patented technology will generally increase both its margin and its market share, and since profit is, roughly speaking, market size multiplied by both margin and market share, exclusionary strength must have a quadratic effect on a PE's profit, i.e., increasing marginal returns to exclusion. By contrast, an NPE experiences diminishing marginal returns to exclusionary strength because potential defendants differ in how profitable they are for the NPE to pursue: Some defendants are easier to find, or are easier to prove an infringement case against, or have less motivation or less ability to defend themselves against the infringement claim. So, potential defendants differ in terms of the expected return that a NPE can obtain on its investment in pursuing an infringement case. Naturally, a profit-maximizing NPE would prefer to pursue the "lowest-hanging fruit" first – i.e., the defendant from whom they can get the highest expected return. After that, the NPE would pursue the defendant with the second highest expected return, and then the third, and so on – prioritizing defendants in decreasing order of expected return, until the costs of litigating against the next defendant outweigh the expected benefits. Thus, as exclusionary strength rises, the marginal defendant becomes successively less profitable for the NPE to pursue. This difference between PEs and NPEs – with the former having increasing marginal returns to exclusionary strength and the latter having decreasing marginal returns – implies that exclusionary strength can have a convex curvilinear effect on the "boundary" level of technological strength where PEs and NPEs share the same valuation of the patent. Depending upon the exact location of this curvilinear boundary and the particular level of technological strength, the model finds that a variety of different scenarios are possible for the main effect of a patent's exclusionary strength on its relative valuation to PEs versus NPEs. We analyze these scenarios and examine the conditions under which each scenario applies.

Finally, we also use our model to analyze one notorious practice of certain NPEs – namely, litigation against firms that are merely end users of infringing products, rather than against the producers of those products (Bernstein, 2016). NPEs may see end-user firms as more attractive targets than producers of infringing products, for two reasons: First, they may have little resources to mount a legal defense, which can cost millions of dollars in terms of attorney fees, court costs, and diverted attention of managers. Second, end users have less incentive to defend a product in court than its actual producer would have. To capture this phenomenon, we extend the baseline model to include end users who do not compete in the product market as a second category of litigation targets.

The paper proceeds as follows: We first discuss how the monetization methods of NPEs differ from those of other parties in the patent market. Then we present a model of how monetization method affects a patent's valuation. Next, we derive conditions under which each method yields a higher valuation and use comparative statics to study the effects of various parameters. Finally, we discuss the model's empirical implications, and the last section concludes.

## 2.2 Alternative Monetization of Patents: PEs, NPEs, and Defensive Aggregators

### 2.2.1 NPEs versus PEs

A firm that owns patented technologies can affect market outcomes via two mechanisms – creating value and capturing value. On one hand, by practicing these technologies, it can create value for the economy, and thereby enhance societal welfare. On the other hand, by excluding others from practicing these technologies (or threatening to do so), it can capture value from the economy in a monopolistic way, and thereby diminish societal welfare. So, the institutions of patenting represent an inherent societal compromise between these two effects. The underlying public policy premise of allowing patents in the first place is that, in aggregate and over the long term, their welfare-enhancing effects outweigh their welfare-diminishing effects, because the opportunity to patent provides an incentive for innovators and thereby increases their motivation to innovate. However, this entire premise is predicated on the assumption that the patent's owner is a practicing entity (PE) that both creates value by innovating and then practicing a new technology and captures a substantial part of that value by temporarily monopolizing the practicing of that technology until the patent expires, so that the exclusionary value capture incentivizes the innovative value creation. This compromise between society and the patent holder only makes sense if value is created by practicing the technology. Otherwise, it may be no compromise at all.

By contrast, NPEs monetize only the exclusionary value of patents, not their practicing value. Rather than producing their own products or services themselves, NPEs appropriate value from their patents by litigating against defendants who might be perceived as infringing, by licensing to such defendants or to others, or sometimes by arbitraging the patent market (Choi and Gerlach, 2018). Due to their focus on value capture without any counterbalancing value creation, the growing activity of NPEs is controversial (Cohen et al., 2016), and might be interpreted as contrary to the social compact underlying the institution of patents. This activity has been shown to hurt innovation and innovative firms' performance (Abrams et al., 2019; Smeets, 2014). Even when courts dismiss NPE-initiated lawsuits as frivolous, defendants must expend substantial resources for their defense. Many defendants find it cheaper and easier to settle such lawsuits, even if they are frivolous, than to fight them. These settlements often require defendants to sign nondisclosure and non-disparagement agreements, which makes it difficult for defendants to help each other or to reveal information that might be useful to future defendants. While large firms may have the financial and human resource to defend against NPE lawsuits, small and mid-size firms, which constitute more than half of the defendants of such lawsuits, suffer more due to their limited capital and personnel, as well as reduced external support from venture capitalists or other investors as a result of increased uncertainty about the startup's future performance (Chien, 2013; Kiebzak et al., 2016). In general, NPE activities have negative effects on innovation (Tucker, 2014; Penin, 2012), entrepreneurial activities (Kiebzak et al., 2016), venture capital investment, and small business employment (Appel et al., 2020). Indeed, the impact of NPEs on small businesses has been poignantly publicized by Austin Meyer's popular and humorous documentary film "The Patent Scam."

In addition to affecting innovation and firm performance, NPEs also disrupt the market for technology, of which a substantial part is the patent market since patents are relatively clearly defined and have high transferability. NPEs, as firms that specialize in patent monetization that lies between invention and commercialization, claim to help inventors overcome the difficulty of identifying and reaching other potential buyers of their technologies (Luo, 2014). However, research indicates that, rather than brokering such transactions, NPEs usually accumulate large portfolios of patents which they select patents not based on their technological value, but on their easiness to assert in court. Thus, NPEs often acquire patents that are in dense technology fields and have wide scope(Fischer and Henkel, 2012), issued by lenient examiners (Feng and Jaravel, 2017), not critical to a firm's business, and are more litigation-prone (Abrams et al., 2019). Such findings suggest that NPEs buy "low quality" patents with negligible commercial value but high litigation value (Choi and Gerlach, 2018; Lemus and Temnyalov, 2017; Cohen et al., 2016). When NPEs' acquire patents, it worth noticing that NPEs often create numerous affiliated entities for patent acquisition and patent holding, perhaps in order to hide the identities of the individuals responsible for initiating litigation or to shield themselves from countersuits. For example, Intellectual Ventures, one of the world's largest NPEs, tops the list with several hundreds of affiliated entities.

As an important caveat to provide a balanced view, none of this discussion should be interpreted to mean that only NPEs use patents in a predatory way, or to mean that no PE ever engages in such predatory behavior. In fact, recent research by Cunningham et al. (2018) indicates that PEs may sometimes acquire patents in order to preclude research that could threaten their business interests (see Capron and Chatain (2008) for a more general theory about this type of strategy). More generally, there is evidence that, due to monopolistic behaviors by PEs, patents may sometimes do more harm than good (Posner, 1975; Gilbert and Shapiro, 1990) including detrimental effects on innovation (Williams, 2013) – even in the absence of NPEs.

NPEs have attracted research in fields of law and economics (Hovenkamp, 2013; Chien, 2013; Cohen et al., 2016), such as the Federal Trade Commission (FTC) survey on PAEs and their practices (Federal Trade Commission, 2016). But in strategy, it is yet to be explored how their patent monetization affect the patent market and patent strategies of firms. Extant studies have primarily focused on firms that appropriate value of patents from product market profit (Gans and Stern, 2003; Marx et al., 2014; Marx and Hsu, 2015; Gans and Persson, 2013) rather than through litigating (Cotropia, 2008).

### 2.2.2 NPEs versus other Non-Practicing patent holders

In this section, we contrast NPEs from other types of organizations that hold patents without practicing them to profit in the product market. For example, although universities may also litigate infringements of their patents, they do not qualify as true NPEs for several reasons: First, universities innovate the technologies that they patent, while NPEs mostly buy patents without undertaking any innovative activity. Second, litigation is not the main way that universities monetize their technology. Instead, the monetization of university-developed technology is more indirect: A university's technology is primarily a tool to boost its research reputation, which enables it to attract more and better students who then pay more tuition, as well as more and better faculty who then are awarded larger research grants from foundations and agencies.

Recently, a new category of patent intermediaries, known as "defensive aggregators" (Hagiu and Yoffie, 2013) have emerged in response to NPEs.[4] Like NPEs, they acquire patents rather than developing technologies themselves, but they do so for the opposite reason. Defensive aggregators, such as RPX Corporation,[5] buy patents from any party as long as the patent is potentially problematic,[6] and license them to subscribers seeking protection from litigation and harassment by NPEs. Defensive aggregators' revenue comes from licensing fees, subscription fees, litigation insurance, and other business intelligence service fees of their customers. Defensive aggregators often acquire and own a large number of patents, but unlike NPEs, their patent ac-

[4]Hagiu and Yoffie (2013) also mentioned other types of patent intermediaries. First, patent brokers who do not buy patents but only connect patent sellers and buyers. Brokers can improve the social welfare by using their expertise to reduce the search cost and transaction cost in the market of patents. Some examples are Thinkfire and IPValue. Second, patent pool, which is a pool of patents that practicing company put together and license to each other. Third, standard setting organizations which are two-sided patent platforms but are already a failed trial. Fourth, super aggregators that combines the properties of defensive aggregators and offensive aggregators.

[5]RPX is one of the most prominent and famous defensive aggregators, whose clients include Cisco, IBM, Intel, and Microsoft.

[6]As written on the website of RPX(one of the largest defensive aggregators) website: "We welcome inquiries from individual inventors/owners, academic institutions, brokers, technology transfer offices, corporate sellers, and non-practicing entities."

quisitions are defensive, and they do not rely on litigation or the threat of litigation to appropriate value from their patents.[7] The pricing of the services, will depend on both the technological value and the exclusionary value of patents. Naturally, defensive aggregators often distance themselves from NPE's and the derogatory "NPE" label.[8] For example, RPX calls the business model of NPEs is "wasteful and dangerous."[9]

Despite this stigma, positive views of NPEs do exist. For example, Sabattini (2015) defines the NPE business model as a firm "that does not commercialize any product or service, but *fosters innovation* by monetizing intellectual property rights (IPRs) through licensing and technology transfer." Some researchers argue that NPEs are just a type of patent intermediaries (Haber and Werfel, 2016) that can improve efficiency in the patent market (Steensma et al., 2016), and that can increase competition, lower downstream prices, enhance consumer choice, and benefit innovation (Geradin et al., 2012). Likewise, Lemus and Temnyalov (2017) theorize that the patent privateering activities reduce the surplus of producing firms, but are in general beneficial to R & D activities.

In this paper, we use the term "NPE" to refer only to offensive patent aggregators who rely on litigation in their business models, and adopt the definition of NPEs as in Hagiu and Yoffie (2013). We are agnostic with respect to the social welfare impact or morality of NPEs and their activities. Rather than making such value judgments, we simply approach the NPE phenomenon from a purely strategic perspective in order to study the conditions under which NPE-style litigation maximizes a patent's value. Accordingly, we present a model that enables us to compare how the valuation of a patent differs according to whether it is monetized via practicing or via litigating.

[7]See the article *Patent Sales* at http://www.rpxcorp.com/rpx-services/rpx-patent-sales/.

[8]In some articles, "NPE" is a neutral term (Lemley and Feldman, 2016), but the other two names, "Non-practicing Assertion Entities" (NAE) and "patent troll" are always used derogatorily.

[9]See http://www.rpxcorp.com/network/patent-risk/

## 2.3 The Model Setup

In the simple model presented below, we discuss the practicing and litigating monetization of patents, with implications for the value of a patent to both PEs and NPEs. Although this model certainly does not capture every detail of the phenomena, it provides a basic broad-brush tool to analyze how the different monetization methods of NPEs and PEs lead to their different valuation of patents, and hence to patent ownership patterns.

### 2.3.1 Patent and firm heterogeneity

Patents, by definition, consist of a novel, useful, non-obvious invention and the right to exclude others from using the invention (Lemley and Shapiro, 2005). Based on this notion, we distinguish two dimensions on which patents can differ – their technological strength for creating value, and their exclusionary strength for capturing value. Let us consider each of these dimensions in turn.

In terms of a patent's technological strength for creating value, it is generally understood that value creation can come either in the form of increasing a customer's willingness to pay for a product (i.e., product differentiation) or in the form of decreasing a firm's cost to produce (i.e., efficiency) or some combination of the two (Brandenburger and Stuart, 1996), and that both forms have similar effects on competitive outcomes (except for a few unusual circumstances, e.g., Schmidt et al. (2016)). For simplicity, we treat a patent's technological strength $v > 0$ as simply the magnitude of cost reduction that the patented technology can provide to firms competing in the product market. Specifically, we treat this as a reduction to the marginal cost of each unit produced, and we leave other possible ways that the technology might create value for future research.

In addition to differing in their technological strength, patents also differ in the exclusionary strength of their right to stop or prevent others from using the technology. Given a set of potential users, a patent with the greatest possible exclusionary strength can prevent all unauthorized users from practicing the technology, while a patent with the least possible exclusionary strength can prevent nobody from practicing the technology. Much research has viewed the exclusionary strength of patents as driven by the institutional and legal environment's "appropriability regime" (Teece, 1986; Cohen et al., 2000; Arora and Ceccagnoli, 2006; Lerner, 2002), a factor that presumably would equally protect all patented technologies from all unauthorized users. By contrast, we assume that a patent's ability to prevent unauthorized use of its technology depends not only on the appropriability regime, but also on characteristics of both the user and the patent itself. For example, some firms may have the right set of technical, financial, and/or legal capabilities either to conceal their unauthorized use of the patented technology, or to circumvent the patent by "inventing around" it in order to practice the technology without technically infringing it (Mansfield, 1985; Ziedonis, 2004; Lieberman and Montgomery, 1998), or to prevent or invalidate an infringement claim. Likewise, even with the same technology, patents can be written in drastically different ways that may differ in related technological classes, and in the number, phrasing, breadth, and precision of claims. Other patent-specific factors may also undermine the legal enforceability of a patent, such as obviousness of the technology, ambiguity about who invented the technology, anticipation of the technology by others, indefiniteness of the patent's language, insufficient disclosure of the technology to enable its replication by others, concealment of other relevant information in the patent application process, or inequitable conduct by the patent's owner. So, let $x \in [0, 1)$ represent the exclusionary strength of a patent, representing the scope of exclusion, and measured as the proportion of potential users that the patent can actually prevent from using the technology. The remaining proportion of users, $(1 - x)$, are assumed to be immune from any infringement claims, perhaps due to concealment of their activities, or circumventing the patent by "inventing around" it, or some legal weakness in the patent itself, or some other reason.

Firms in our theory are categorized into two types: Practicing Entities (or practicing firms, PEs) and Non-Practicing Entities (NPEs). PEs and NPEs differ in their value appropriation mechanism from a patent in that a PE's monetization of the patent will only be adopting the technology and use in the production of a product (or service), while an NPE's monetization of the patent will only be asserting patent rights against the PEs in the market and being paid by PEs through settlement fees or awarded court damages. Acknowledgedly, firms in reality may adopt dual value appropriation mechanisms, but we study representative pure PEs and NPEs shed more light on the mechanisms. There are several important implications from the distinctions of PEs and NPEs. At first, the innovativeness of a patent has little to do with the NPEs' value appropriation, since it rely primarily on the exclusivity of the patent to assert patent rights. However, for PEs who practice the patent, obviously the innovativeness of a patent matter as the invention directly affect product market profit, the degree of exclusivity also matters, not for the potentiality to profit from litigating, but from the right to exclude other competitors in the product market to restrain rivalry and obtain economic rent (Makadok, 2010). In addition, we introduce another dimension of heterogeneity among PEs in that each firm have different capability in using the invention. Some firms may be more technologically capable so that they may find ways to invent around, using the technology but not infringe the patented invention, but some other firms may be less capable so that the only way to use the technology is to obtain the right such as acquiring the patent. Firms differ in their capability to appropriate from patents (Reitzig and Puranam, 2009), and also in their capability to avoid being appropriated by other patent owners.

Thus, we write the value of a patent from litigating monetization as $\Pi^l(x)$ and the value from practicing monetization as $\Pi^p(x, v)$.

### 2.3.2 Decisions

Below we outline decisions regarding practicing and litigating monetization. For the patent market, we make no particular assumption about the market mechanism by which the patent is offered for sale, nor any particular assumption about the selling price of the patent. We assume only that the patent is sold to whichever type of firm – either PE or NPE – has the highest expected net valuation for it, where a firm's expected net valuation is the difference between the expected amount of value that it will appropriate from the patent and the expected costs that it will pay to maintain the patent. We characterize decisions of firms in a game that proceeds as follows:

1. The technology is invented and patented by an independent inventor who lacks the capability or motivation to monetize it in any way – neither through practicing nor through litigating.[10] The inventor makes the patent available for sale, both to a set of NPEs and also to $n$ PEs in the industry where the patent can create value.[11]
2. If a PE acquires the patent, then $(1-x)n$ competing PEs have strong enough technical and/or legal capabilities to use the technology without risk of being sued for infringement. [12] Only the remaining $xn$ competing PE firms will actually be excluded from using the technology. The patent-owning PE's profit from practicing monetization realized with this partial exclusion is designated as $\Pi^p$.
3. If an NPE acquires the patent, it can assert patent rights against multiple PEs. For a given PE $j$, the NPE can threat and demand a settlement fee $S_j$.
4. The threatened PE chooses whether to settle with the NPE or go to court based on the demanded settlement fee $(S_j)$. If the threatened PE settles, the NPE realizes profit from litigating monetization $\Pi^l$. If going to court, the PE will incur a legal cost of $L_j$, and the NPE will also incur a legal cost of $L^N$.

[10] We treat all expenses that the inventor paid in order to be granted the patent in the first place (e.g., research costs, legal costs) as sunk costs and therefore irrelevant to our analysis.

[11] However, the patent may not actually be sold, even at a price of zero, because any firm that obtains the patent from the inventor will subsequently have to pay some additional costs in order to maintain the patent. This additional investment may include periodic fees for patent maintenance or renewal and the possibility of filing for patent extensions. If the expected value of these costs exceed the expected value that a firm can appropriate from the patent, then that firm's expected net valuation for the patent is negative, in which case that firm will not purchase the patent. If no firm purchases it, then the patent is deemed as dormant and remains the property of the inventor. Thus, the patent may not actually be sold, even if its price were zero.

[12] For example, these capable PEs can use the technology without risk of being sued by concealing their activity, "inventing around" the patent, or exploiting some legal weaknesses in the patent

5. The court will decide the case to be a normal case or an exceptional case, depending on whether the case is baseless. If the case is identified as normal, the NPE has a positive chance of winning and each party is responsible for its own legal fee. But if the case is baseless thus ruled to be exceptional, not only will the NPE lose the lawsuit, but the NPE must also reimburse the prevailing PE's legal fee $L_j$.
6. In a normal case, then there is a probability of $\theta_j$ that the plaintiff NPE wins and be awarded a damage of $D_j$, then the NPE realizes profit from litigating monetization $\Pi^l$.

We show the timeline of agents' decisions in our setting in Figure 2.1.

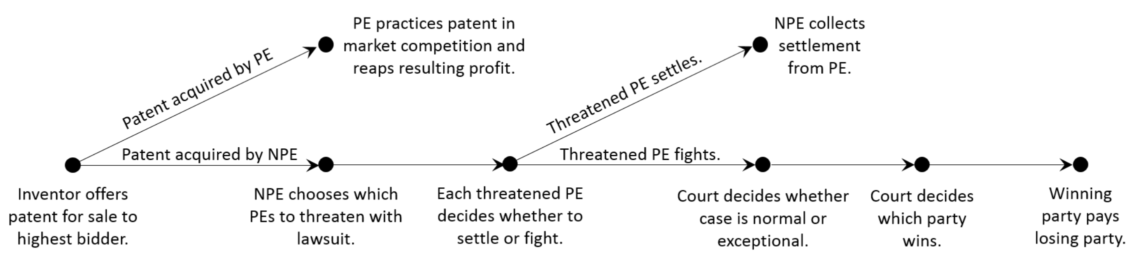



Figure 2.1.: Timeline of the model

## 2.4 Value Appropriation Mechanisms

With the above setup regarding firm and patent heterogeneity and decisions made by firms, below we discuss different value appropriation mechanisms and how the heterogeneity in the valuation of resources emerges endogenously among firms that differ in their use of resources (Chatain, 2014; Schmidt and Keil, 2013; Adegbesan, 2009).

### 2.4.1 Practicing Monetization

#### Product market demand

There are $n$ firms competing in the product market with substitutable products and assume that all these firms are potential users of the technology. Let $q_i$, $q_{-i}$ be the quantity of firm $i$ and all other firms respectively, and define $Q \equiv q_i + q_{-i} \equiv \sum_{i=1}^{N} q_i$. For a firm $i$, its marginal cost of production is $c_i$ and the price of the product it produces is $p_i$, and. Then we follow a standard linear demand structure as employed by Singh and Vives (1984) and Zanchettin (2006), and yield the industry's inverse demand function: $p = A - BQ$, where $A, B > 0$.[13]

#### Baseline case for product market competition

We normalize $B = 1$ and use the special case of Cournot quantity competition (Cournot, 1838) with different firms having the same marginal cost, $c_i = c < 1$ and $p_i = p, \forall i$. This yields the demand function for one firm: $p = A - q_i - \sum_{j \neq i} q_j = A - Q$. Each firm chooses quantity that maximizes its profit $\pi_i = q_i(p(q_i) - c)$. Then the best response function is given by: $q_i = \frac{1}{2}(A - \sum_{j \neq i} q_j - c)$. Then, summing all $i$ firms' best response functions yields: $2Q = n - (n-1)Q - nc$. Solving for $Q$ and substituting it to the demand function, we obtain the quantity and the equilibrium price are: $Q = \dfrac{n}{n+1}(A - c)$ and $p = \dfrac{A}{n+1} + \dfrac{n}{n+1}c$. Then the output and profit for each firm are:$q_i^* = \dfrac{A-c}{n+1}$ and $\pi_i^C = \dfrac{(A-c)^2}{(n+1)^2}$.

In this setting, we can see that all PE firms will earn the same profit so that all firms are active in the industry. If one of the active PE firms possesses the patent, we assume that the PE firm only seeks for profit gain from the product market by using the technology itself to achieve cost reduction, and by acting to block other PE firms

[13]Derived from a representative consumer's quadratic utility function: $U = AQ - \frac{B}{2}\left(\sum_{i=1}^{N} q_i^2 + \sum_{\substack{i=1 \\ i \neq j}}^{N} \sum_{j=1}^{N} q_i q_j\right) + m$, where $m$ is a numeraire good and $A, B > 0$.

from using the technology (Bessen and Maskin, 2009; Capron and Chatain, 2008). Although PEs can choose practicing while simultaneously licensing the technology to other players (Arora and Fosfuri, 2003), we argue that the value from practicing exemplifies the technological strength of the patent, and the value from licensing exemplifies the exclusionary value of the patent. After all, if the patent has no exclusionary strength, then other firms could simply use the technology with impunity and would therefore have no reason to pay to license the patent at all. So, our model still captures these two parts of patents' value.

**Strength of PEs and patents' imperfect exclusion**

Assume that the patented technology can bring a net cost reduction of $v \in (0, c)$ to a practicing firm, which we designate the patent's technological strength. In order to preserve the right to exclude others from using the patented technology, the patent's owner must pay a fixed cost $C^p$ required to maintain the patent. However, patents neither grant perfectly effective protection of the technology nor guarantee the exclusive use of the technology (Cohen et al., 2000). In fact, some firms will be able to imitate or use the technology during the patent period by "inventing around" the patent to avoid infringement (Gallini, 1992; Mansfield, 1985). Especially with the publication of the technology in the application, the granted patent, or elsewhere, other firms are likely to engage in such imitation if they are capable and find it profitable (Horstmann et al., 1985). So, some firms, other than the patent-owning firm, may also exploit the patented technology with impunity. Of course, firms differ in their capability to exploit the technology while avoiding infringement. Firms with deeper technical and/or legal resources are better able to create solutions (Ziedonis, 2004) that bypass the patent and thereby use the patented technology without infringing the patent (Agarwal et al., 2009).

Assume that we can rank all PE firms from the weakest to the strongest according to their capability to bypass and "invent around" the patent. With a patent of exclusivity $x$, a share of $x \in [0, 1)$ PE firms that are weaker in their capability to bypass and "invent around" are not able to disregard the patent and freely use the technology. We refer to those PE firms as Weak User PE firms. However, the rest $(1 - x)n$ firms, knowing the existence of patent as well as the technology, can figure out a way to use the patented technology while still preventing any infringement accusation. We refer to those PE firms as Capable User PE firms. Thus, the sets of Weak and Capable users differ across patents and each patent's $x$ captures its specific exclusionary value (Ordover, 1991). If a patent has a high $x$, i.e., a high exclusionary strength, then even firms with strong capabilities and deep pockets cannot bypass the patent and use the technology without risking an infringement claim. On the other hand, if a patent has a low $x$, i.e, a low exclusionary strength, perhaps because it was badly written or perhaps because it is difficult to enforce for other reasons (e.g., obviousness, ambiguous inventorship, anticipation by others, indefiniteness, insufficient disclosure, concealment, or inequitable conduct), then even weak firms can bypass it with impunity.

When a firm practices the patent and excludes $xn$ rival firms from using the technology, thus making those excluded firms disadvantaged in the market, [14] the patent-owning firm's profit under Cournot quantity competition is: [15]

$$\tilde{\pi}_i^C = \left( \frac{A - c + (nx + 1)v}{n + 1} \right)^2 - C^p \tag{2.1}$$

On the one hand, when the patent is extremely strong so that all other firms, no matter how capable, cannot use the technology without infringing the patent, and

[14] When some firms have adopted the technology, the other firms that have not are in a disadvantage. In our model, we assume that those disadvantaged firms will not be driven out of the market, i.e., the optimal quantity $\tilde{q}_i$ is non-positive, because they did not use that specific technology. Formally, this means that we assume the Nash Equilibrium output and profit margin of the disadvantaged firms are still positive, or formally:

$$\tilde{q_i}^{Cdis} = \tilde{p} - c = \frac{A - c - (1 - x)nv}{n + 1} > 0 \Rightarrow \frac{A - c}{n} > (1 - x)v$$

notice that when the patent is WTP-enhancing instead of cost-reducing ($v < 0$, as will be specified in the text later), the assumption automatically holds.

[15] The focal firm's quantity: $\tilde{q}_i^C = \frac{A-c+(1+nx)v}{n+1}$, and the price: $\tilde{p} = \frac{A+n(c-(1-x)v)}{n+1}$.

only the patent-owning firm use the patented cost-reducing technology, $x = \frac{n-1}{n}$, the profit of the patent-owning PE firm will be the maximal: $\bar{\pi}_i^C = \left(\frac{A-c+nv}{n+1}\right)^2 - C^p$. On the other hand, in the situation where the patent has minimal power protecting the technology such that all firms can use the technology while avoiding the patent, the profit of the patent-owning firm will be: $\underline{\pi}_i^C = \left(\frac{A-c+v}{n+1}\right)^2 - C^p$.

Let $\Pi_i^p$ be the profit gain of Firm $i$ from practicing the patented technology. For a Weak User PE firm, it will not be able to use the technology without acquiring the right to use, so the value of the patent to such a PE firm will be the difference between $\tilde{\pi}_i^C$ (the profit with patent protection) and $\pi_i^C$ (the profit without practicing the patented technology):

$$\tilde{\Pi}_i^{pW} = \tilde{\pi}_i^C - \pi_i^C = \frac{(nx+1)^2v^2 + 2(nx+1)(A-c)v}{(n+1)^2} - C^p \tag{2.2}$$

However, for a Capable User, since it can invent around and will use the technology even without acquiring the right and paying the fixed cost $C^p$, the value of the patent purely comes in the exclusion of other PEs. Thus, the value of the patent lies in the profit gain between the situation that the Capable User pays no cost to the patent but that every other firm also uses the technology, and the situation where the Capable User obtain $\tilde{\pi}_i^C$. Therefore, for such Capable PE firms:

$$\tilde{\Pi}_i^{pC} = \tilde{\pi}_i^C - (\underline{\pi}_i^C + C^p) = \frac{(n^2x^2 + 2nx)v^2 + 2nx(A-c)v}{(n+1)^2} - C^p \tag{2.3}$$

Comparing the payoff of the Weak User to that of the Capable User, the difference is the pure benefits brought by the technology: $\Pi_i^t = \Pi_i^{pW} - \Pi_i^{pC} = \frac{v^2+2(A-c)v}{(n+1)^2}$. As we can see, the technological benefit satisfies $\frac{\partial \Pi_i^t}{\partial v} > 0$ and $\frac{\partial^2 \Pi_i^t}{\partial v^2} > 0$.

Up to this point, we have assumed that the patented technology reduces PEs' per unit cost by $v$, without affecting customers' willingness-to-pay (WTP), but the situation for WTP-enhancing inventions is similar. The difference is that, instead of reducing a PE firm's marginal cost from $c$ to $c - v$, which imposes the constraint that $v < c$ for all firm $i$, a WTP-enhancing innovation will increase $A$ in consumers' utility function such that $A$ will become $A + \Delta A$. Therefore, the demand function of firms that adopt the innovation will be different from that of firms that do not adopt the innovation. But, $\Delta A$ enters the profit function $\pi_i$ in the same fashion as $v$. Thus, the discussion above should still hold for WTP-enhancing innovations with a simple replacement of $v$ by $-\Delta A$.

Now that we incorporate both cost-reducing and WTP-enhencing inventions, we can expand $v$'s domain to $v \in (-\infty, c)$. Without loss of generality, further simplifying by normalizing $c$ to zero, the profit gain from practicing a patent for a Weak User and a Capable User are:

$$\Pi_i^{pW} = \frac{(nx+1)^2 v^2 + 2A(nx+1)v}{(n+1)^2} - C^p \tag{2.4}$$

$$\Pi_i^{pC} = \frac{(n^2x^2 + 2nx)v^2 + 2Anxv}{(n+1)^2} - C^p \tag{2.5}$$

For both Weak and Capable PE firms, defining the exclusivity $x$ as the proportion of product market rivals that a patent can exclude, and the innovativeness $v$ as the relative magnitude of cost reduction (or WTP enhancement), we propose that:

**Proposition 1.** *As either a patent's exclusivity $x$ or its technological strength $v$ increases, the profit from practicing the patent increases at an increasing rate. In other words, the profit from practicing a patent is both upward-sloping and convex in both $x$ and $v$.* [16]

Although the rationale for the upward slope in this proposition may be intuitively obvious, the convexity rationale might not seem so intuitive, but can be understood as follows: Increasing either a patent's technological strength or its exclusivity increases the magnitude of the patent holder's competitive advantage in the product market. In most market structures, [17] the optimal way for a firm to exploit such

[16]It worth noticing that although $\frac{\partial \Pi_i^{pW}}{\partial x} = \frac{\partial \Pi_i^{pC}}{\partial x}$ and $\frac{\partial^2 \Pi_i^{pW}}{\partial x^2} = \frac{\partial^2 \Pi_i^{pC}}{\partial x^2}$, which means $x$ the exclusivity of the patent has the same marginal effect on the profit of both types of PEs, $\frac{\partial \Pi_i^{pW}}{\partial v} > \frac{\partial \Pi_i^{pC}}{\partial v}$ and $\frac{\partial^2 \Pi_i^{pW}}{\partial v^2} > \frac{\partial^2 \Pi_i^{pC}}{\partial v^2}$, which reflect the fact that the technology itself has larger impact on firms that cannot invent around and need the patent to adopt technology than firms that can find other ways to use the technology.

[17]The exception is the Bertrand price competition with perfectly undifferentiated products.

a competitive advantage is by increasing both its margin and its output together, rather than increasing only one individually. Since profit is, roughly speaking, the product of margin and output, the multiplication of the two effects yields a quadratic – i.e., convex – combined effect on profit. This convexity is indicated by the positive coefficients on the quadratic terms ($v^2$ and $x^2$) in Eq. 2.4 and Eq. 2.5.

Due to the fixed cost $C^p$ needed to practice the patented technology, there is a minimum requirement on $x$ to make practicing profitable enough to cover the fixed investment. Let $x^p$ be the requirement for profitable practicing monetization in that $x^p = \min\{x|\Pi^p(x) \geq 0\}$. In addition, profitable practicing monetization also requires a sufficiently low fixed cost $C^p$, a sufficiently valuable technology ($v$), and a sufficiently small number of firms competing to share the product market profit ($n$). So, we propose that:

**Corollary 1.** *When $C^p < v^2 + \frac{2Av}{n+1}$, there exists a unique $x^p \in [0, 1)$ such that when $x \geq x^p$, $\Pi^p(x) \geq 0$, and $x^p$ has below properties:*

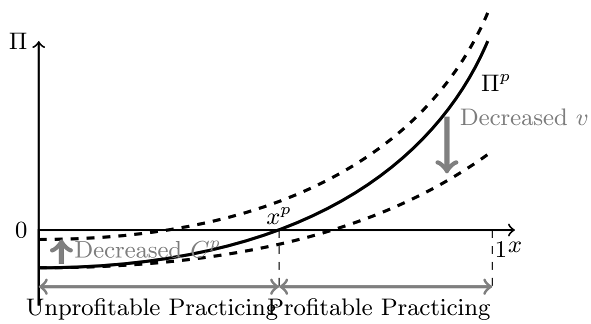
*(a) The more innovative the patent is (the higher the $v$), the lower the exclusivity requirement (lower $x^p$) for profitable practicing.*

*(b) The more difficult implementing the patent (the higher the $C^p$), the higher the exclusivity requirement (higher $x^p$) for profitable practicing.*

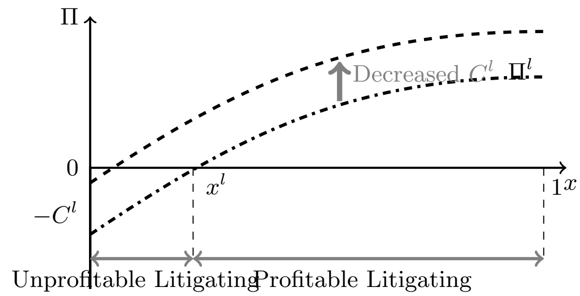
*(c) The more firms in the industry (the higher the $n$), the lower the exclusivity requirement ($x^p$) for profitable practicing.*

The corollary above informs us that, when a patent can only reach a low exclusivity and has a low $x$, the imitation problem from other PEs is severe, which reduces a firm's incentive to practice the patent (Polidoro and Toh, 2011). The requirement of minimal exclusivity $x^p$, however, depends on the innovativeness of the technology itself, and also the cost to implement the patented technology.

Figure 2.2a plots the relationship between $\Pi^p$ and $x$, with dotted lines showing effects of changes in the fixed cost ($C^p$) and the innovativeness of the patent ($v$).




(a) Practicing Monetization




(b) Litigating Monetization

Figure 2.2.: Values from Practicing and Litigating monetization in $x$

Note: The x-axis is exclusivity $x$, the y-axis is value $\Pi$. The Blue line is $\Pi^p$ and the Orange line is $\Pi^l$. Regions of profitable and unprofitable monetization are marked below each graph.

### 2.4.2 Litigating Monetization

Unlike the practicing profit that comes from the product market, the litigating monetization represents the scenario that a typical NPE can make a profit by threatening legal action against PEs demanding monetary payment in exchange for dropping this threat. After some initial communication and a hearing of initial evidence by the court, if the target PE firm still does not pay, the NPE would proceed with a patent infringement litigation against the firm. [18]

After receiving an initial demand letter asking for a payment of $S$, the defendant PE's payoff to settle is $-S$. But if the PE choose to go to court, there are two cases. If the case is viewed by the court as normal, the payoff of the defendant to fight at court is $-(\theta_j D_j + L_j)$, where $L_j$ is the defendant firm's legal cost, $\theta_j$ is the focal defendant PE firm's probability of losing to the plaintiff, and $D_j$ is the damage the court would order to be paid if it rules in favor of the plaintiff. For the plaintiff NPE, its payoff for taking a normal case to court is $\theta_j D_j - c^t - L^N$, where $c^t$ is the NPE's variable cost to threaten one target, and $L^N$ is the NPE's legal cost to pursue the trial. In the normal case, both party pay their own legal fee.[19] However, if the court rules the case to be exceptional, the losing party must pay for the prevailing party's reasonable legal fee, in which case the payoffs would be 0 for the defendant and $-(c^t + L^N + L_j)$ for the plaintiff. [20] To qualify as an exceptional case, the court must find the lawsuit to be both baseless and filed in bad faith.

We assume that if the defendant is a Capable User – e.g., it invented around the patent and used a substitute technology in order to avoid infringing the focal patent – its probability of losing to a plaintiff is $\theta_j = 0$ and the case will be regarded as exceptional. Therefore, in cases against a Capable User, not only will the NPE plaintiff have no chance of winning, but will also have to pay the defendant its legal

[18]NPEs often acquire patents from individual patent holders, since individuals often have neither the skills nor the financial resources to finance the costs of such litigation (Haber and Werfel, 2016).
[19]Under the British court rule, however, the prevailing party will always be awarded the legal fees by the losing party.
[20]35 U.S.C. §285: "The court in exceptional cases may award reasonable attorney fees to the prevailing party."

fee, resulting in a negative payoff of $-(L_j + L^N + c^t)$. Thus, an NPE will never take a Capable User to court, and would not bother paying to threaten a Capable User with a demand letter, because the threat would not be credible. So, a NPE will only target Weak Users. Letting the Weak User and the NPE engage in a Nash Bargaining, the equilibrium settlement fee $S$ will be solved from:

$$\max\{(S - c^t - (\theta_j D_j - c^t - L^N))(-S - (-\theta_j D_j - L_j))\} \tag{2.6}$$

Further assuming $L_j = L$ such that all PE firms have similar litigation cost, we obtain:

**Lemma 1.** *An NPE can maximize its expected profit from threatening one PE firm by offer settle the litigation at a fee of* $S_j^* = \theta_j D_j + \dfrac{L - L^N}{2}$.

In reality, NPEs usually seek to settle a litigation.[21] According to the managing director of IP Edge, an NPE firm: "The vast majority of patent lawsuits settle before trial — 95 % to 97 % of them."[22] We describe the game of an NPE threatening a target PE in the game tree in Figure 2.3, payoffs are written in the order of ($V^{NPE}$, $V^{PE}$):

[21] However, if the plaintiff of a litigation is a PE, since they are evaluating the damage it experiences in the product market, its likelihood to settle a litigation decreases with the increase in the value and its strategic stake of the litigated patent (Somaya, 2003).

[22] Source: https://www.iam-media.com/litigation/why-plaintiffs-us-patent-cases-who-understand-odds-victory-are-almost-always-best.

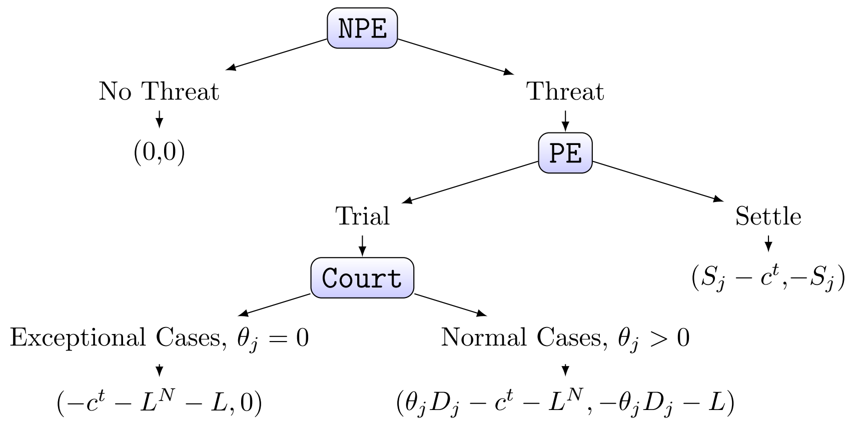



Figure 2.3.: The Litigating Game Tree

**Strength of PEs and litigation outcome probabilities.**

Recall that a patent's scope of exclusion divides PEs into Weak Users and Capable Users. Let $\kappa_j$ be the strength of a firm's capability to use its own technical and/or legal skills to circumvent the patent, so that firms with higher $\kappa_j$, are less likely to lose to the plaintiff in court. Specifically, we rank firms by the strength of their capability to circumvent the patent, from the weakest to the strongest, and define $\kappa_j \in [0, 1)$ as a firm's percentile in the ranking among all the $n$ PE firms. For Weak Users firms with $\kappa_j \in [0, x]$, we assume a linear relationship between the chance of a plaintiff win $\theta_j$ and firm capability. Then for Capable Users with $\kappa_j \in (x, 1)$, due to the fact taht they successfully invented around and avoided infringing the patent, we assume that $\theta_j = 0$. Thus, we have:

**Assumption 1.** *$\theta_j$, the probability of losing to the plaintiff in a patent infringement litigation, decreases with a defendant firm's strength of the capability to invent around ($\kappa_j$).*

*(a) $\theta_j = \theta_0 - \alpha\kappa_j$, and $\theta_0 \geq \alpha$, for Weak Users with $\kappa_j \in [0, x]$ that cannot avoid the patent.*

*(b) $\theta_j = 0$, for Capable Users with $\kappa_j \in (x, 1]$ that can avoid the patent.*

This assumption also reflects the fact that NPEs as plaintiffs often target firms that are less capable (Cohen et al., 2020). Thus, PEs that are incapable of inventing around but are using the patented technology intentionally or unintentionally will be NPEs' targets for threatening.

**Asserting strategy of NPE.**

Using Assumption 1, we can write a price-discriminating NPE's expected profit from threatening to litigate one PE that use the patent as: $\pi_j^l = S^* - c^t = (\theta_0 - \alpha\kappa_j)D_j + \frac{L-L^N}{2} - c^t$ with $c^t$ being the marginal cost for validly threatening a firm. [23] Most patent litigations settle at the pre-trial hearing stage. For a threat to be profitable, $S^* \geq c^t$. Given the fact that while most PEs are not familiar with patent litigations, NPEs are proficient in handling litigations and their cost sending letters to threat multiple targets are low, we assume that:

**Assumption 2.** *A PE's cost to defend itself is higher than an NPE's legal cost to assert patent rights at court in that* $L \geq L^N + 2c^t$.

Thus, threatening a Weak User is always expected to be profitable in that $\pi_j^l = (\theta_0 - \alpha\kappa_j)D_j + \frac{L-L^N}{2} - c^t \geq 0$, for all firms with $\kappa_j < x$.

As Choi and Gerlach (2018) discussed, NPEs usually target multiple firms for infringement cases. In particular, we assume that NPEs naturally pursue the "lowest-hanging fruit" first before climbing up to pick fruit from the upper branches. That is, we assume that a NPE first targets the weakest target in order to have the highest probability of winning, and then the second weakest target, and so on until the probability of winning drops too low to justify pursuing the next target. So, the complete set of targets will be all Weak User firms with $\kappa_j \in [0, x]$. Thus, we can

[23] To validly threaten a firm requires initial research, sending a demand letter, and appearing at a pre-trial hearing.

obtain an NPE's total expected litigation monetization profit by summing the NPE's expected profit from all eligible Weak firms:

$$\Pi^l = n \int_0^x \pi^l(\kappa) d\kappa - C^l \tag{2.7}$$

with $C^l$ being the fixed cost for litigating monetization, including costs such as an NPE's patent search, research, and acquisition. For convenience, we let $D_j = D$, meaning that the damage asserted by an NPE at court for infringing a given patent is the same across all defendant PE firms. Thus, the total expected profit of the NPE is:

$$\Pi^l = -\frac{1}{2}\alpha n D x^2 + (D\theta_0 + \frac{L - L^N}{2} - c^t)nx - C^l \tag{2.8}$$

Notice that the profit from litigating monetization is not related to the innovativeness of the technology itself, but is only a function of a patent's exclusivity. And we propose:

**Proposition 2.** *As a patent's exclusivity $x$ increases, the expected profit from litigating the patent increases, but at a decreasing rate. In other words, the expected profit from litigating a patent is both upward-sloping and concave in $x$.*

The rationale for the upward slope part of Proposition 2 is that when exclusivity increases, the patent-owning NPE can validly threaten more target firms. However, because the NPE targets defendants in order from weaker to stronger, every additional defendant targeted is more capable than the previous defendants, so that the NPE's probability of winning in court against the marginal defendant constantly decreases as more defendants are targeted. This diminishing marginal benefit to the NPE implies a concave profit function for litigating monetization. This concavity is indicated by the negative coefficient on the quadratic term ($x^2$) in Eq. 2.8.

However, litigating monetization is not guaranteed a positive profit due to the existence of the fixed cost $C^l$. So in order to cover this fixed cost of maintaining the patent, there must be a significant mass of firms that are potential targets, i.e., firms in the industry that use the technology and potentially infringe the patent. This requirement imposes conditions on the exclusivity of the patent, $x$, as well as the number of firms in the industry $n$. In addition to having a significant number of potential targets, profitable litigating monetization also requires a sufficiently plaintiff-friendly legal regime, e.g., the court tends to reward sufficiently large damages to the plaintiff, or has a sufficiently high probability to rule in favor of the plaintiff.

Let $x^l$ be the requirement for profitable litigating monetization in that $x^l = \min\{x|\Pi^l(x) \geq 0\}$.

**Corollary 2.** *When $n > \frac{C^l}{D(\theta_0 - \frac{\alpha}{2}) + \frac{L-L^N}{2} - c^t}$, there exists a unique $x^l \in [0,1)$ such that when $x \geq x^l$, $\Pi^l(x) \geq 0$, and $x^l$ has below properties:*

(a) *The lower the fixed cost to assert the patent rights (the lower the $C^l$), the lower the exclusivity requirement (lower $x^l$) for profitable litigating monetization.*

(b) *The more firms that are potential users of the technology (the higher $n$), the lower the exclusivity requirement (lower $x^l$) for profitable litigating monetization.*

(c) *The more friendly the legal regime to the plaintiff, represented by a low plaintiff legal cost (the lower $L^N$), a high defendant cost (the higher $L$), a high damage award ordered by the court (the higher $D$), or a high probability for a plaintiff win (the higher $\theta_0$), the lower the exclusivity requirement (lower $x^l$) for profitable litigating monetization.*

Figure 2.2b shows the relationship between $\Pi^l$ and $x$ and the position of $x^l$, where the exclusivity makes litigating monetization profitable enough to justify the threatening and litigating costs.

For tractability, we make the simplifying assumption that $\alpha = \theta_0 = 1$,meaning that the NPE will always win against the weakest defendant and always lose against strongest defendant. Moreover, we assume that $L = L^N + 2c^t$ to indicate that the

PE defendant has a similar legal fee compared to the NPE plaintiff. This yields the simplified expression below for litigating monetization:

$$\Pi^l = -\frac{1}{2}nDx^2 + nDx - C^l \tag{2.9}$$

Notice that now for litigating monetization, we have that $\frac{\partial \Pi^l}{\partial x}|_{x=1} = 0$, indicating that threatening the most capable user will bring the NPE zero marginal revenue.

## 2.5 Equilibrium

### 2.5.1 Equilibrium monetization method as a function of technological and exclusionary strength

Based on the technological and exclusionary strengths of a patent, we determine PEs' and NPEs' respective valuations for the patent, and these valuations in turn determine the equilibrium ownership and use of the patent. There are three possible mutually exclusive outcomes – The patent may be acquired and practiced by a PE (outcome P for "practicing"), acquired and monetized litigatively by a NPE (outcome L for "litigating"), or retained by the inventor and kept unused or dormant (outcome D for "dormancy").

For the relevancy of the technological value of the patent to our analysis, we use the Weak User's profit in Eq.2.4 as the payoff for practicing monetization and compare it with that of litigating monetization in Eq.2.9. Define the strategy space $S = \{D, P, L\}$, $s \in S$, and indicator functions $\mathbb{1}_D(s) = 1$ if $s = D$, $\mathbb{1}_P(s) = 1$ if $s = P$ , and $\mathbb{1}_L(s) = 1$ if $s = L$. Let $\sigma$ be the optimal strategy, then the optimal monetization strategy of a patent is given by: $\sigma(x, v) \equiv \text{argmax}_s\{\mathbb{1}_D 0 + \mathbb{1}_P \Pi^p(x) + \mathbb{1}_L \Pi^l(x)\}$, or simply:

$$\sigma(x, v) \equiv \underset{s}{\text{argmax}}\{\mathbb{1}_P(s)\Pi^p(x, v) + \mathbb{1}_L(s)\Pi^l(x)\} \tag{2.10}$$

Thus, on the two-dimensional plane of $x$ and $v$, we derive regions on which each of the three strategy options will prevail.

**Proposition 3.** *With patents that differ in their exclusivity $x$ and innovativeness $v$, there exist $\underline{x}^l$, $\underline{v}^p$, and $v^*$ such that $\sigma(x, v)$, the optimal monetization strategies for patents are:*

*(a) Dormancy (D), for patents with $x \leq \underline{x}^l$ and $v \leq \underline{v}^p$;*

*(b) Litigating Monetization (L), for patents with $x > \underline{x}^l$ and $v \leq v^*$;*

*(c) Practicing Monetization (P), for patents with (1) $x \leq \underline{x}^l$ and $v > \underline{v}^p$ or (2) $x > \underline{x}^l$ and $v > v^*$.*[24]

As an example, Figure 2.4 graphically shows a special case of Proposition 3 for a particular set of values for the other parameters. The horizontal axis is the exclusivity of a patent $x$ and the vertical axis is the innovativeness of the patented invention $v$. The three regions, i.e., D region, P region, and L region, are regions that each strategy dominates. It is worth noticing that the relative size of regions in Figure 2.4 does not imply the relative amount of patents in each region. In order to do so, we need a distribution of all patents on the two-dimensional plane of $\{x, v\}$. To help illustrating the figure, we define several points in Figure 2.4: $Z_1$, $Z_2$, $Z_3$, and $Z_4$. $Z_1$ is point that at the edge of for the D-P boundary, $Z_2$ is the D-P-L intersection point, $Z_3$ is the peak point of the P-L boundary, and $Z_4$ is the edge point for the P-L boundary.

Intuitively speaking, patents that have neither technological nor exclusionary strength (the lower left region with $x \leq x_{Z_2} = \underline{x}^l$, and $v$ below $\underline{v}^p$, which is represented by the $Z_1Z_2$ curve) remain dormant in the possession of the inventor. Patents that reach a sufficient level of exclusivity ($x > x_{Z_2} = \underline{x}^l$), but are weaker technically (orange region where $v$ is below $v^*$, as represented by the $Z_2Z_3Z_4$ curve) are acquired by a NPE and monetized via litigation. Only the technically strong patents (blue region where $v$ is above both the $Z_1Z_2$ curve and the $Z_2Z_3Z_4$ curve). However, depending on the patent's exclusivity, the thresholds of minimum technological strength for practicing monetization differ ($\underline{v}^p$ for the P-D boundary shown as the $Z_1Z_2$ curve , and v for the P-L boundary shown as the $Z_2Z_3Z_4$ curve), with patents of medium

[24] $v > v^*$ can also be written as $x \in (0, x^{*1}) \cup (x^{*2}, 1)$, where $x^{*1} < x^{*2}$ are the two solutions to $\Pi^p - \Pi^l = 0$. Similarly, the condition of $v \leq \overline{v}^*$ can also be written as $x \in [x^{*1}, x^{*2}]$.

exclusivity having the highest minimum technological strength required for practicing to be the equilibrium outcome (Point $Z_3$).

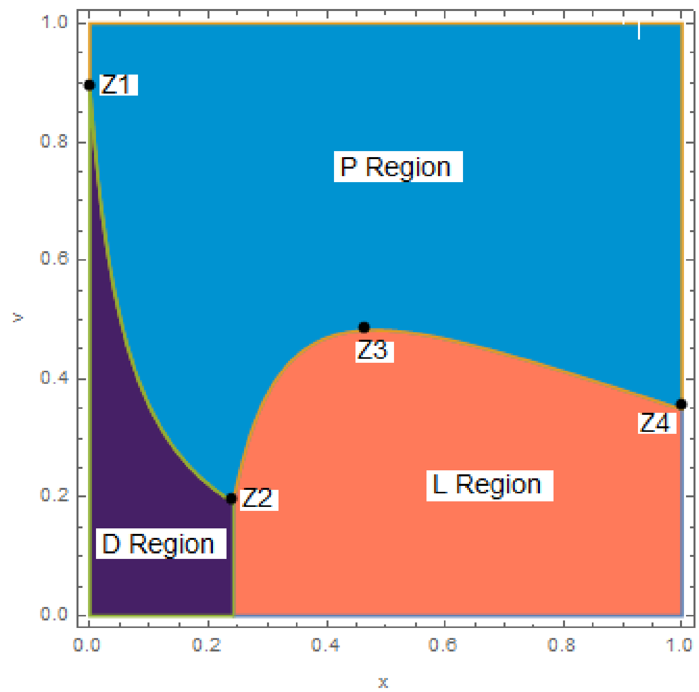



Figure 2.4.: Optimal Monetization Method

Note: The horizontal axis is exclusivity $x$, the vertical axis is innovativeness $v$. The Purple region is the Dormancy region (D Region), the Blue region is the Practicing region (P Region), the Orange region is the Litigating region (L Region).

Depending on different parameter configurations, there can be multiple scenarios for optimal monetization methods. Figure 2.5 shows those scenarios on the two-dimensional plane characterized by $x$ and $v$. When the number of firms $n$ increases, the L region expands with the P-L boundary shifts up and the D-L boundary shifts left. If the cost of implementing the patent ($C^p$) decreases, the P region expands with the D-P boundary shifts down and the P-L boundary shifts down. A combination of the above two effects result a shift from Figure 2.5a (which replicates the same scenario in Figure 2.4) to a graph that is similar to Figure 2.5b in which the L region significantly enlarged and the P region mainly concentrates on areas with patents of either extremely high or extremely low exclusionary strength. As the NPE's expected damage from winning in court ($D$) decreases or the cost for initiating a campaign against multiple defendant ($C^l$) increases, the L region shrinks with the P-L boundary shifts down, and the D-L boundary shifts right. The result is a shift from Figure 2.5b to Figure 2.5c. But if $D$ is sufficiently low or if $C^l$ is sufficiently high (or as an extention, the NPE's chance of winning at court ($\theta_0$) decreases), Figure 2.5c gets transformed into a graph that looks like Figure 2.5d in which the L region completely disappear and there is no room for litigating monetization to prevail.

### 2.5.2 Equilibrium monetization method as a function of exclusivity alone

The dotted horizontal lines in Figure 2.5 illustrate all possible scenarios for the effect of patent exclusivity on the equilibrium monetization method. Depending on the values of the other parameters, there are a total of nine sequences for how the equilibrium monetization method changes as $x$ increases from 0 to 1. We denote each equilibrium sequence as an ordered list of the equilibrium monetization methods in the order that appear as $x$ increases from 0 to 1. For example, the equilibrium sequence (D,L,P) means that the equilibrium monetization method is Dormancy, Litigating, and Practicing for patents in regions $x \in [0, x^a)$, $[x^a, x^b)$, and $[x^a, 1)$ respectively.

**Proposition 4.** *There are nine possible sequences for how the equilibrium monetization method changes as a function of the patent exclusionary strength $x$. These nine scenarios are determined by the relative positions of $x^l$, $x^p$, $x^{*1}$, and $x^{*2}$, as shown below in Table 2.1.*

When will each of the equilibrium sequence appear depends on the positions of $x^l$, $x^p$, $x^{*1}$, and $x^{*2}$. [25] Detailed conditions for each scenario are also given in Table 2.1. The nine plots in Figure 2.6 show the relative positions of $\Pi^p$, $\Pi^l$, and relevant intersections.

[25] When $\frac{\left(D - \frac{2v(v+1)}{(n+1)^2}\right)^2}{2\left(\frac{D}{n} + \frac{2v^2}{(n+1)^2}\right)\left((C^l - C^p) + \frac{v(v+2)}{(n+1)^2}\right)} > 1$, there exists $x^{*1}, x^{*2} \in \mathbb{R}$ such that when $x \in (x^{*1}, x^{*2})$, $\Pi^l > \Pi^p$. So, on the patent exclusivity dimension, there will be a convex region that the value from litigating monetization surpasses that of practicing monetization.

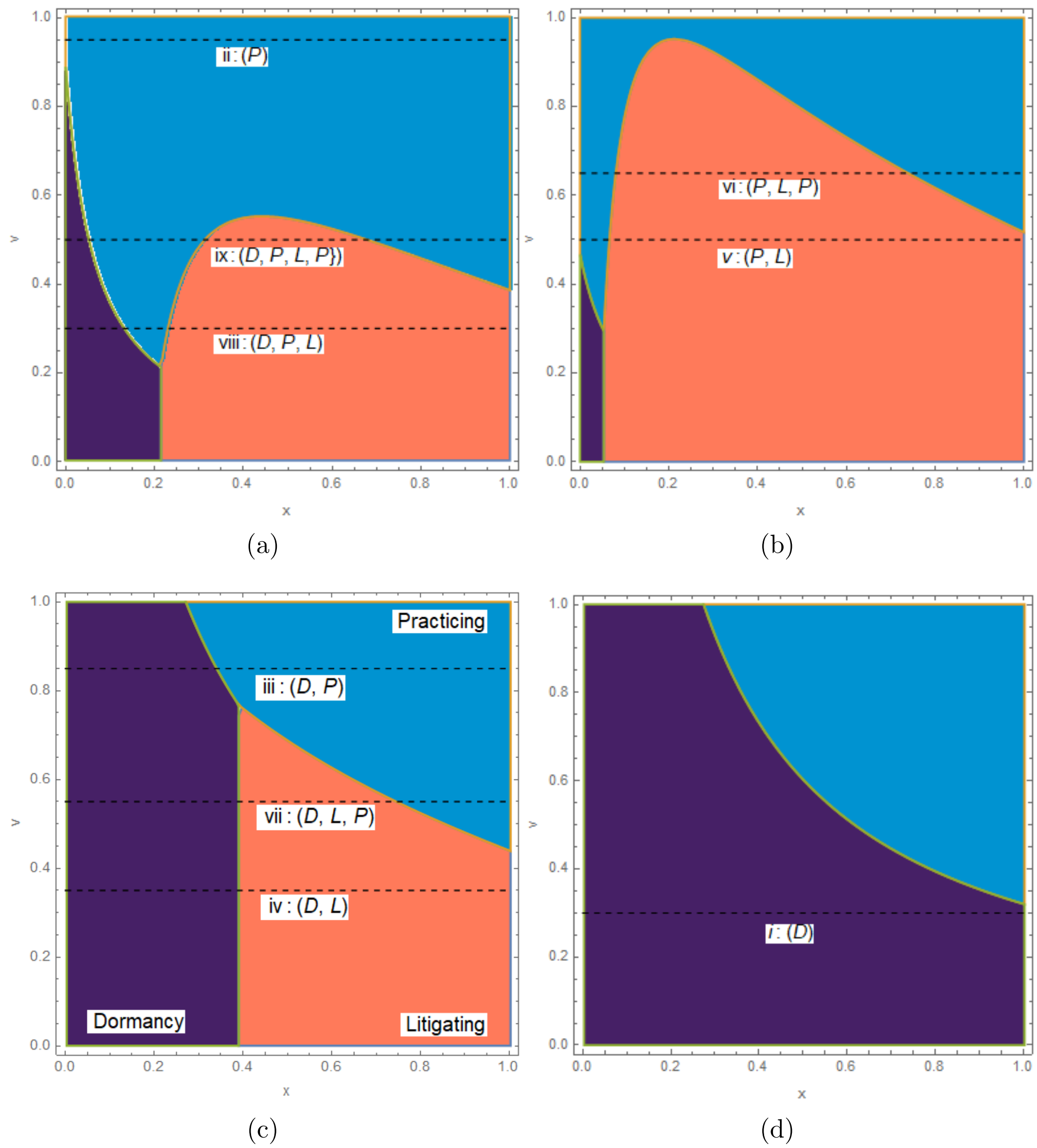



Figure 2.5.: Region of Optimal Monetization Method

Note: The x-axis is exclusionary strength $x$, the y-axis is technological strength $v$. The Purple region is the Dormancy region (D Region), the Blue region is the Practicing region (P Region), the Orange region is the Litigating region (L Region). Thus, the borderline of the P Region and the L Region is the PE/NPE borderline. Letters in the graphs indicate the index of equilibrium sequences as in Figure 2.6.

Table 2.1.: Summary of Nine Equilibrium Sequences

| # | Notation | Optimal Strategies $\sigma(x)$ | Conditions |
|---|---|---|---|
| i | (D) | D for $x \in [0,1)$ | $\{x^p > 1\} \bigcap \{x^l > 1\}$ |
| ii | (P) | P for $x \in [0,1)$ | $\{x^p < 0\} \bigcap \{\{x^{*1} > 1\} \bigcup \{x^{*2} < 0\} \bigcup \{dx < 1\}\}$ |
| iii | (D,P) | D for $x \in [0, x^p)$ and P for $x \in [x^p, 1)$ | $\{x^p \in (0,1)\} \bigcap \{\{x^{*1} > 1\} \bigcup \{x^{*2} < x^p\} \bigcup \{dx < 1\}\}$ |
| iv | (D,L) | D for $x \in [0, x^l)$ and L for $x \in [x^l, 1)$ | $\{x^l \in (0,1)\} \bigcap \{x^{*1} < x^l\} \bigcap \{x^{*2} > 1\}$ |
| v | (P,L) | P for $x \in [0, x^{*1})$ and L for $x \in [x^{*1}, 1)$ | $\{x^p < 0\} \bigcap \{x^{*1} \in (0,1)\} \bigcap \{x^{*2} > 1\}$ |
| vi | (P,L,P) | P for $x \in [0, x^{*1})$, L for $x \in [x^{*1}, x^{*2})$ and P for $x \in [x^{*2}, 1)$ | $\{x^p < 0\} \bigcap \{x^{*1} > 0\} \bigcup \{x^{*2} < 1\}$ |
| vii | (D,L,P) | D for $x \in [0, x^l)$, L for $x \in [x^l, x^{*2})$, and P for $x \in [x^{*2}, 1)$ | $\{x^l \in (0,1)\} \bigcap \{x^{*1} < x^l\} \bigcap \{x^{*2} \in (0,1)\}$ |
| viii | (D,P,L) | D for $x \in [0, x^p)$, P for $x \in [x^p, x^{*1})$, and L for $x \in [x^{*1}, 1)$ | $\{x^p \in (0,1)\} \bigcap \{x^{*1} > x^p\} \bigcup \{x^{*2} > 1\}$ |
| ix | (D,P,L,P) | D for $x \in [0, x^p)$, P for $x \in [x^p, x^{*1})$, L for $x \in [x^{*1}, x^{*2})$, and P for $x \in [x^{*2}, 1)$ | $\{x^p \in (0,1)\} \bigcap \{x^{*1} > x^p\} \bigcap \{x^{*2} < 1\}$ |

We highlight three critical conditions that differentiate the above nine equilibrium sequences. First, when $C^p$ and $C^l$ are sufficiently large, meaning the maximal value appropriation from the patent cannot justify the cost to either practicingly or litigatingly monetize the patent, the equilibrium sequence will be (D).[26] Second, when the technology is sufficiently valuable,[27] and fixed cost of practicing ($C^p$) or the number of firms in the market ($n$) is sufficiently small in that $C^p(n+1)^2 \leq 4$, which results $x^p < 0$, then the equilibrium sequences will have no D region and start from P. This means for patents with strong technological strength, practicing them would be preferred even with even zero scope of exclusion, which is the case similar to open knowledge. Third, when the technological value $v$ or the NPE's litigating cost $C^l$ is sufficiently large, or when $n$, $C^l$, and the damage awarded to te NPE ($D$) are sufficiently small, in that they altogether satisfy $\frac{v(2A+v+nv)}{1+n} - C^p > \frac{Dn}{2} - C^l$, the

[26] The conditions for the equilibrium sequence (D) are $C^p > v^2 + \frac{2Av}{n+1}$ and $C^l > \frac{nD}{2}$.

[27] To be specific, when $v > \sqrt{C^p(n+1)^2 + 1} - A$.

equilibrium sequences will end with P, which means patents with the widest scope of exclusion will be optimally acquired by an PE to practice.

Also in Figure 2.5, we give example lines and show the index for each of the nine situations in Table 2.1. Notice that the horizontal axis in Figure 2.5 is $x$, so the horizontal lines in Figure 2.5 capture the optimal strategy on $x$ given a fixed level of $v$.

We now explain insights derived from the different equilibrium sequences. At first, in some scenarios, in addition to the P region when the patent has high exclusivity on $x > x^{*2}$, the existence of another P region on $x \in [x^p, x^{*1})$. This reflects the fact that a part of the practicing profit gain comes from the pure technological value of the invention which is not related to exclusivity. Some good inventions with bad patents, may still be practiced, but due to the low exclusivity, will be out of NPEs' radar. Second, regarding the thresholds for profitable monetization, $x^l$ is always greater than zero since when $x = 0$, $\Pi^l = C^l < 0$. When the patent has no exclusivity, then the patent would be completely useless for litigating monetization. When litigating is profitable, there is always $x^l > 0$. However, the threshold for profiting practicing monetization, $x^p$ can be smaller than zero since even when $x = 0$, $\Pi^p = \frac{v^2+2v}{(n+1)^2} - C^p$, which is not necessarily negative. This captures the pure value of the technology, even without any exclusion power of the patent, or without a patent at all. Third, when $x^{*2} \in (0, 1)$, the most exclusive patents, i.e., patents with $x \in [x^{*2}, 1)$, will always more profitable monetized via practicing. This means that the profit from excluding other PE rivals, together with the profit from the technology itself, dominate the profit from litigating. Fourth, the least exclusive patents $x < \min\{x^p, x^l\}$, will be unprofitable either through litigating or practicing monetization, thus will stay in dormancy, due to the existence of the fixed costs, $C^p$ and $C^l$, to initiate either monetization strategy. Fourth, patents that will be litigated will always be patents with medium exclusivity range, i.e., $x \in \{x^{*1}, x^{*2}\}$ and $x > x^l$.

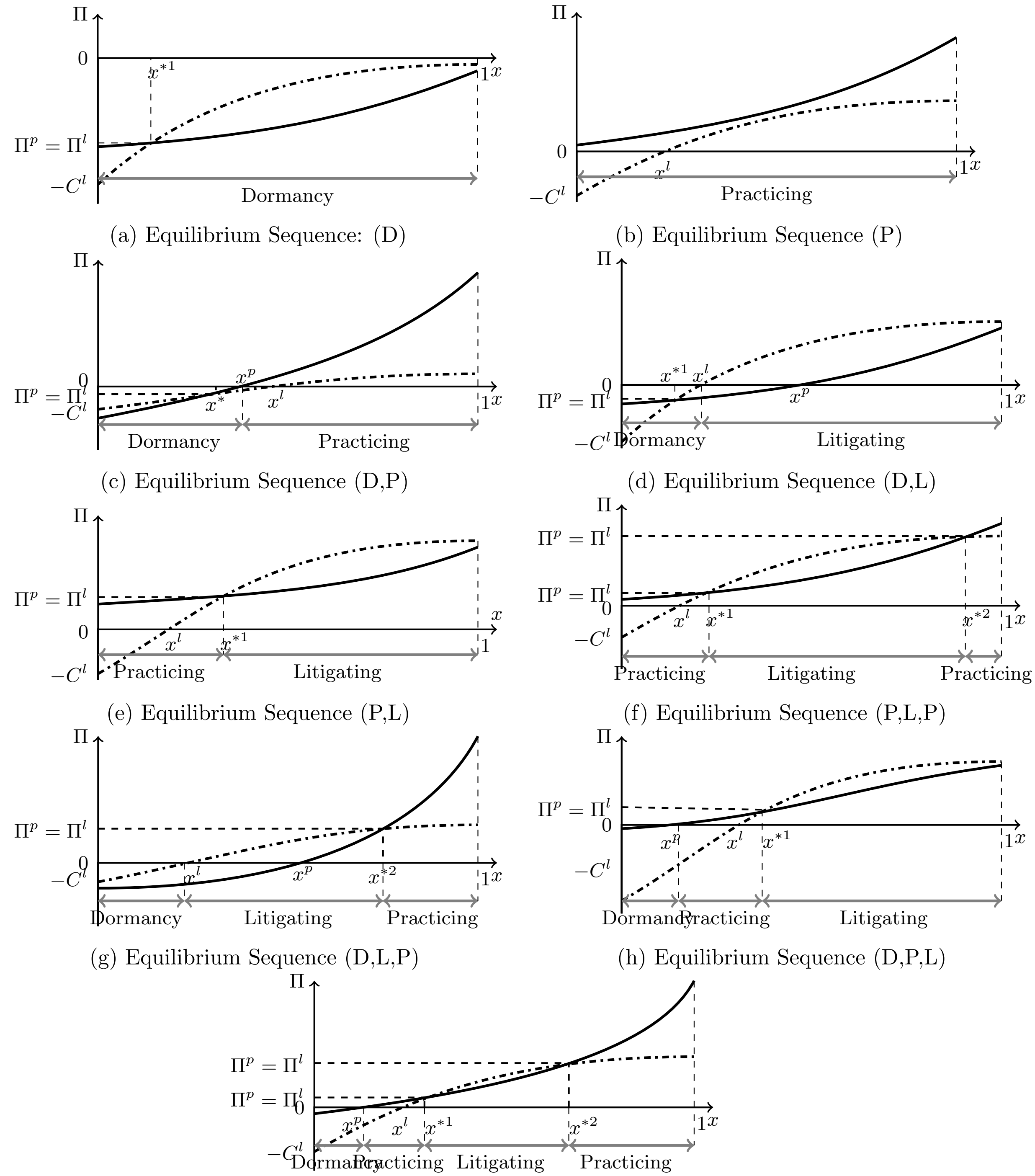



Figure 2.6.: Equilibrium Monetization Method as a function of $x$

Note: The horizontal axis is the exclusionary strength of patents $x$, the vertical axis is value Π. In each graph, Solid curves plots the value from practicing monetization ($\Pi^p$) and Dash dot curves plots the value from litigating monetization ($\Pi^l$). Dormancy, Practicing, and Litigating regions, as well as positions of $x^l$, $x^p$, $x^{*1}$, and $x^{*2}$, are marked in each graph.

## 2.6 Extension: End Users as Litigation Targets

One notorious practice of litigating patent monetization is targeting end users of infringing products, rather than against the actual producers of those products (Bernstein, 2016). NPE's target end users may have little, if anything, to do with each other, and these end users do not participate in the competition among producers in the product market. Therefore, being able to target end users in patent litigations additionally incentivizes litigating monetization. For a product whose end users are in large number, NPEs may have relatively more to gain from owning a patent than PEs. In this scenario, we use $\Pi^l(n^U)$ and $\Pi^p(n)$ to denote the profit from litigating monetization and practicing monetization as a function of number of targets $n^U$, and number of active producers in the industry $n$ respectively.

**Proposition 5.** *The more end users relative to producers in an industry (i.e., higher $n^U/n$ ratio), the more profitable litigating monetization becomes, relative to practicing monetization.*

## 2.7 Empirical Implications

Our propositions suggest several avenues for future empirical research, provided that a patent's practicing value can be distinguished from its litigating value. It may be possible to proxy for these values at the patent class level, since certain patent classes are known to have, on average, relatively higher exclusionary strength and/or practicing value than others. For example, regulations requiring clinical trials make pharmaceutical patents especially difficult to "invent around," while patents for computer hardware are relatively easier to circumvent because the possibility of recombining electronic components in multiple configurations offers "more than one way to skin a cat." It may also be possible to find proxies that distinguish patents according to their practicing value. For example, among pharmaceutical patents, some drugs are slight variations on existing molecules in longstanding therapeutic classes and are therefore likely to have relatively low practicing value, while other drugs pioneer entirely new types of molecules or entirely new therapeutic classes and are therefore likely to have much higher practicing value.

It may be possible to test our propositions in situations where natural experiments shift the litigating and/or practicing value of patents in ways that precipitate observable sales of patents from PEs to NPEs or vice versa. For example, as one possible natural experiment, the U.S. Food and Drug Administration's 1997 deregulation of direct-to-consumer advertising and the 1983 Orphan Drug Act both increased the practicing value of pharmaceutical patents. Likewise, court rulings like the 2010 *Bilski v. Kappos* and 2014 *Alice v. CLS* decisions on software and business-process patents can suddenly shift the exclusionary value of specific patent classes. Broader changes to the exclusionary value of patents across many classes may result from patent reform legislation, such as the 2012 America Invents Act (AIA). Specifically, the Act increased the cost for litigating by banning combining cases based on infringing the same patent, thus increases the fixed cost that the plaintiff has to pay to initiate a series litigations – i.e., our parameter $C^l$. Second, the AIA paved ways for easier patent invalidation by the defendants, thereby decreasing NPEs' likelihood of successfully extorting a PE firm – i.e., our parameter $\theta_j$.

## 2.8 Managerial Implications

Since our model includes three different types of agents – inventors, practicing entities, and non-practicing entities – we consider the managerial implications for each of these three in turn. First, from an inventor's perspective, the model provides guidance about which type of buyer – PE or NPE – is likely to be willing to pay more for any given type of patent. This guidance would be particularly helpful for an inventor who may have never considered selling a patent to a NPE. At the very least, it may enable an inventor to avoid wasting time selling a patent to a PE when a NPE is clearly the optimal buyer. Moreover, when there are more potential bidders for a patent, its selling price is likely to be higher ceteris paribus; this is good news for inventors of patents whose characteristics put them on or near the PE/NPE borderline, since these patents may appeal to both PEs and NPEs, and thereby attract a larger number of bidders. When considering the impact of changing the model's parameters, inventors benefit from any parameter changes that diminish the size of the dormancy region, such as reduced patent maintenance cost (lower $C^l$ or $C^p$).

Second, from the perspective of a PE, our model provides guidance about what type of patents it would benefit most from acquiring. It can be a waste of a PE's time and effort to seek to acquire patents in cases where a NPE has a clear incentive to outbid it. Conversely, our model may also offer PEs some guidance about opportunities for patent divestitures. PEs may own large portfolios of patents, some of which may have lost much of their technical and commercial value due to obsolescence, or due to substitution by some other competing technology. As a patent's commercial value depreciates over time, a PE may benefit from divesting such a patent by selling it to an NPE, who would not care about its diminished technical value. A PE may anticipate this eventuality, yet still be uncertain about the exact point at which divestiture would yield the greatest value. Our model suggests that the optimal divestiture point would be at the PE/NPE borderline in our figures. Depending upon the underlying parameter values, this borderline may be a curvilinear function of exclusionary strength (as in Figure 2.5b), or decreasing function (as in Figure 2.5c), or even an increasing function. When considering the impact of changing the model's parameters, PEs benefit from any parameter changes that increase the size of the practicing region, such as less rivalry in the product market (a smaller $n$).

Finally, some of the model's implications for PEs apply to NPEs as well, but in reverse. In terms of patent acquisition strategy, it can be a waste of a NPE's time and effort to seek to acquire patents in cases where a PE has a clear incentive to outbid it. When considering the impact of changing the model's parameters, NPEs benefit from any parameter changes that increase the size of the litigating region. (After all, a NPE cannot profit from litigating a patent that it does not own.) For example, a more plaintiff-friendly legal regime in terms of a higher chance for plaintiff win (a larger $\theta_j$) and a higher expected damage award (a larger $D$) will both enlarge the relative size of the litigating region compared to the practicing region.

## 2.9 Concluding Remarks, Caveats, Limitations, and Opportunities

In this paper, by decoupling the technological and exclusionary strength of the patent, we study how firms' value appropriation mechanisms relate to patent monetization methods and implications in the market for patents. Relationships among concepts are summarized below in Figure 2.7.

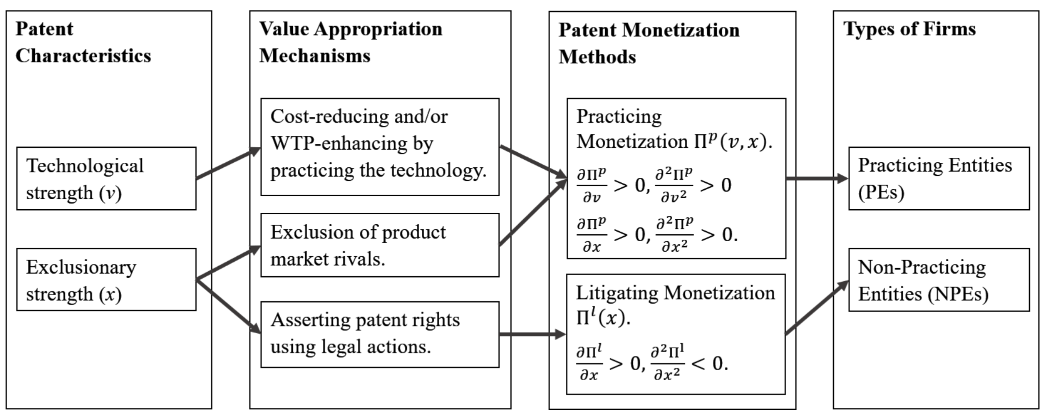



Figure 2.7.: Value Appropriation and Patent Monetization Framework

Different firms, with their different monetization mechanisms and different synergies, have heterogeneous valuations for resources. Inspired by the NPE phenomenon, this study contributes to resource-based theory by examining the role that differing monetization mechanisms plays as a source of firms' valuation of resources (Asmussen, 2015), and highlighting the resulting implications for the trading of resources (in this case, patents) in a strategic factor market (Barney, 1986). Since the monetization mechanism is one of the most important dimensions on which business models usually differ, our model also contributes to research on competing business models (e.g., Casadesus-Masanell and Zhu 2010, 2013) by shifting the focus of competition from the product market to the resource market. We believe that the impact of competing business models and differing monetization methods on the resource market, and not just on the product market, is a topic that is ripe for future research.

This study also contributes to the literature in market for technology by analyzing monetization methods based on differentiating the value of exclusion from the practicing value of the technology itself. Most extant research studies the value of patents in general while not separating the two (Bessen, 2008; Harhoff et al., 2003; Lanjouw et al., 1998). We argue that the technological value matters for firms that commercialize the patented technology, whereas the exclusionary value of patents matters for both practicing monetization and litigating monetization (Lemley and Shapiro, 2005). Moreover, our theory highlight firms' difference in monetizing the exclusionary value of patents. The exclusion in practicing monetization means excluding other firms from using the technology in their products and services; but in litigating monetization, it means being able to assert patent rights and profit from litigating (Chien, 2013). Thus, while firms that use practicing monetization prefer less infringement to maximize their competitive advantage, firms that exploit litigating monetization prefer more infringement in order to maximize the set of potential defendants. Extensions of the model may incorporate characteristics of the industry and the product market overlapping among PEs. Studying how they affect the competitive rivalry among firms (Ross, 2014) in the factor market can also be fruitful.

In addition, given the significant attention given by other fields on the non-practicing monetization of patents, we join the current discussion on Non-Practicing Entities (NPEs) and shed light on their patent acquisition behavior. Existing studies presented mixed findings regarding whether NPEs acquire high or low quality patents (Feng and Jaravel, 2017; Abrams et al., 2013).In an effort to solve the puzzling mixture of findings, we propose that the value of technology is only reflecting one facet of patent quality, and NPEs make their acquisition based on the exclusionary value of patents, which may not necessarily related to the technological value. For instance, a valuable technology that is written badly into a patent may still be highly valuable for practicing monetization, but it may have no value in eyes of NPEs for litigating monetization. We found while practicing monetization is convex, litigating monetization is concave in patent's exclusionary strength. This difference in value functions have substantial implications for the optimal resource monetization, since it implies a curvilinear boundary between the patents that are practiced by PEs and the patents that are litigated by NPEs.

Although our model provides a starting point for understanding NPEs and competing patent monetization methods, it certainly does not represent a complete theory of these phenomena. We hope that future research will extend our model in ways that overcome its limitations and omissions. One such limitation is that there are more patent monetization methods than the two we considered (practicing and litigating), such as licensing that does not involve threat of litigation (Fosfuri, 2006). However, licensing is a form of contract whose value (represented in licensing fee) will hinge on whether the ultimate value appropriation mechanism is from the product market or from the threat to litigate. In this regard, licensing might be expected to behave like an intermediate blend of practicing and litigating. So, it would be interesting to extend the model and discusses various scenarios of licensing. A second limitation is that we use a static model and assume that all uses of the patent and its underlying technology happen instantaneously. However, in reality, litigation, technology adoption, and inventing around patents are dynamic processes that take time (Gort and Klepper, 1982). In a dynamic model, differences in the speeds with which these different processes occur might generate different results. Finally, although our model focuses on the two specific aspects of patents – their technological strength and their exclusionary strength – that seem to us to be the most important determinants of monetization methods, these are certainly not the only two dimensions on which patents differ, and may not be the only drivers of monetization decisions. Accordingly, future theories of patent monetization may incorporate a broader range of independent variables.

# CHAPTER 3 LITIGATING MONETIZATION AND PATENT TROLLS: EVIDENCE FROM THE PATENT MARKET

## 3.1 Introduction

Innovation is a critical source of economic growth and firm profitability (Teece, 1986). To protect innovators' profit and innovative efforts, patent grants their owners a scope of exclusive rights of the technology (Kitch, 1977). Most firms that produce or buy patents appropriate value from their product markets, either directly via practicing the technology in their products or services and excluding rivals from using it, or indirectly by charging a licensing fee proportional to the licensees' product market profit. Such profiting from the product market, both directly and indirectly, is referred to as the practicing monetization of patents. However, recent years have witnessed the fast-growing business models used by firms to appropriate value from patents through enforcement of patent rights. These business models share a feature of aggressively using patent litigations to claim payments from other parties, such practices are referred to as the litigating monetization of patents. Due to the assertive nature of litigating monetization, firms that specialize in such business model are called Patent Assertion Entities (PAEs). Hagiu and Yoffie (2013) defines PAEs as *arbitrageurs, first acquiring patents, typically from individual inventors or small companies, and then seeking licensing revenues from operating companies through litigation or the threat of litigation.*

The key to PAEs' source of profit is using lawsuits to assert patent rights. Since PAEs do not practice the patented technologies, they are also referred to as Non-Practicing Entities (NPEs) or patent trolls. Since PAEs have no stake in the product market (Choi and Gerlach, 2018), in addition to potential patent invalidation, they are almost immune to counter lawsuits. The immunity empowers PAEs to aggressively exploit the judicial system sue other firms. The lawsuits disrupt the patent system (Schwartz and Kesan, 2014) and bring wide controversies and criticisms to PAEs (Lemus and Temnyalov, 2017; Cohen et al., 2016; Leiponen and Delcamp, 2019). Figure 1.1 shows quarterly numbers of patent lawsuits initiated by PAEs and other entities at US Federal District Courts from 2000 to 2018. At its peak, PAEs make up more than 60% of all patent litigations filed (RPX, 2019).[1] Also, recent changes in the number of patent litigations are primarily driven by the changed behavior of PAEs, partly due to the changing policy environment towards litigating monetization.

PAEs' litigating monetization is controversial to policymakers. The intention for building a strong patent system is to encourage innovation, to lower the transaction cost, to develop of the market for technology (Arora and Fosfuri, 2003), and to facilitate the commercialization of technologies (Dechenaux et al., 2008). However, PAEs' activities of exploiting the patent system could hurt innovation as frivolous litigations distract substantial firm resources to handling lawsuits and threats meanwhile depriving firms' capabilities to innovate (Leiponen and Delcamp, 2019). It is especially consequential for entrepreneurial firms, which consist of more than half of PAEs' defendants (Chien, 2013; Hovenkamp, 2013). As startups usually lack resources, they have to slow or even halt growth to deal with lawsuits (Smeets, 2014). Several studies have found PAE activities negatively affect firm innovation (Tucker, 2014; Smeets, 2014; Penin, 2012), entrepreneurial activities (Kiebzak et al., 2016), venture capital investment, and employment (Appel et al., 2020).

Nevertheless, positive views of PAEs emphasize their critical role in market for technology. In a well-developed market for technology, the division between invention and commercialization should increase welfare through the trade and specialization (Arora et al., 2016). However, inventors often suffer from the difficulty of accessing

[1]Very often, PAEs use names of shell companies to sue, Hall (2019) quotes the number reported in Love et al. (2018) that more than 83% of post acquisition patent assertion comes from "aptly named PAEs."

potential buyers (Luo, 2014) and capturing inventors' fair share of value creation. PAEs' existence can help overcome such inefficiencies, Lemus and Temnyalov (2017) find that though patent privateering activities reduce surplus of producing firms, they are in general beneficial to R&D activities. PAEs are said to "*foster innovation by monetizing intellectual property rights through licensing and technology transfer.*"[2] Some studies argue that PAEs are just another type of normal patent intermediaries (Haber and Werfel, 2016) that use their expertise in finding complementaries among patents in different domains to improve the efficiency of the patent market (Steensma et al., 2016), and that can promote competition, lowers price, and benefit consumers (Geradin et al., 2012).

The role of PAEs becomes more obscure when looking at their patent acquisitions. Extant literature reports that PAEs acquire low-quality patents (Lerner, 2006; Abrams et al., 2013). Specifically, PAEs tend to buy patents with wide scope, patents that are in densely patented technology fields (Fischer and Henkel, 2012), that were issued by lenient examiners (Feng and Jaravel, 2020), that are not critical to a firm's business and litigation-prone (Abrams et al., 2019), and that are close to the end of their technological cycle (Fischer and Henkel, 2012; Orsatti and Sterzi, 2018). However, some others find that PAEs acquire high-quality patents with more citations and claims (Fischer and Henkel, 2012; Shrestha, 2010). In fact, PAEs' patent acquisition is indeed highly concentrated in several technology fields in which there exists numerous patent thickets and that are highly active in patent litigations, such at IT, telecommunications, digital communications, and semiconductors. Figure 3.1 shows PAEs' shares in patent acquisitions by IPC technology fields.

In light of the academic interest in PAEs and the market for technology in general, however, there has not been a theory to reconcile the seemingly contradictory findings on PAEs' patent acquisition. Trying to shed light on the issue, I start from distinguishing business models of practicing and litigating monetization, which combines different resources and generate different types of synergies with patents. In

[2] Matteo Sabattini, NPEs vs Patent Trolls: How to build a healthy innovation ecosystem.

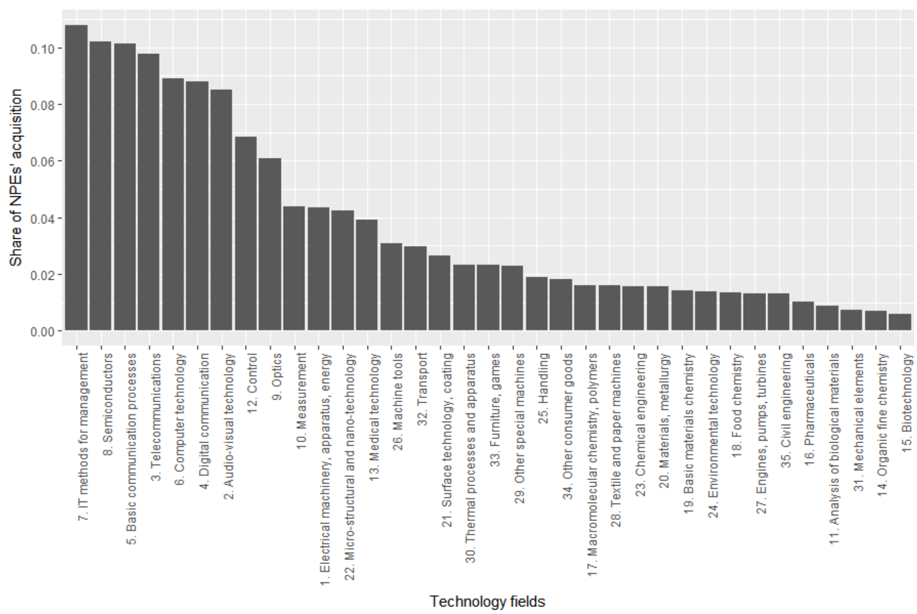



Figure 3.1.: Share of PAEs' Patent Acquisitions by Technology Fields

Notes: The x-axis ranks 35 International Patent Classification (IPC) technology fields as in (Schmoch, 2008) by the shares of PAE acquisitions in each field's total transactions during 2007-2017.

this paper, I theorize on how PAEs' business model shape their patent acquisition, and compare it to that of other firms. Drawing insights from the litigating-oriented to the practicing-oriented patent acquisitions, this study deepen our understanding of the multifaceted value of patents.

This study also contributes to the literature of technology commercialization. Existing studies have primarily focused on practicing monetization via market entry or licensing (Gans et al., 2008; Gans and Stern, 2003; Marx and Hsu, 2015). The litigating monetization strategy, though missing in strategy literature, has been discussed in literatures of law (Allison et al., 2009, 2017), economics (Lemley and Feldman, 2016; Choi and Gerlach, 2015, 2017; Turner, 2018), and policy (Cohen et al., 2017; Federal Trade Commission, 2016). I argue that while the technological strength and the exclusion scope of patents matter to practicing and litigating monetization in different ways. A firm that seek product market profit is incentivized to deter infringement, whereas a PAE is incentivized to allow (if not encourage) infringements. Furthermore, compared to practicing monetization, litigating monetization is much more dependent on the security of patent rights. When the regime is less friendly to patent owners, patent assertion will also be less profitable. Besides, studies have primarily examined uncertainties in the intellectual properties (IP) regime from events such as disclosure (Hegde and Luo, 2017; Luck et al., 2020) and patent grant (Gans et al., 2008), few has looked at circumstances where risks surrounding validity of patents increase, and from an angle that look upstream to the acquisition of IP.

When primarily focusing on the acquisition of IP, this paper contributes to the broader strategy literature by discussing how firms with competing business models behave differently in the strategic factor market (SFM). Theoretical studies in SFM have shown that firms' idiosyncratic valuation and the subsequent acquisition of resources originate from firms' heterogeneous information and expectation of the value creation (Barney, 1986; Makadok and Barney, 2001), firms' existing resource stock and the degree of complementarity between existing resources and the target resource (Adegbesan, 2009; Dierickx and Cool, 1989), and firm's position in the product market (Schmidt and Keil, 2013; Chatain, 2014). However, extant literature has not yet studied how firms' heterogeneity in the type of complementarity drives different expectations of the resource value and the equilibrium ownership and allocation of resources among such different firms. This study fills in the gap of the existing literature and adds to the line of research that examines the competition of firms with different business models in the SFM (Markman et al., 2009; Casadesus-Masanell and Zhu, 2010, 2013).

## 3.2 PAEs as Patent Intermediaries and Litigating Monetization as a Business Model

PAEs are a type of patent intermediaries. Based on the categorization by Hagiu and Yoffie (2013), intermediaries that purchase patents from individuals and firms can be either a defensive aggregator or an offensive aggregator.[3] Defensive aggregators acquire patents from other parties and collect licensing, subscription, and other business intelligence service fees from subscribers to protect those entities from litigations and harassment of patent trolls. Defensive aggregators often own large numbers of patents, but unlike offensive aggregators, they do not rely on litigations or the legal threats to appropriate value from firms. Two of the most prominent defensive aggregators are RPX and Applied Security Trust (AST), whose clients include Cisco, IBM, Intel, Toyota, Samsung, and Microsoft.[4] While defensive aggregators usually do not litigate their patents, offensive aggregators do the opposite and always litigate and in many cases even assert their patents to profit from settlement fees, licensing fees, and compensations out of litigations. By this definition, universities are also of-

[3]Hagiu and Yoffie (2013) also mentioned other types of patent intermediaries. First, patent brokers who do not buy patents but only connect patent sellers and buyers. Second, patent pool, which is a pool of patents that practicing company put together and license to each other. Third, standard setting organizations which are two-sided patent platforms. Fourth, super aggregators that have some attributes of both defensive and offensive aggregators.

[4]As written on the website of RPX, they are open to all sorts of entities interested in their patents: "We welcome inquiries from individual inventors/owners, academic institutions, brokers, technology transfer offices, corporate sellers, and non-practicing entities." Web: http://www.rpxcorp.com/rpx-services/rpx-patent-sales/

fensive (Lemley, 2007). But universities may have different motivation and incentives compared to firms. In this study, to better focus on litigating monetization, PAEs or patent trolls only refer to non-university offensive aggregators.

Regardless of the buyer type, patents are options that can be monetized in different ways (Cotropia, 2008), litigating monetization is a way to exercise, and it has deterministic implications. In sum, though patents are essential for both business models, they substantially differ in several aspects: (1) Source of competitive advantage. when a firm adopts litigating monetization, the source of competitive advantage is legal capabilities, while patents are somewhat substitutable. But for a firm that practices certain technology, there are usually patents that are essential and important so that the substitutability is low. (2) Attitude towards infringement. Infringement is necessary for litigating monetization, and a large number of firms infringing the patent benefits the value from litigating monetization. But infringement is detrimental to firms that profit from practicing the technology. (3) Timing of value appropriation. Value appropriation of litigating monetization occurs after firms have practiced or used the patented technology, whereas value appropriation from practicing the patent starts with the initial practicing of the patent. (4) Sensitivity to the property rights. Litigating monetization is very sensitive to changes in the legal regime as the regime directly determines the strength of property rights. But the sensitivity is much lower for practicing monetization, as their value appropriation depends on a wide range of factors.

Unlike practicing monetization, for which profit comes from the product market, litigating monetization typically starts with a PAE sending demand letters to target firms asking for monetary payments and threatening to sue if targets do not pay. An important feature of demand letters is that, since the PAE often does not have resources and capabilities to evaluate the value of the patent to each target, the PAE sends standard demand letters that list the infringed patents, give a number of payment claimed, and request communications, without much discriminating upon different targets.[5] The PAE's goal is to maximize the probability of targets' yielding to their demands without actually entering the expensive litigations.

The key to secure a payment by the target upfront without falling in the swamp of patent litigations is that the settlement fee demanded by the PAE shall not exceed the costs from possible litigations. Because if the threatened target decides to fight at court and insists to the end, even if the plaintiff PAE wins, the PAE will also have to spend significant time[6] and legal cost to deal with the case. This indicates that compared to getting straight payment of settlement fees, fighting at court is not in the interest of plaintiff PAEs. Therefore an informed PAE would demand the maximal monetary payment from a target firm such that settlements would be favored by the target over litigations. In reality, PAEs almost always seek to settle a litigation while PEs' likelihood to settle a litigation as a plaintiff decreases with the PEs' product market stake of the litigated patent (Somaya, 2003). Such settlement, often in forms of licensing fee, differs from licensing in practicing monetization in that such payments are usually a lump-sum payment, instead of a percentage of profit shared with the patent owner over future years.

## 3.3 Theory

### 3.3.1 Technological strength and patent acquisition

For a patent to be granted, the invention has to be novel, non-obvious, and useful (Hall et al., 2005). In the patent market, variations in technological strength exists in two dimensions. First, for technologies invented at the same time, there is a cross-sectional variation of the technological quality among patents; second, for technologies of the same quality but were invented in different time, there is a temporal variation of the strength of the technology in that the best technologies patented ten years

[5]For an example of demand letter, see: https://www.nar.realtor/window-to-the-law/window-to-the-law-patent-troll-demand-letters

[6]The average time from a complaint is filed at a district court to the trial is longer than two years (PriceWaterhouseCoopers, 2018; Lex Machina, 2019)

agao may no longer be valuable now. Below I discuss how these two dimensions of technological strength matter for patent acquisition.

Since PAEs often seek to claim fees from multiple firms, PAEs want the technology to be as widely "infringed" as possible to maximize value of each patent. Specializing in enforcing patent rights, PAEs' essential resource is their acquaintance and proficiency with the legal procedures regarding patents and patent lawsuits (Cohen et al., 2016), and PAEs usually do not possess the capabilities to evaluate the value that a technology brings to a specific firm or industry.[7] Due to PAEs' disinterest of the technology itself, no matter what the technology is, if there are not a significant number of adopters, the patent is of little value to PAEs since there is not a sufficient number of firms that can be targets of PAEs' assertions.[8]

Thus, for PAEs, without the ability to discern whether a patent is of high private value for a firm, PAEs would go after high quality technologies that are generic and attracts a large audience. However, the value of patent is highly firm-specific, since product market profit a firm appropriates are determine by many complementary resources other than the technology itself (Teece, 1986). Firms' idiosyncratic complementary assets leads them to differ drastically in acquisition of patents. A patent of low technological quality may still be acquire by firms to build a portfolio to protect their own core technologies, while PAEs only acquire relatively high quality technologies that firms actually uses since it is the only ground for claiming infringement payments.

Also, from the perspective of litigation, while PAEs do not distinguish among defendants on whether they are rivals or clients since PAEs do not have product market presence, PEs do not aggressively litigate unrelated firms outside their area (Simcoe et al., 2009), especially not on potential clients. Thus, the more widely used is the patented technology, the higher the likelihood of a patent to be acquired by a

[7]However, there are some exceptions, such as InterDigital, who produces lots of patents itself, though many of InterDigital's patents are criticized for low technological strength.

[8]This also indicates that if there is only technology but no patent, with nothing to assert, the technology is useless to a PAE.

PAE buyer. Among patents in the same cohort, patents with higher quality in that they on average generate more value are more likely to be purchased by PAEs.

**Hypothesis 1a.** *Everything else equal, the better the technological quality such that the more widely adopted is the patent, the probability of acquisition by a PAE as compared to a PE.*

However, the dilemma for PAEs is that, though patents of high technological quality are desired, they will also be expensive if PEs are also competing for ownership. But, in addition the cross-sectional difference among technological quality, for the same technology, its strength changes over time. For practicing monetization, a PE either appropriate value by using the technology to gain competitive advantage via differentiation or cost reduction(Bessen and Maskin, 2009; Porter, 1985) or from licensing the technology to other firms (Arora and Fosfuri, 2003). Either way, first, when the technology is new, its contribution to the focal firm to improve a product or a process is likely to be higher. Second, when the patent ages, the knowledge spillover (Somaya, 2002; Agarwal et al., 2009) may enable other firms to be able to use the technology, so that the superior profit the patent brings to the patent-owning firm may be wiped out. Third, as the patent ages, there is a higher chance that upgraded versions of the technology become available so that the old patent, though maybe more radical than the new incremental patents, also becomes obsolete (Fischer and Leidinger, 2014; Lanjouw, 1998; Pakes and Schankerman, 1984). When the technological strength is weakened, so is PEs' valuation of the patent, but this means a good opportunity for PAEs.

Although the weakened technological strength reduces the practicing value for PEs, a PAE may be able to extract more litigating value from the patent. At first, a PAE cannot commit and acquire a patents when the technology is still too new and uncertain about whether it will accrue a significant number of adopters, who are PAEs' potential targets (Fischer and Leidinger, 2014). In addition, firms that developed or used updated technologies that partially overlap with the old patent could also be targets of PAEs. Therefore, the larger the age of a patent, the more likely it will be purchased by PAEs.

In sum, PEs have high willingness-to-pay for new technologies, which often outbid PAEs, for which patents are substitutable resources. But older technologies that were of high quality before are likely to have accumulated more adopters that increases the litigating value of the patent. I hypothesize that:

**Hypothesis 1b.** *Everything else equal, the older the patent, the higher the probability of acquisition by a PAE as compared to a PE.*

### 3.3.2 Scope of property rights and patent acquisition

While the technological strength is important, the right to exclude is what defines the scope of property rights. Sometimes, claiming a scope of property rights is more important than the technology itself, as an example, the skyrocketing of software patents in recent years is not well explained by changes in firms' investment in software, R&D, computer programmers or engineers employment, or productivity growth, but is highly correlated to the change in the legal regime that strengthens the effectiveness of the exclusion rights (Bessen and Hunt, 2007). For PEs and PAEs, their monetization of the scope also differs.

For PEs, a patent neither provides perfect protection of the technology nor guarantees that the patent owner or the legitimate licensees enjoy the exclusive access to the patented technology .[9] In many technological fields, patents are not the primary method for protecting intellectual properties (Cohen et al., 2000) since other firms will often be able to imitate or use the technology and/or invent around to create their own solution and avoid infringement (Gallini, 1992; Mansfield, 1985). Especially with the publication of the technology in the patent application or other materials, rivals will imitate if they find it profitable and if they are capable (Horstmann et al.,

[9]As stated on the website of World Intellectual Property Organization (WIPO): "(some patents) would be so innovative that they give the owner a complete monopoly over an entire industry and are extremely valuable, often worth billions of dollars." See: *https : //www.wipo.int/sme/en/documents/valuing$_p$atents$_f$ulltext.html*. Retrieved on May 16th, 2019.

1985). The result is that there are still a number firms can access technology (Lemley, 2008).

However, for whichever firm, having access to the technology does not guarantee profitability (Teece, 1986), and a PE still have other methods to protect profit (Cohen et al., 2000). So a patent with a narrow exclusion scope may still be well protected in other ways so that the patent can be highly valuable. But rival firms differ in their capabilities to create alternative solutions (Ziedonis, 2004; Polidoro and Toh, 2011) and the strength of legal support team so that the firm can deter potential adversarial accusations(Agarwal et al., 2009). So as the exclusion scope widens, more firms would be unable to avoid this patent without infringing or licensing from the patent owner, leading to a higher value appropriation of the firm that owns the patent (Klemperer, 1990). For a patent with a wide scope that other firms cannot avoid, the patent-owning firm can not only use the patent itself, but also reap the licensing income by allowing other firms to commercialize (Kamien and Tauman, 1986). Patents with widest scopes becomes Standard Essential Patents (SEPs). For those patents with widest scope of applications, they are so crucial and valuable, so that PEs will secure their control and acquire at high prices in necessary.

Then as the exclusion scope of a patent widens, the increment of practicing value of the patent comes from (1) an increased market share due to a reduced number of firms competing using the technology and (2) a higher profit margin on each unit of product or service. Given such dual profit gain, I argue that the value from practicing monetization has an **increasing** return on the exclusion scope (Teece, 1998).[10]

[10] A formal framework is presented in Appendix B.1. Figure 3.2 plots the relationship between the practicing value ($\Pi^p$) and the exclusion scope ($x$) of the patent. As the exclusion scope increases, the practicing monetization becomes increasingly more profitable.The technological strength of the patent is exogenous to this plot, with the same exclusion scope, a higher the technological strength will shift the curve in Figure 3.2 to higher. There is a minimum level for exclusion scope ($x^{*p}$) for practicing monetization to be profitable, due to the cost to implement the technology and to maintain the patent ($C^p$). But, when the cost of implementation and maintenance is sufficiently low, it is possible that even a technology has no exclusion scope (or in other words, the technology is open knowledge), practicing monetization is still profitable for PEs. That profit will purely come from the value of the technology. The potential profitability from only the technology even without exclusion rights is a key difference of practicing monetization as compared to litigating monetization, which I will discuss in detail below.

As to PAEs, to improve profitability, they often target on firms that are less capable to defend themselves (Cohen et al., 2020). For instance, a startup with zero experience to patent litigations and weak legal or technological capabilities would be a great target for PAEs since the startup will be more likely to yield to PAEs' demands. Seeking to quickly settle the case, PAEs price the licensing based on the potential legal cost but not the target's product market profit. Thus, the weaker the target firm, the higher the target's predisposition to settle, and the higher the PAE's expected profit. However, the more firms a PAE sue, as easier targets are exhausted, PAEs will have to spend more cost threating more difficult targets. Besides, the more firms a PAE sue, the more assertive it behaves. Being more assertive will raise the red flag for courts, which will be less likely to judge in favor of the PAE. Also, the more firms a PAE sue, the more likely that the firm will find evidence to invalidate the patent, once invalidated, there will be no more future profit from assertion. Hence, as the exclusion scope of patents widens, litigating monetization will be faced with a decreasing margin giving a downward sloping "demand" curve, unlike practicing monetization, in which the marginal profit increases with the exclusion scope.

As a result, the increased difficulty in asserting the patent against firms leads to a concave profit function for litigating monetization. Thus, everything else equal, the profitability of litigating monetization increases with the exclusion scope of patents at a **decreasing** rate.[11] Figure 3.2 shows how profits for PEs and PAEs increase as exclusion scope increases, as well as their regions of patent acquisition.

Given practicing monetization has an increasing return to scope and litigating monetization has a decreasing return; while both PAEs and PEs would also prefer patents with wider scope, it is unlikely that PAEs will outbid PEs on patent with widest scopes, such as the SEPs. On the other hand, patents with narrow scope,

[11] Figure 3.2 shows the relationship between the litigating profit ($\Pi^l$) and exclusion scope ($x$), and the position of the minimal exclusion scope ($x^{*l}$) for profitable litigating monetization, the point where the exclusion scope makes litigating monetization profitable enough to justify the threatening and litigating costs ($C^l$).

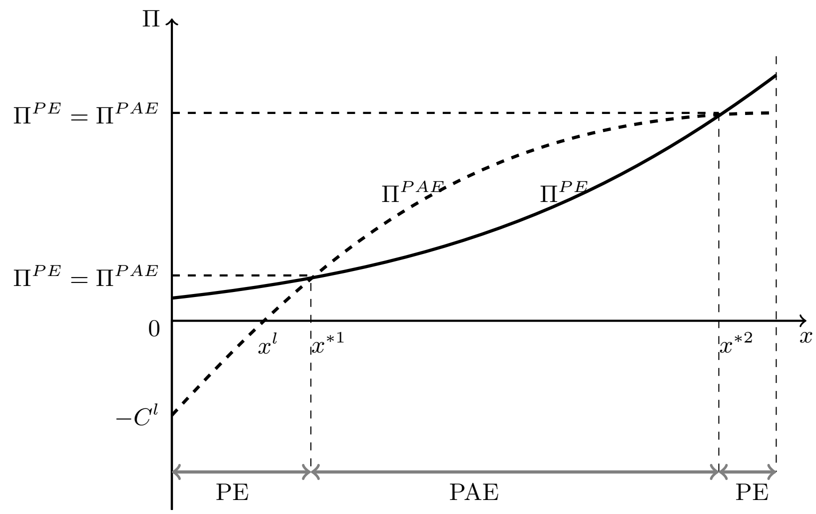



Figure 3.2.: Observed patent acquisitions by PEs and PAEs

Notes: The horizontal axis is a patent's exclusion scope $x$ and the vertical axis is value $\Pi$. The solid curve is the value appropriation of PEs ($\Pi^{PE}$) and the dashed line is the value appropriation by PAEs ($\Pi^{PAE}$). PEs have positive value even when the exclusion scope is close to zero, while PAEs' value is negative. PAEs' return to exclusion scope is decreasing, whereas PEs' return to exclusion scope is increasing. The simple model suggests PAEs are more likely to acquire patents with medium scope, while patents of either very narrow or vary wide scopes are less likely to be acquired by PAEs.

though unprofitable for PAEs, PEs can have positive profit from the product market using other measures to protect the technology. Thus, I hypothesize:

**Hypothesis 2.** *There is an inverted U-shaped relationship between patent scope and the probability of acquisition by a PAE as compared to a PE.*

### 3.3.3 Security of patent rights, invalidation risk and patent acquisition

Aside from patent characteristics, institutions regarding security of intellectual property rights is another factor determining value appropriation from patents (Teece, 1986), and this is especially so for litigating monetization. Only when the legal regime is sufficiently supportive of patent rights can PAEs' threat be valid. Currently, the average success rate for patent holder in trial is more than 60%,[12] and the median damage payment awarded by the court is more than \$5 million[13](Lex Machina, 2019; PriceWaterhouseCoopers, 2018). High cost of litigations put great threat on the defendant, however, the threat is weakened if the defendant can easily challenge the patent and seek for invalidation. When the challenge is successful, claims or the whole patent will be invalidated and the patent holder will have zero profit. So the higher the risk of invalidation, the lower the profitability from litigating monetization.

For PEs, though PEs also utilize patent litigations as a competitive strategy against their product rivals (Lanjouw and Schankerman, 2001; Meurer, 1989) and that invalidation risk also threats profitability of PE patent buyers, patented technologies is only one of the many factors that determine profitability. In addition, as mentioned before, firms have multiple methods to protect the patented technology, such as secrecy and complementary resources (Cohen et al., 2000). Hence, a PE's profit on the patent is much less affected by the validity of patents rights. So I hy-

[12]A trial can be a bench decision or a jury decision. In the two scenarios, the average success rate for patent holders is more than 50% for bench trials, and is more than 70% for jury trials. (Lex Machina, 2019; PriceWaterhouseCoopers, 2018)

[13]During 2013-2017, the median damage awarded to PAE plaintiffs was \$14.8 million and the median for PE plaintiffs was \$4.2 million (PriceWaterhouseCoopers, 2018).

pothesize that as the risk of invalidation heightens, it negatively effects PAEs' patent acquisition relative to that of PEs:

**Hypothesis 3.** *The higher the invalidation risk, the lower the probability of acquisition by a PAE as compared to a PE.*

While the invalidation risk is institutional, the risk does not influence each patent equally. Controversies over validity of patents are more likely to arise for patents of weak technological strength in terms of low-quality technology and old patents. Especially for old patents, as they were granted relatively early in the life cycle of the technology, when patent examiners' understanding of the technology is incomplete so that inaccurate claims may be granted to patents.

**Claim 1.** *The negative effect of institutional invalidation risk on PAE acquisition will be larger for patents with low technological strength.*

When a patent has an expansive scope, on the one hand, it may overlap with many other patents and technologies so that more firms that feel threatened will have the incentive to challenge the patent. Also, once challenged, it is likely that a part of the claimed territory will be weakly justified when the patent was granted. Whichever mechanism will hurt PAEs' litigating monetization which solely depends on enforcing patent rights.

**Claim 2.** *The negative effect of institutional invalidation risk on PAE acquisition will be larger for patents with wide scope.*

## 3.4 Empirical Strategy

### 3.4.1 Data

To test the above hypotheses on patent monetization and PAEs' preferences and valuation of patents in the market, I first obtained the patent reassignment data from the USPTO. The data contain roughly 8 million voluntarily reported assignments that involve a total of around 13.1 million patents and patent applications reassigned after the grant; the data range from the years 1970 to 2017(Marco et al., 2015). However, not all of these assignments are valid transactions. Among these records, I excluded employee assignments, which are assignments from employees to the employer firm and do not reflect market transactions. Employee assignments consist of more than 80% of all records (Marco et al., 2015). Also, I only kept assignments with the conveyance type of “assignment”, nor other types such as “merger”, “change of name”, and “government interest agreement,” which represent other patent reassignment motivations that go beyond the current papers focus on the value of the patent. Reassignments that occur between different subsidiaries of the same company were also excluded. In addition, I limited the sample to transactions conducted from 2007-2017 to better focus on some major institutional changes in the 2010s’. After these procedures, the data set contains more than 257,000 assignments and 830,000 patent-level transaction records.

Among these records, to identify transactions that involve PAEs, I used a name list of entities. For this name list, I relied on the PAE identification from multiple sources, including RPX,[14] PlainSite.org,[15] and other sources and then constructed a list of PAEs that contains more than 5,200 entity names. With the names of PAEs, I matched them with the assignee names of patent transactions to locate assignments to PAEs. I was able to identify more than 23,000 assignments where the buyer was a PAE. For those PAEs that acquire patents, it is worth noting that many of them are affiliated entities that are used for patent transactions and patent holding for large parent PAEs. For example, Intellectual Ventures is one of the world’s largest and most famous PAEs; it tops the list with more than 1,000 affiliated entities and 548 of them appear in the patent transaction data. Although thousands of PAEs participate

[14]Details on RPX’s procedures of identifying PAEs can be found in the RPX Patent Litigation and Marketplace Report, available at https://www.rpxcorp.com/wp-content/uploads/sites/6/2019/04/RPX-2018-Patent-Litigation-and-Marketplace-Report-Public-Excerpt-040919.pdf

[15]PlainSite.Org gives lists of subsidiaries of several large PAEs, such as Intellectual Ventures and Acacia

in the patent market, most acquisitions are made by several of the largest ones. Table B.1 gives the top 20 PAEs with the most patent acquisition records.[16]

In addition to PAE names and patent transactions, I obtained the patent characteristics from PATSTAT and variables published by OECD. For data on patent litigations, from LexMachina, I obtained the records of all the 68,000 patent litigations in the 91 regional Federal District Courts from January 2000 to March 2019 and more than 10,000 patent challenge petitions filed at the PTAB from the establishment of the PTAB in September 2012 to March 2019. With the litigation data, I was able to identify all the litigation and challenge records for the transacted patents, which are important in drawing conclusions on the litigating monetization of patents.

### 3.4.2 Measures

Regarding measures, the main dependent variable is a binary variable which equals one if the acquiring entity of a transaction is a PAE and zero if a PE. Then, normalized forward citation within five years of the application is used as a proxy for the technological quality of patents. For patent age, I subtracted the date when the patent application was filed from the transaction date.[17] Then to measure patent scope, from PatentsView, I obtained all the CPC codes associated with the transacted patents. At the level of CPC subclasses, I counted how many subclasses each patent spans, as my measure for the exclusion scope. Third, to capture the change in the invaldiation risk, a post-AIA dummy variable was created which equals 1 if the quarter is after 2012 Q3 and 0 otherwise. Definitions of key variables used in the anal-

[16] Among the Top 20 PAE entities in the table, some are different subsidiaries of the same parent PAE. For example, Intellectual Ventures I, Intellectual Ventures II, and several other entities in the list are all subsidiaries of Intellectual Ventures. In the Top 20 list, subsidiaries of Intellectual Ventures are: Intellectual Ventures I, Collahan Cellular, Ol Security, Gula Consulting, The Invention Science Fund I, Intellectual Ventures II, Empire Technology Development, and Xylon.

[17] The patent grant date is not used because there is usually a gap between the application date and the grant date, and the difference can be significant. There are patents that were granted more than ten years after the initial application date. So counting age from the application date is a better measure, which I intend to use as proxy for the technological strength of patents.

ysis are given in Table 3.1. The descriptive statistics for the patent-transaction-level data are given in Table 3.2. The correlation matrix is given in Table B.3.

### 3.4.3 Institutional background

To test the effect of invalidation risk on PAEs' patent acquisition, I exploit recent changes in the US patent system that weakens the power of assertive plaintiffs. Specifically, I look into events following the enactment of America Invents Act (AIA) which significantly changed the institution in the United States. Figure 3.3 shows major events that modifies the US patent system, especially ones that are pertinent to PAEs. As shown, while in the decade prior to AIA, several events confirmed the patentability of business methods (with implementation using technologies) and the method of awarding damages to plaintiffs, which laid the foundation of patent assertions, after the enactment of AIA, executive actions from the White House and the two major supreme court rulings of *Alice v. CLS Bank* and *TC Heartland v. Kraft Foods* all aimed to restrain patent assertions.

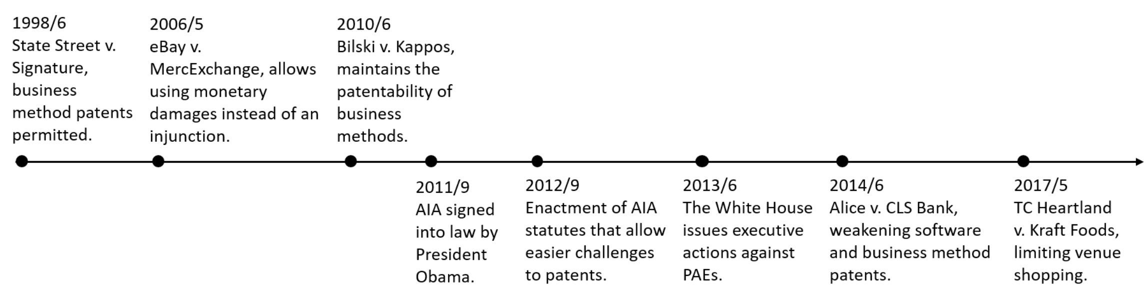



Figure 3.3.: Timeline of major events relevant to PAEs

Notes: Since the enactment of AIA in 2012, a series of supreme court rulings continue the trend of limiting the power of assertive plaintiffs and tightening the patentability of business methods.

On September 16th, 2011, President Obama signed the AIA, and the Act took effect on September 16th, 2012. The AIA revised the inter partes reexamination – the channel for challenging the validity of granted patents – and replaced it by the three

Table 3.1.: Variable Definitions

| Variable | Measure |
|---|---|
| PAE Buyer | A binary variable which equals 1 when the buyer of a patent is a PAE, 0 otherwise. |
| Post | A binary variable which equals 1 when the time of patent acquisition is after the enactment of AIA, 0 otherwise. |
| Technological Quality | The number of forward citations a patent receives within five years after its publication, normalized by the mean number of patents in the same cohort (year and technology class). |
| Age | Age (in years) since the filing of the patent application when the property was transacted. |
| Patent Scope | The logarithm of the number of CPC subclasses a patents spans, normalized by the mean number of patents in the same cohort (year and technology class). |
| Family Size | The number of patent offices where the same patent was filed, normalized by the mean family size of patents in the same cohort (year and technology class). |
| N of Ind Claims | The number of independent claims a patent has, normalized the mean number of patents in the same cohort (year and technology class). |
| NPL Citation | The logarithm of the proportion of a patent's backward citation to non-patent literature (such as academic papers), normalized by the mean of patents in the same cohort (year and technology class). |
| Generality | A normalize Herfindahl Index of the diversity in IPC classes in forward citations a patent receive. |
| Exposure | A patent's exposure to post grant patent challenges, measured at the level of CPC-subclasses by their shares in complaints filed to PTAB 2012-2019. |
| Software | A binary variable which equals one if a patent is a software patent. |
| Litigation History | A binary which equals one if a patent was litigated prior to the transaction. |
| Lit Future | A binary variable which equals one if a patent was litigated after the transaction. |
| NWFC Z-Score | Number of words in the first claim, z-score of the distribution within the art unit. |
| Toughness | Toughness score of patent examiner. |
| Tech Field | Categorical variable of the 35 fields identified by the IPC-Technology Concordance table. |
| Year Quarter | Year and quarter of the transaction. |

Notes: Sources of patent data are USPTO and OECD (which is compiled from Patstat of EPO); PAE names are from RPX and other sources; and litigation data is from LexMachina. NWFC and Toughness data is from Kuhn and Thompson (2019), Software patent data is from Webb et al. (2018).

Table 3.2.: Patent-Transaction-Level Descriptive Statistics

| Statistic | N | Mean | St. Dev. | Min | Pctl(25) | Pctl(75) | Max |
|---|---|---|---|---|---|---|---|
| PAE Buyer | 830,400 | 0.06 | 0.24 | 0 | 0 | 0 | 1 |
| Post | 830,400 | 0.53 | 0.50 | 0 | 0 | 1 | 1 |
| Forward Citations | 829,751 | 1.62 | 5.13 | 0.00 | 0.21 | 1.42 | 373.16 |
| Raw Forward Citations | 829,751 | 17.80 | 57.14 | 0.00 | 2.00 | 15.00 | 2,810.00 |
| NPL Citation | 828,780 | 0.46 | 0.55 | 0.00 | 0.00 | 0.85 | 3.85 |
| Raw NPL Citation | 828,780 | 0.15 | 0.21 | 0.00 | 0.00 | 0.22 | 1.00 |
| Age† | 830,400 | 6.75 | 5.72 | −9.89 | 2.04 | 10.82 | 46.16 |
| Scope | 829,751 | 0.69 | 0.27 | 0.24 | 0.47 | 0.84 | 2.83 |
| Raw Scope | 829,751 | 1.99 | 1.29 | 1.00 | 1.00 | 2.00 | 30.00 |
| Family Size | 829,751 | 1.08 | 1.00 | 0.08 | 0.35 | 1.48 | 15.72 |
| Raw Family Size | 829,751 | 4.09 | 4.40 | 1.00 | 1.00 | 5.00 | 55.00 |
| N Ind. Claims | 829,741 | 3.26 | 3.49 | 0.23 | 1.58 | 3.56 | 329.99 |
| Raw N Ind. Claims | 830,390 | 6.99 | 10.68 | 1.00 | 2.00 | 7.00 | 868.00 |
| Generality | 742,830 | 1.05 | 0.55 | 0.00 | 0.74 | 1.42 | 4.33 |
| Exposure | 830,382 | 6.89 | 5.20 | 0.00 | 0.54 | 8.01 | 19.65 |
| Software | 830,400 | 0.09 | 0.29 | 0 | 0 | 0 | 1 |
| Litigation History | 830,400 | 0.01 | 0.10 | 0 | 0 | 0 | 1 |
| Litigation Future | 830,400 | 0.02 | 0.13 | 0 | 0 | 0 | 1 |
| NWFC Z-Score | 215,401 | 0.08 | 0.94 | −24.77 | −0.32 | 0.70 | 2.02 |
| Toughness | 215,401 | −0.01 | 1.00 | −5.66 | −0.75 | 0.67 | 8.23 |
| Year Quarter | 830,400 | 2,012.67 | 3.04 | 2,007.00 | 2,010.00 | 2,015.25 | 2,017.75 |

Notes: † Some transacted properties have Age smaller than zero because a patent application was filed after they were traded. In some cases, it was because the patent was extended so that a new application date was recorded.

proceedings of Inter Partes Review (IPR), Post-Grant Review (PGR),[18] and Covered Business Method Review (CBM).[19] In the past, the patent would be reexamined by patent examiners if challenged and the challenging party could NOT participate in the process; but after the AIA, the challenging party was allowed participate in the process and the cases would be handled centrally by the newly established Patent Trial and Appeal Board (PTAB), which shortens the duration of each case from 4-8 years to 1-1.5 years. Patent challenges are similar to infringe lawsuits where two parties discover evidence regarding the validity of the patent. For the challenging party, filing such a complaint has a time and monetary cost. Most often, the challenging party was a defendant in previous patent lawsuits and seeks to invalidate patents that were used against the defendant. Once the challenging party wins, the patent or the complained claims of the patent, are often invalidated. So, with broadened fast processing of patent challenges, the AIA incrased the risk of invalidation and reduced the patent owner's power to assert rights. [20]

Figure 3.4 plots the by-subclass numbers of patent complaints filed from the establishment of the PTAB to March 2019. From the numbers, it is clear that G06F and H04L are the CPC subclasses with most patent complaints.[21]

[18]Notably, IPR is a proceeding that allows any third party to challenge a patent that were granted more than nine months prior. In addition, PGR is a proceeding that allows patents to be challenged within nine months of its grant.

[19]The CBM is a transitional program that is specifically for accused infringers to challenge the validity of the Covered Business Method Patents, and will be available until September 15, 2020. A CBM patent, according to 37 CFR 42.301, is a patent that (1) claims *"a method used in the practice, administration, or management of a financial product or service"*, and (2) that its claims *do not include 'technological inventions.'"*

[20]The AIA also bans PAEs' common cost-saving practice of combining litigations on the same patents and strengthens the power of Prior Art in invalidating patents. Changes made by the AIA would not affect the profit from the product market of the patent much, if at all; however, it should substantially affect PAEs' litigating monetization strategy. First, in the past, PAEs could combine defendants that they claim are infringing the same patents before trial, thus saving PAEs' costs significantly. The AIA introduced a new statute, 35 U.S.C. 299, which states that *"accused infringers may not be joined in one action as defendants or counterclaim defendants, or have their actions consolidated for trial, based solely on allegations that they each have infringed the patent or patents in suit."* This restriction on the consolidation of defendants increases the cost that the plaintiff must pay to initiate litigation against a series of defendants.

[21]Table B.9 gives descriptions of more relevant CPC patent subclasses with the most complaints filed at PTAB.

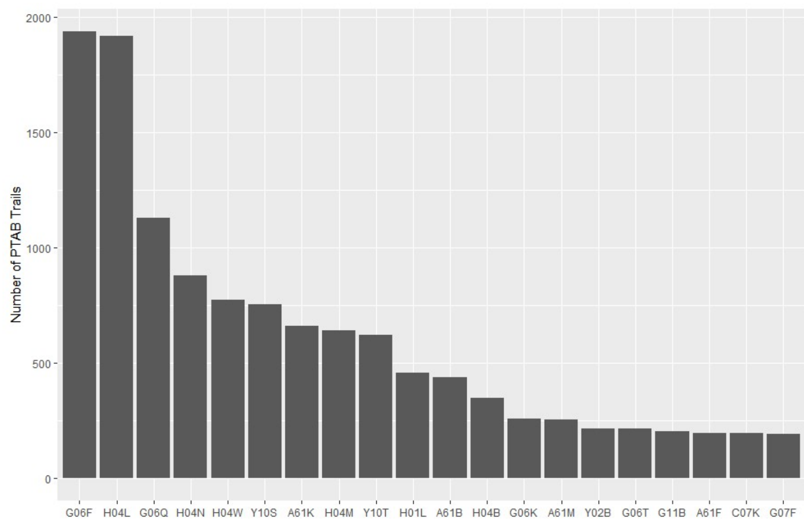



Figure 3.4.: Number of PTAB Complaints Filed by CPC Subclasses 2012/9-2019/3

Notes: (1) On the x-axis are patent CPC Subclasses ranked by total complaints filed to PTAB since its establishment to March 31st, 2019. The y-axis is the count complaints. (2) As shown in the figure, subclasses G06F and H04L received the most complaints. Descriptions of the top CPC subclasses are given in Table B.9.

After the AIA, which is a system-wide change of the legal institution regarding patents, another critical rulings is the *Alice v. CLS Bank* in June 2014, in which the Supreme Court ruled that the implementation an abstract idea on generic computers is not patentable. Specifically, Supreme Court judges agreed that Alice's patent on a "computer-implemented scheme for mitigating 'settlement risk,'" was invalid (Supreme Court of United States, 2014). In the patent, the tackled "settlement risk" refers to the risk that in a financial transaction only one party performs the action while the other does not comply; here the proposed solution was simply by using a third-party intermediary. This ruling puts challenges the validity of all software patents, which have similar central claims and are most heavily used for strategic purposes (Bessen and Hunt, 2007). Serrano and Ziedonis (2018) show that in IT-related areas, PAEs are much more active patent buyers as compared to in areas such as medical devices.[22] Thus, Alice, I expect a further dip in PAEs' patent acquisition of software patents.[23] Figure 3.5 shows quarterly shares of PAEs' patent acquisitions as the proportion of all patent transactions.

### 3.4.4 Exposure to patent challenges

Although the AIA allows patents to be challenges via IPR, PGR, and CBM proceedings, patents do not have the same exposure to the challenges after law change. Patents in some areas, such as mechanical engineering, are rarely litigated in lawsuits before the AIA, indicating there are fewer controversies and conflicts regarding those groups. So for those patents, even though the AIA expanded the channels for challenges, they are not likely to be affected and the impact of the AIA will be low. However, for some other areas, such as software and information technology, there

[22]Serrano and Ziedonis (2018) also shows that PAEs often acquire patents from failed IT startups.

[23]Other Supreme Court rulings may have effect on the business model of PAEs as well. One example is *TC Heartland v. Kraft Foods Group Brands* in 2017. Before that ruling, patent owners could file the infringement anywhere. But the ruling held that patent infringement may only be filed in districts where the defendant resides, or where the defendant committed the alleged infringement and has a regular place of business. Therefore, this ruling is likely to affect the commonly used "venue shopping" practice by PAEs.

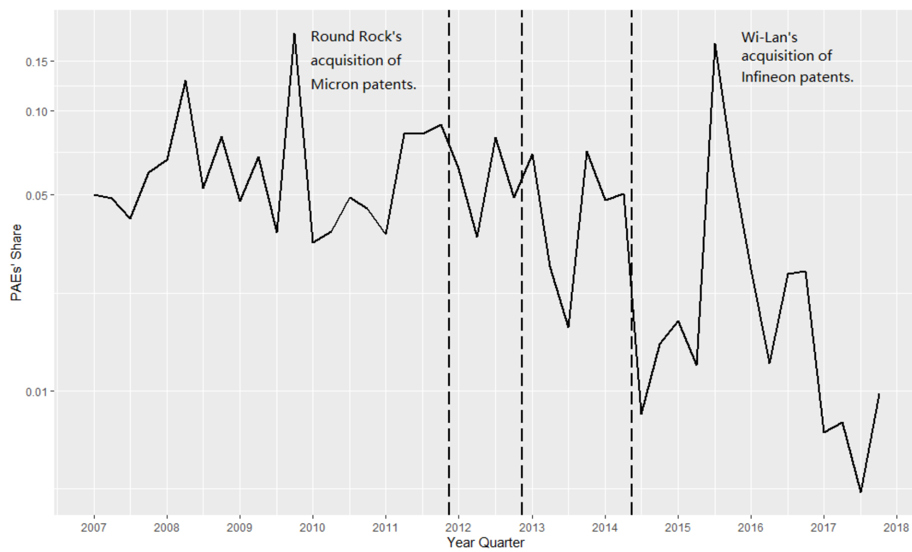



Figure 3.5.: Share of PAEs' Patent Acquisitions in All Transactions

Notes: (1) The x-axis is Year-Quarter that covers from 2007 Q1 to 2017 Q4. The y-axis is the share of PAE acquisitions among all transactions in a quarter. (2)The three vertical lines mark 2011 Q4, 2012 Q4, and 2014 Q3 respectively, the time when the AIA was signed to bill, when the AIA statutes took effect, and the time of Alice v. CLS Bank. (3) Spikes in the data are resulted from major acquisition events of large patent portfolios.

were many patent litigations before the AIA, and those previous conflicts and lawsuits should provide incentive for the defendants and related parties of those litigations to file complaints with the PTAB, trying to invalidate patents in those groups. We shall expect aggressive patent invalidation efforts made after the AIA, especially from firms that suffer from previous infringement accusations. Thus, patent in areas that are heavily litigated are naturally more exposed to the risk of challenges, compared with patent groups that are seldom litigated. This allows me to use the difference-in-difference design with continuous treatment (Zwick and Mahon, 2017; Card, 1992; Acemoglu and Autor, 2004).

To exploit the difference of exposure across different patent groups, I create a measure for the exposure to the invalidation risks following AIA for each patent group (Mezzanotti, 2017). I use the variation in each patent group's representativeness in patent complaints and calculate each patent group's share in all the 11 thousand patent complaints since the establishment of PTAB.[24] Then for each patent group (CPC subclass) $s$, its exposure to challenges is measured as:

$$E_s = \frac{100\Sigma_{i=1}^{N}\mathbb{1}_s(i)}{N} \tag{3.1}$$

where $i$ is one patent-plaintiff-defendant observation, $N$ is the total number of observations, and $\mathbb{1}_s(i)$ is an indicator function that equals one if the patent $i$ is in CPC subclass $s$, and 0 otherwise. The distribution of this index is described in Table B.2. Then for each patent, its exposure is measured as the average of the exposure of the patent subclasses that it is associated with. For example, US Patent 6922728 is a challenged patent in CPC subclasses H04L and H04W, and its exposure is the average of the exposures of CPC subclasses H04L and H04W. Formally, the calculation is:

$$e_i = \frac{\Sigma_{i\in s}E_s}{\Sigma_{i\in s}1} \tag{3.2}$$

[24]One complaint may involve multiple patents, plaintiffs (petitioners) or defendants (patent owners), so I transform the data to the patent-plaintiff-defendant level to give more weight to patents that appear in litigations multiple times and to patents that involve multiple plaintiffs and defendants. After this, for each litigated patent, I obtain its CPC subclasses.

Therefore, we obtain a patent-level index for its exposure to the post-AIA patent challenges. I also use other measures to capture the variation in exposure to the regime change. Details can be found in Appendix B.3.5.

## 3.5 Results

### 3.5.1 Technological strength, Scope, and PAE acquisition

To show differences of PAEs' and PEs' acquisition patterns, I estimate how independent variables affect the likelihood of a patent being acquired by a PAE, conditional on the patent being traded. To test how are the technological strength and scope of patents are related the likelihood of a patent being acquired by a PAE, I estimate the below empirical model using linear, Logit, and Probit specifications:

$$y_{it} = \beta_0 + \beta_1 TechQuality_i + \beta_2 Age_{it} + \beta_3 Scope_i + \beta_4 Scope_i^2 + \beta_5 Controls + \beta_6 X_i + \epsilon_{it} \tag{3.3}$$

Results are shown in Table 3.3, Model 1 estimates linear probability model, Model 2 estimates a Logit model with coefficients reported in Column 2 and marginal effects reported in Column 3. Model 3 estimates a Probit model with coefficients reported in Column 4 and marginal effects reported in Column 5. At first, Hypothesis 1a is supported by the significant and positive coefficient on $TechQuality$. Combining results from Colume 1, 3, and 5, on average, doubling the forward citation relative to the mean is associated with a 0.6- 0.7 percentage point increase, in the likelihood of the patent being acquired by a PAE. Given the overall mean probability of a traded patent being acquired by a PAE is 6%, doubling the forward citation lead to a 10%-16% increase of the probability of PAE acquisition. This shows PAEs are more likely to acquire patents that have higher technological quality in their cohort.

Hypothesis 1b is also supported by the significant positive coefficient on $Age$. The three models suggest that, on average, one year increase in the age of the patent is associated with a 0.26 - 0.44 percentage point increase of the likelihood of being purchased by a PAE. Figure 3.6 visualizes PAEs' preference in old technologies. In Panel 3.6a, there is a clear difference between age distributions of patents acquired by PAEs and other firms, with the peak of PAEs' acquisition much later than PE, while PEs strongly prefer new patents. Panel 3.6b shows the overall trend that the older the patent, the higher the share of PAEs in all acquisitions. Then in Panel 3.6c, I estimate a univariate Cox Proportional Hazard model in which a dummy variable of PAE is used to predict the age when the patent/application was transacted. This plot also shows that PAEs' timing of commitment to acquire patents is significantly later than that of PEs.

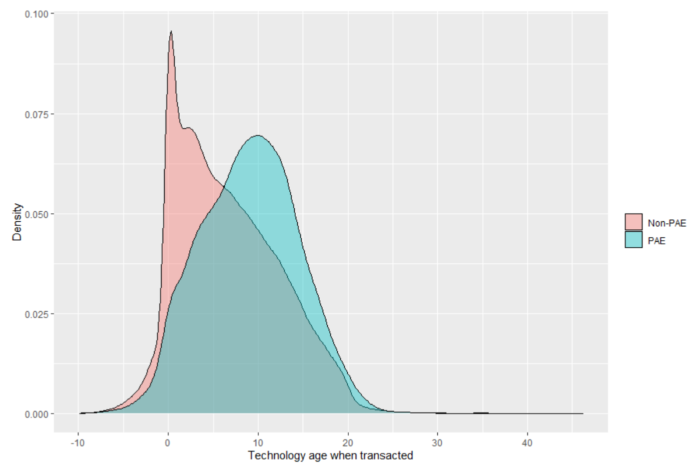
Hypothesis 2 suggests an inverted U-shaped relationship between the exclusion scope of patents and the likelihood of a PAE acquisition. *Scope* is already normalized and is in logarithm form to correct for skewness. From Table 3.3, initial support for this hypothesis comes from the negative and significant coefficient of $Scope^2$ and the positive and significant coefficient of *Scope* in all models. Second, a valid inverted U-shaped relationship shall have positive and negative slopes at the minimum and the maximum of the range of the independent variable of interest (Haans et al., 2016). This requirement is also met. In our data, the minimum and maximum of *Scope* are 0.24 and 2.83. Corresponding signs of slopes can be conveniently identified in Figure 3.7 in which the three parabolas plot the three quadratic functions of *Scope* estimated. Third, the turning point of the quadratic curve, $x^* = -\beta_3/2\beta_4$, is around 1.15, which is well between the minimum and maximum of *Scope*. turning point is at the 95th percentile of the data. This means that, for the top 5% of traded patents with widest scope, the likelihood of a PAE acquisition declines, while for the rest 95% of patents, the likelihood of a PAE acquisition increases as the scope increases. When the turning point is close to the right end of the data, a valid concern is that whether it is the outliers driving the results. I will test the validity of the inverted U-shaped relationship using different specifications and alternative measures in robustness checks.

Table 3.3.: Technological strength, scope, and the likelihood of PAE acquisition

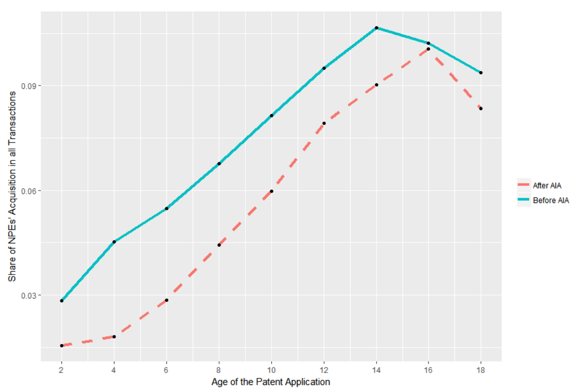
| | Model 1 | Model 2 | | Model 3 | |
|---|---|---|---|---|---|
| | LPM | Logit | Margins | Probit | Margins |
| Tech Quality | 0.007*** | 0.215*** | 0.006*** | 0.102*** | 0.007*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Age† | 0.440*** | 9.184*** | 0.264*** | 4.298*** | 0.315*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Tech Quality*Age | −0.014* | −1.162*** | −0.033*** | −0.388*** | −0.028*** |
| | (0.072) | (0.000) | (0.000) | (0.000) | (0.000) |
| Scope | 0.039*** | 0.800*** | 0.023*** | 0.375*** | 0.027*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Scope$^2$ | −0.017*** | −0.359*** | −0.010*** | −0.160*** | −0.012*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Litigation History | 0.071*** | 0.811*** | 0.034*** | 0.437*** | 0.047*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Post | −0.008* | −0.102 | −0.003 | −0.076* | −0.006* |
| | (0.123) | (0.105) | (0.111) | (0.019) | (0.023) |
| Year-Quarter FE | Yes | Yes | | Yes | |
| Tech Field FE | Yes | Yes | | Yes | |
| $R^2$ | 0.071 | | | | |
| Adj. $R^2$ | 0.071 | | | | |
| McFadden Pseudo-$R^2$ | | 0.163 | | 0.159 | |
| Num. obs. | 829751 | 829751 | | 829751 | |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

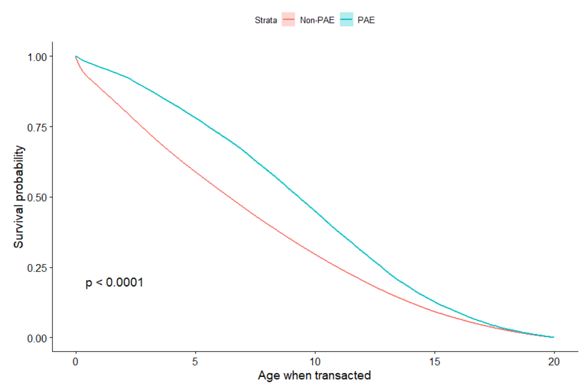
Notes: †Age is divided by 100 for better presentation in the table. P-values calculated using robust standard errors are in parentheses. The table reports Linear, Logit, and Probit results testing the relationship between patent technological quality, age, scope and the likelihood of a PAE acquisition conditional on an observed transaction. The normalized forward citations of a patent is used to capture the cross-sectional variations in the Technological Quality, and the age of the technology when being acquired captures the temporal changes in technological strength. PAEs are more likely to acquire good but old technologies are shown by the positive coefficient on NPL Citation and on Age. The linear term of Scope is highly significant and positive while the quadratic term is significant but negative, suggesting the inverted U-shaped relationship between Scope and the probability PAE acquisition, with the peak at 95% percentile. Litigation history, year-quarter and technology field fixed effects are also included.




(a)



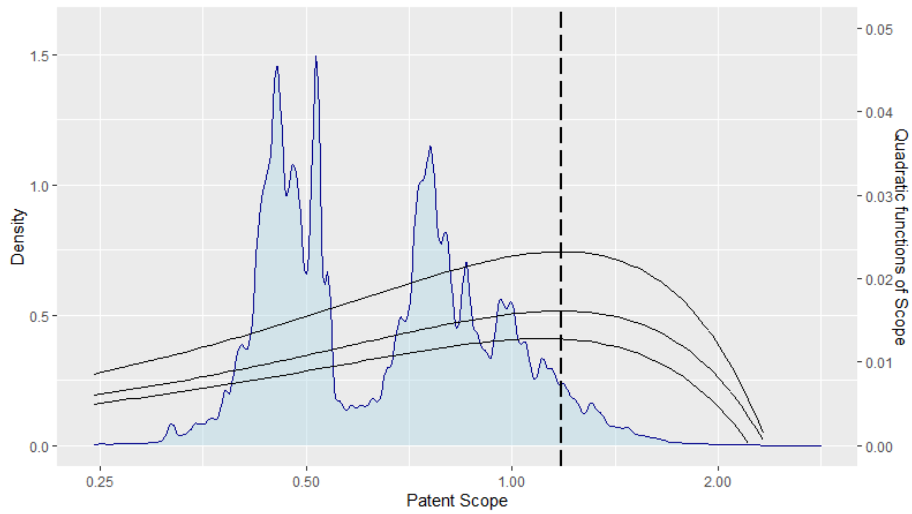

(b)




(c)

Figure 3.6.: Age and PAE acquisition

Notes: Panel (a) shows the distribution of age of patents/applications acquired by PAEs and Non-PAEs. While other firms predominantly acquire new patents, PAEs' preference significantly lean towards old patents. Panel (b) shows among all patents transacted, shares of PAE acquisitions for each two-year age group (Patents with age larger than 18 years were coded as 18). As shown, PAEs' shares increases over the age of patents. The lower level of dashed line indicates PAEs' reduced patent acquisition after AIA. Panel (c) shows results of univariate Cox Proportional Hazard model in which a dummy of PAE is used to predict the age when the patent/application was transacted. This plots also shows that PAEs' timing of commitment to acquire patents is significantly later than that of other firms.




S

Figure 3.7.: Scope and PAE acquisition

Notes: The x-axis is Scope in log-scale. Density of Scope is plotted to y-axis on the left, while the three quadratic functions estimated in Table 3.3 are plotted to y-axis on the right. The dotted vertical line marks the peak of parabolas. There are around 5% of all observations fall at the right side of the peak, consisting of around 40,000 patent transactions.

### 3.5.2 Invalidation risk and PAE acquisition: The impact of AIA

I argue that AIA heightens the institutional invalidation risk of patents, using *Exposure* to measure different patent groups' exposure to additional invalidation risks after AIA, I estimate the following continuous treatment difference-in-differences equation to test for Hypothesis 3:

$$y_{it} = \beta_0 + \beta_1 Exposure_i * Post_t + \beta_2 Exposure_i + \beta_3 Post_t + \beta_4 Controls + \beta_5 X_i + \epsilon_{it} \quad (3.4)$$

$Post * Exposure$ is the key variable in interest. Results from linear, Logit and Probit models are reported in Table 3.4. In all models, the coefficient of $Post * Exposure$ is negative and highly significant, showing evidence that the AIA dampened PAEs' patent acquisition. An average patent, with its *Exposure* at the mean of 6.89, is 0.7-2.1 percentage points less likely to be acquired by a PAE as compared to a PE.

To visualize differences in exposure to the heightened invalidation risk, Figure 3.8 divides all traded patents to Low, Medium, and High groups by the three equal quantiles of their Exposure, and plots PAEs' share in transactions for each group. The pre-treatment trends among the three groups are parallel, with PAEs having much higher share in acquisitions of patents more exposed to risks prior to the law change. The peak can be observed at 2011 Q3 and 2011 Q4, when PAEs' shares in high, medium, and low groups were 0.18, 0.10, and 0.05, respectively. But following AIA, PAEs' acquisitions in all the three groups dropped, and the largest decline is in the group with High exposure.

To further explore how the heightened risk of invalidation affect the probability of PAE acquisition, I estimate the equation below for the time varying effect of $Exposure_i * YQ_t$, where $YQ_t$ are fixed effects for each quarter.

$$P(PAE|Transacted)_{it} = \beta_0 + \sum_t \beta_t Exposure_i * YQ_t + \delta_1 Post_t + \delta_2 Controls + \delta_3 X_i + \epsilon_{it} \quad (3.5)$$

Table 3.4.: Invalidation Risk and PAE patent acquisition

| | Model 1 | Model 2 | | Model 3 | |
|---|---|---|---|---|---|
| | LPM | Logit | Margins | Probit | Margins |
| **Post*Exposure** | $-0.003^{***}$ | $-0.019^{***}$ | $-0.001^{***}$ | $-0.009^{***}$ | $-0.001^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Exposure | $0.001^{***}$ | $0.004^{***}$ | $0.000^{***}$ | $0.004^{***}$ | $0.000^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Tech Quality | $0.007^{***}$ | $0.215^{***}$ | $0.006^{***}$ | $0.101^{***}$ | $0.007^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Age† | $0.440^{***}$ | $9.159^{***}$ | $0.264^{***}$ | $4.294^{***}$ | $0.315^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Tech Quality*Age | $-0.011$ | $-1.118^{***}$ | $-0.032^{***}$ | $-0.372^{***}$ | $-0.027^{***}$ |
| | (0.185) | (0.000) | (0.000) | (0.000) | (0.000) |
| Scope | $0.043^{***}$ | $0.839^{***}$ | $0.024^{***}$ | $0.387^{***}$ | $0.028^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Scope$^2$ | $-0.019^{***}$ | $-0.379^{***}$ | $-0.011^{***}$ | $-0.167^{***}$ | $-0.012^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Litigation History | $0.071^{***}$ | $0.814^{***}$ | $0.035^{***}$ | $0.437^{***}$ | $0.047^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Post | $0.008^{*}$ | 0.056 | 0.002 | $-0.002$ | $-0.000$ |
| | (0.125) | (0.376) | (0.380) | (0.953) | (0.954) |
| Year-Quarter FE | Yes | Yes | | Yes | |
| Tech Field FE | Yes | Yes | | Yes | |
| $R^2$ | 0.072 | | | | |
| Adj. $R^2$ | 0.072 | | | | |
| McFadden Pseudo-$R^2$ | | 0.163 | | 0.159 | |
| Num. obs. | 829733 | 829733 | | 829733 | |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: †Age is divided by 100 for better presentation in the table. P-values using robust standard errors are in parentheses. The table reports Linear, Logit, and Probit results testing the impact of heightened invalidation risk on the likelihood of PAE acquisition. All models use a difference-in-differences design with Exposure being a continuous treatment intensity. A higher Exposure means that the patent is more susceptible to invalidation. The variable of interest, Post*Exposure, is highly significant and negative, showing that the probability of PAE acquisition is negatively affected by the increased invalidation risk following the AIA. All models include patent-level variables as controls, as well as year-quarter and tech field fixed effects.

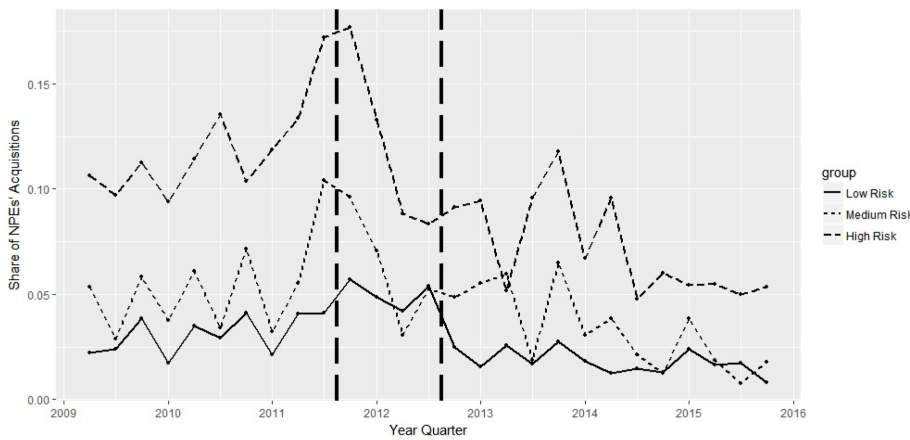



Figure 3.8.: PAEs' acquisitions by exposure to patent invalidation

Notes: (1) This figure plots PAEs' share in transactions for patents of Low risk (solid), Medium risk (dotted), and High risk (dashed) of invalidation for the quarters from 2009 to 2015. Groups of Low, Medium, and High are categorized by the three equal quantiles of their Exposure (2) The two vertical lines mark 2011 Q4 and 2012 Q4 respectively, the time when the AIA was signed to bill and the time when the AIA statutes regarding patent challenges took effect. (3) The pre-treatment trends among the three groups are parallel, with PAEs' have much higher share in acquisitions of patents more representive in litigations. The peak is observed at 2011 Q3 and 2011 Q4, when PAEs' shares in high, medium, and low groups were 0.18, 0.10, and 0.05, respectively. But following the law change, PAEs' acquisitions in all the three groups dropped, and the largest decline is in the group with High exposure.

With Exposure taking the mean value of 6.89, coefficients of each quarter $\beta_t$, as well as upper and lower bounds of the 95% interval are plotted in Figure 3.9. This graph shows for a patent with average exposure to invalidation risk, its likelihood to be purchased by PAE in each quarter as compared to a patent with zero exposure. As can be seen, the coefficient was mostly positive prior to AIA. However, the coefficient turned mostly negative after AIA, indicating the litigation-prone patents which were preferred by PAEs became less desirable due to the heightened invalidation risk. Interestingly, though still mostly positive, the magnitude of the coefficient started to decline several quarters prior to the formal enactment of AIA. This finding suggests that PAEs' decisions are not instantaneously following policy changes, but are probably planned beforehand when institutional changes are already being expected. Also in the graph are shown the times of events in the legislation history of AIA. Also as expected, we observe another negative impact after Alice.

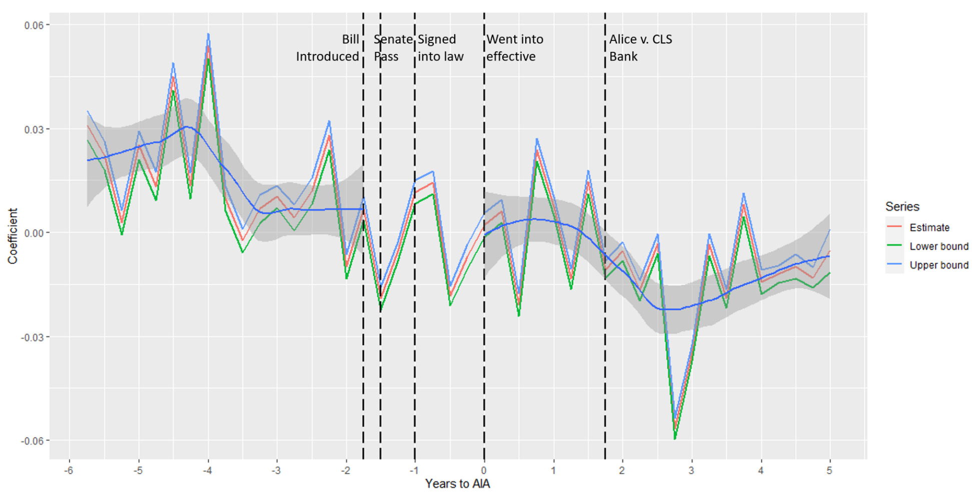



Figure 3.9.: Coefficient plot of exposure to invalidation and PAE acquisition

Notes: Coefficients of Exposure*Quarter for each quarter, as well as upper and lower bounds of the 95%interval are plotted, with Exposure taking the mean value. This graph shows for a patent with mean exposure to litigation risk, its likelihood to be purchased by PAE in each quarter, as compared to a patent with zero exposure. The likelihood of PAE acquisition was positive prior to AIA, while became negative after AIA, indicating the heightened risk for invalidation makes the litigation-prone patents less desirable for PAEs.

Results regarding heterogeneous impacts of the heightened invalidation risk are reported in Table 3.5 using linear, Logit, and Probit model. The main effect of heightened invalidation risk is negative and highly significant, and the magnitude does not differ substantially from results in Table 3.4. The negative impact, is less severe for patents with higher technological qualities as shown by the positive sign on $Post * Exposure * TechQuality$. These results verifies that the law change went in the same direction as intended, that is, to weakening the power of weak patents. In addition, I argued and expected a negative sign on $Post * Exposure * Age$, but the results give limited support to the claim as the statistical significance of the coefficient disappears after all two-way interaction terms were added. Also, results on the interaction effect with patent scope is also mixed, and further examination is needed.

In sum, the above evidence suggests that PAEs' patent acquisition decreased following heightened invalidation risk the AIA, but the impact is less severe for patents with higher technological quality, i.e., more forward citations.

## 3.6 Robustness

### 3.6.1 Other measures of technological quality

Citation to non-patent literature has been used as an indicator of the higher technological quality of patents (Branstetter, 2005). Results are shown in Table 3.6, the positive and significant signs on $NPLCitations$ lends support to Hypothesis 1a that PAEs are more likely to purchase patents of better technological quality, the negative and significant sign on $Post * Exposure$ verifies Hypothesis 3. The positive and significant sign on $NPLCitations * Post * Exposure$ lends support to Claim 1.

Table 3.5.: Heterogeneous impact of invalidation risk on PAE acquisition

| | Model 1 | Model 2 | | Model 3 | | Model 4 | Model 5 | | Model 6 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LPM | Logit | Margins | Probit | Margins | LPM | Logit | Margins | Probit | Margins |
| **Post*Exposure** | −0.004*** | −0.044*** | −0.001*** | −0.021*** | −0.002*** | 0.001** | 0.006 | 0.000 | 0.007 | 0.001 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.004) | (0.540) | (0.535) | (0.132) | (0.121) |
| Post*Exposure*Age† | −0.006*** | −0.045*** | −0.001*** | −0.036*** | −0.003*** | −0.006*** | 0.025 | 0.001 | 0.004 | 0.000 |
| | (0.000) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) | (0.248) | (0.277) | (0.750) | (0.760) |
| Post*Exposure*Tech Quality | 0.000*** | 0.006*** | 0.000*** | 0.003*** | 0.000*** | 0.000** | 0.008*** | 0.000*** | 0.003** | 0.000** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.029) | (0.000) | (0.000) | (0.007) | (0.004) |
| Post*Exposure*Scope | 0.002*** | 0.044*** | 0.001*** | 0.021*** | 0.002*** | −0.009*** | −0.087*** | −0.002*** | −0.050*** | −0.004*** |
| | (0.000) | (0.001) | (0.001) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Post*Exposure*Scope$^2$ | −0.001* | −0.015* | −0.000* | −0.007* | −0.001* | 0.004*** | 0.058*** | 0.002*** | 0.032*** | 0.002*** |
| | (0.041) | (0.060) | (0.044) | (0.061) | (0.036) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Post*Exposure*Lit. Hist. | 0.006*** | 0.041*** | 0.001*** | 0.023*** | 0.002*** | −0.001 | −0.003 | −0.000 | −0.002 | −0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.347) | (0.736) | (0.724) | (0.627) | (0.615) |
| Two-way Interactions | No | No | | No | | Yes | Yes | | Yes | |
| Main Effects | Yes | Yes | | Yes | | Yes | Yes | | Yes | |
| Year-Quarter FE | Yes | Yes | | Yes | | Yes | Yes | | Yes | |
| Tech Field FE | Yes | Yes | | Yes | | Yes | Yes | | Yes | |
| $R^2$ | 0.073 | | | | | 0.074 | | | | |
| Adj. $R^2$ | 0.073 | | | | | 0.074 | | | | |
| McFadden Pseudo-$R^2$ | | 0.164 | | 0.160 | | | 0.165 | | 0.160 | |
| Num. obs. | 829733 | 829733 | | 829733 | | 829733 | 829733 | | 829733 | |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: †Age is divided by 100 for better presentation. P-values using robust standard errors are in parentheses. The table reports Linear, Logit, and Probit results on the heterogeneous impact of the heightened invalidation risk. The main DID effect of Post*Exposure is negative. The negative impact, is less severe for patents with better technologies and with past lawsuits. However, there is limited evidence on that the negative impact is more severe for old patents (higher Age). All models include patent-level variables as controls, as well as year-quarter and tech field fixed effects.

Table 3.6.: Citations to Non-Patent Literature and the likelihood of PAE acquisition

| | Model 1 | Model 2 | | Model 3 | | Model 4 | Model 5 | | Model 6 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LPM | Logit | Margins | Probit | Margins | LPM | Logit | Margins | Probit | Margins |
| NPL Citations | 0.004*** | 0.062*** | 0.002*** | 0.047*** | 0.003*** | 0.002* | 0.038* | 0.001* | 0.036*** | 0.003*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.020) | (0.028) | (0.027) | (0.000) | (0.000) |
| NPL Citations*Post | | | | | | −0.004** | −0.141*** | −0.004*** | −0.055*** | −0.004*** |
| | | | | | | (0.002) | (0.000) | (0.000) | (0.000) | (0.000) |
| NPL Citations*Exposure | | | | | | 0.000+ | 0.003+ | 0.000+ | 0.001 | 0.000 |
| | | | | | | (0.137) | (0.058) | (0.055) | (0.218) | (0.209) |
| NPL Citations*Post*Exposure | | | | | | 0.001*** | 0.017*** | 0.000*** | 0.007*** | 0.001*** |
| | | | | | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Post*Exposure | | | | | | −0.003*** | −0.027*** | −0.001*** | −0.013*** | −0.001*** |
| | | | | | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Post | | | | | | 0.010* | 0.113+ | 0.003+ | 0.021 | 0.002 |
| | | | | | | (0.078) | (0.080) | (0.083) | (0.529) | (0.539) |
| Exposure | | | | | | 0.001*** | 0.004*** | 0.000*** | 0.004*** | 0.000*** |
| | | | | | | (0.000) | (0.001) | (0.001) | (0.000) | (0.000) |
| Age | 0.435*** | 8.397*** | 0.243*** | 4.063*** | 0.299*** | 0.437*** | 8.395*** | 0.244*** | 4.066*** | 0.300*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Scope | 0.036*** | 0.717*** | 0.021*** | 0.331*** | 0.024*** | 0.041*** | 0.760*** | 0.022*** | 0.344*** | 0.025*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| $Scope^2$ | −0.014*** | −0.284*** | −0.008*** | −0.119*** | −0.009*** | −0.016*** | −0.305*** | −0.009*** | −0.128*** | −0.009*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Litigation History | 0.073*** | 0.831*** | 0.036*** | 0.452*** | 0.049*** | 0.072*** | 0.832*** | 0.036*** | 0.451*** | 0.049*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Year-Quarter FE | Yes | Yes | | Yes | | Yes | Yes | | Yes | |
| Tech Field FE | Yes | Yes | | Yes | | Yes | Yes | | Yes | |
| $R^2$ | 0.070 | | | | | 0.072 | | | | |
| Adj. $R^2$ | 0.070 | | | | | 0.072 | | | | |
| McFadden Pseudo-$R^2$ | | 0.162 | | 0.158 | | | 0.163 | | 0.158 | |
| Num. obs. | 828780 | 828780 | | 828780 | | 828762 | 828762 | | 828762 | |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: P-values using robust standard errors are in parentheses. The table reports Linear, Logit, and Probit results on the relationship between the share of NPL citation of a patent and the likelihood of PAE acquisition. NPL citation is a proxy for the technological quality. Overall, NPL citation is positively related to the likelihood of a PAE acquisition.

### 3.6.2 Instrumental variable results on exclusion scope

Kuhn and Thompson (2019) propose using normalized number of words in the first independent claim of the patent as a measure of patent scope, with a longer claim meaning a narrower scope. Further, since the scope of the patent is influenced by patterns of patent examiners, they propose exploiting the random assignment of patent examiners[25] and using the toughness of patent examiners as an instrument of patent scope. The toughness of the examiner affects the scope of the patent, but does not affect PAEs' acquisition. Thus, below I employ their method and use 2SLS to test the curvilinear relationship between patent scope and the likelihood of PAE acquisition. Since both $Scope$ and $Scope^2$ are in the RHS of models, we use $Toughness$ and $Toughness^2$ as two instruments. Then I test for linear, Logit and Probit links in Stage 2. Results are reported in Table 3.7.

The negative coefficients on NWFC2, though only at level of 0.10, lends support to the quadratic relationship between PAE acquisition and patent scope hypothesized in Hypothesis 2. The linear term has very small coefficient and is insignificant across models, suggesting that the peak point of the parabolas is around zero. This indicates for patents with the length of first claim below mean, the likelihood of PAE acquisition increases with scope, while for patents with the length of first claim above mean, the likelihood of PAE acquisition decreases with scope.

### 3.6.3 Other measures of the exclusion scope

In this section, I use other Scope measures as a robustness checks for Hypothesis 2. Results are reported in Table 3.8. At first, in Model 1-3, I explore the role of Generality, which is the Herfindahl index of the diversity of forward citations a patent received within five years of the application (Squicciarini et al., 2013). $Generality$ has significant and positive coefficient while $Generality^2$ has a negative coefficient,

[25]Righi and Simcoe (2019) points out problems on the empirical assumptions regarding the assignment of examiners.

Table 3.7.: IV Regression of Patent Scope and PAE acquisition

| | Stage 1 | Stage 2 | | | | |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | | Model 4 | |
| | NWFC | LPM | Logit | Margins | Probit | Margins |
| Toughness | $-0.196^{***}$ | | | | | |
| | (0.000) | | | | | |
| $\text{Toughness}^2$ | $-0.001$ | | | | | |
| | (0.417) | | | | | |
| NWFC | | 0.007 | 0.056 | 0.003 | 0.031 | 0.004 |
| | | (0.357) | (0.665) | (0.676) | (0.625) | (0.636) |
| **$\text{NWFC}^2$** | | $-0.017$ | $-0.373^{+}$ | $-0.023^{+}$ | $-0.170^{+}$ | $-0.022^{+}$ |
| | | (0.130) | (0.069) | (0.073) | (0.082) | (0.085) |
| Tech Quality | $0.020^{***}$ | $-0.001$ | $-0.007$ | $-0.000$ | $-0.003$ | $-0.000$ |
| | (0.000) | (0.359) | (0.555) | (0.565) | (0.637) | (0.644) |
| Age | $0.009^{***}$ | $0.004^{***}$ | $0.060^{***}$ | $0.004^{***}$ | $0.030^{***}$ | $0.004^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Scope | $0.022^{*}$ | 0.002 | 0.043 | 0.003 | 0.022 | 0.003 |
| | (0.002) | (0.588) | (0.185) | (0.182) | (0.205) | (0.197) |
| $\text{Scope}^2$ | $-0.003$ | 0.001 | 0.002 | 0.000 | 0.001 | 0.000 |
| | (0.035) | (0.633) | (0.781) | (0.779) | (0.821) | (0.815) |
| Litigation History | $-0.050$ | $0.071^{***}$ | $0.722^{***}$ | $0.061^{***}$ | $0.373^{***}$ | $0.062^{***}$ |
| | (0.227) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| $R^2$ | 0.048 | 0.004 | | | | |
| Adj. $R^2$ | 0.048 | 0.004 | | | | |
| McFadden Pseudo-$R^2$ | | | 0.009 | | 0.009 | |
| Num. obs. | 145221 | 145221 | 145221 | | 145221 | |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: P-values computed using robust standard errors are in parentheses. The table reports 2SLS IV regression testing the quadratic relationship between patent scope and the likelihood of PAE acquisition. NWFC is the patent-level z-score from the distribution of the Number of Words in the First Claim for patents in each art unit. Following Kuhn and Thompson (2019), the higher the score, the shorter the first claim, and the broader the scope. The negative coefficients on $\text{NWFC}^2$ verifies the hypothesized quadratic relationship. The linear term has very small coefficient and is insignificant across models, suggesting that the peak point of the parabola is around zero. This indicates for patents with the length of first claim below mean, the likelihood of PAE acquisition increases with scope, while for patents with the length of first claim above mean, the likelihood of PAE acquisition decreases with scope.

confirming the quadratic relationship between the scope measure in terms of diversity of patent citation and the likelihood of PAE acquisition. The turning point is around 1.2, which is well within the limits of data. Patent scope not in logarithm is the second alternative measure of patent scope, reported in Model 4-6 of Table 3.8. The linear term is again positive and highly significant and the quadratic term is negative and significant across all models with control variables (Model 4-6), showing consistent results with the main analysis and lending support to the proposed inverted U-shaped relationship. The number of independent claims in a patent as another measure of the exclusion scope of patents and results are in Model 7-9. The inverted U-shaped relationship is also supported by signs of coefficients on the linear term $N.IndClaims$ and the quadratic term $N.IndClaims^2$. The turning point is around 5.6 -6.1, which is within the data region and is at around 86th-88th percentile. In addition, the slope when scope is at its minimum of 0.22 is positive and the slope when scope is at its maximum is negative. In sum, various other measures show additional evidence on the inverted U-shaped relationship between scope and PAE acquisition.

### 3.6.4 Invalidation risk, the case of software patents

In the main analysis, I exploit the fact that patents of different groups have different exposure level to the AIA changes, and also find that G06F and H04L are the leading patent subclasses in PTAB complaints. One important reason is that those subclasses contain a large proportion of the most controversial type of patents – software patents. The validity and patentability of software patents has been undergoing heated debate since their existence and especially recently as they became increasingly an issue in patent litigations. Thus, IPR and PGR do not affect all patents homogeneously, and I argue that software patents have much higher exposure to the impact of AIA. To identify software patents I use the method of Webb et al. (2018), which is a revised method used in Bessen and Hunt (2007).

Table 3.8.: Alternative Measures of Patent Scope

| | Model 1 LPM | Model 2 Logit | Model 3 Probit | Model 4 LPM | Model 5 Logit | Model 6 Probit | Model 7 LPM | Model 8 Logit | Model 9 Probit |
|---|---|---|---|---|---|---|---|---|---|
| Generality | $0.017^{***}$ | $0.350^{***}$ | $0.146^{***}$ | | | | | | |
| | (0.000) | (0.000) | (0.000) | | | | | | |
| Generality$^2$ | $-0.007^{***}$ | $-0.139^{***}$ | $-0.051^{***}$ | | | | | | |
| | (0.000) | (0.000) | (0.017) | | | | | | |
| Post*Generality | $-0.000$ | $-0.003$ | 0.027 | | | | | | |
| | (0.862) | (0.953) | (0.299) | | | | | | |
| Post*Generality$^2$ | $-0.002$ | $-0.046^{+}$ | $-0.030^{*}$ | | | | | | |
| | (0.271) | (0.074) | (0.016) | | | | | | |
| PS | | | | $0.014^{***}$ | $0.287^{***}$ | $0.130^{***}$ | | | |
| | | | | (0.000) | (0.000) | (0.000) | | | |
| PS$^2$ | | | | $-0.002^{***}$ | $-0.051^{***}$ | $-0.022^{***}$ | | | |
| | | | | (0.000) | (0.000) | (0.000) | | | |
| Post*PS | | | | $-0.004^{*}$ | $-0.114^{**}$ | $-0.043^{*}$ | | | |
| | | | | (0.041) | (0.085) | (0.187) | | | |
| Post*PS$^2$ | | | | $0.001^{***}$ | $0.026^{**}$ | $0.012^{**}$ | | | |
| | | | | (0.003) | (0.184) | (0.190) | | | |
| N Ind Claims | | | | | | | $0.250^{***}$ | $2.003^{***}$ | $1.165^{***}$ |
| | | | | | | | (0.000) | (0.000) | (0.000) |
| N Ind Claims$^2$ | | | | | | | $-0.063^{**}$ | $-0.437^{+}$ | $-0.303^{*}$ |
| | | | | | | | (0.005) | (0.011) | (0.002) |
| Post*N Ind Claims | | | | | | | $-0.323^{***}$ | $-2.053^{***}$ | $-1.185^{***}$ |
| | | | | | | | (0.000) | (0.000) | (0.000) |
| Post*N Ind Claims$^2$ | | | | | | | $0.312^{***}$ | $2.044^{*}$ | $1.220^{*}$ |
| | | | | | | | (0.000) | (0.009) | (0.004) |
| Post*Exposure | $-0.002^{***}$ | $-0.020^{***}$ | $-0.010^{***}$ | $-0.003^{***}$ | $-0.019^{***}$ | $-0.009^{***}$ | $-0.003^{***}$ | $-0.020^{***}$ | $-0.010^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Exposure | $0.001^{***}$ | $0.008^{***}$ | $0.006^{***}$ | $0.001^{***}$ | $0.006^{***}$ | $0.005^{***}$ | $0.001^{***}$ | $0.008^{***}$ | $0.006^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Post | $0.018^{***}$ | $0.214^{**}$ | $0.064^{+}$ | $0.010^{*}$ | $0.139^{*}$ | 0.026 | $0.017^{***}$ | $0.127^{+}$ | 0.040 |
| | (0.003) | (0.003) | (0.082) | (0.067) | (0.071) | (0.504) | (0.001) | (0.049) | (0.233) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Quarter FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Tech Field FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| $R^2$ | 0.071 | | | 0.072 | | | 0.072 | | |
| Adj. $R^2$ | 0.071 | | | 0.072 | | | 0.072 | | |
| McFadden Pseudo-$R^2$ | | 0.157 | 0.153 | | 0.162 | 0.158 | | 0.162 | 0.158 |
| Num. obs. | 742062 | 742062 | 742062 | 828762 | 828762 | 828762 | 828752 | 828752 | 828752 |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: P-values using robust standard errors are in parentheses. The table reports results from Linear, Logit, and Probit models using three alternative measures of patent scope. Model 1-3 use normalized generality score, Model 4-6 use unlogarithmized normalized Patent Scope, and Model 7-9 use the normalized number of independent claims. The inverted U-shaped relationship is supported in all measures by the positive and significant coefficients on the linear term and the negative and significant coefficients on the quadratic term. Number of Independent Claims are measured in thousands to amplify the coefficients for better presentation. Outliers patents with more than ten times of the mean were excluded. All models control for other patent variables, year quarter, and technology field fixed effects.

Among 6,366,664 patents that were granted until August 2017, I identified a total of 364,471 software patents, which is only 5.7% of all patents.[26] Software patents consist approximately 10% of all transactions. In addition, among all 7,322 PTAB complaints that were filed since the establishment of PTAB to August 2017, 1,491 of them are software patents, consisting 20.4% of all PTAB complaints. Setting software patents apart from other patents and arguing software patents are the most affected by the AIA is not to say that the AIA does not affect non-software patents. With the enactment of AIA, all patents are exposed to challenges from new outlets. But empirically, by employing a difference-in-difference specification, we shall observe the effect of the AIA to be much more prominent on software patents. Figure 3.10 plots the share of PAEs' acquisition for software and non-software patents. As shown in the figure, PAEs' acquisiton in both software and non-software patents are negatively affected. However, the effect is much larger for software patents.

I estimate the following equation using Software patents as the treated group:

$$\begin{aligned} y_{it} = \beta_0 + \beta_1 Software_i + \beta_2 Post_t + \beta_3 Alice_t + \beta_4 Software_i * Post_t \\ + \beta_5 Software_i * Alice_t + \beta_6 Controls_i + \epsilon_{it} \end{aligned} \tag{3.6}$$

Results of Linear, Logit, and Probit models are reported in Table 3.9. Coefficients of $Software * Post$ is highly significant (p-value=0.000) and negative across all models, showing the evidence that the AIA has deincentived PAEs from acquiring software patents. On average, after the enactment of the AIA, software patents are 1.2-5.1 percentage points less likely to be acquired by a PAE compared to other patents. Interestingly, Alice v. CLS Bank, which is widely acknowledged to have challenged the validity of software patents, seems to have no further impact to PAEs' acquisition of software patents. Figure 3.11 plot the dynamic coefficient of Software for

[26]The Webb et al. (2018) method for identifying software patents is more conservative than the method employed by Bessen and Hunt (2007). Using the method of Bessen and Hunt (2007), the number of identified software patents is about five times more than that identified by the method of Webb et al. (2018).

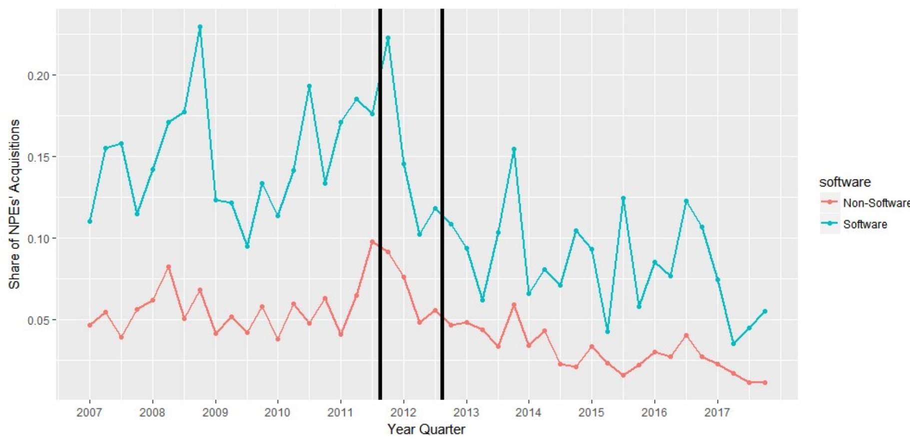



Figure 3.10.: PAEs' acquisition of Software Patents before and after AIA

Notes: (1) This figure plots PAEs' share in transactions for software and non-software patents for quarters from 2007 to 2017. (2) The two vertical lines mark 2011 Q4 and 2012 Q4 respectively, the time when the AIA was signed to bill and the time when the AIA statutes regarding patent challenges took effect. (3) PAEs consists 10% to 18% of all acquisition of software patents, while their shares for other patents were only between 4% to 10%. (4) Before the AIA, a parellel trend existed for PAEs' share in acquisitions of software and other patents, and their share in software was consistently higher. After the AIA, PAEs' share in software patent acquisition significantly dropped compared to non-software patents. (5) Transactions regarding mergers of firms and acquisitions of large patent portfolios with more than 50 patents in a single transaction are excluded. Data used to produce this graph contain 502,312 patent-level transactions.

each quarter. As can be seen, PAEs' acquisition of software patents started dropping before Alice during the period when AIA shows its effect.

Table 3.9.: Software patents and PAE acquisition

| | Model 1 | Model 2 | | Model 3 | |
|---|---|---|---|---|---|
| | LPM | Logit | Margins | Probit | Margins |
| **Software*Post** | $-0.051^{***}$ | $-0.531^{***}$ | $-0.012^{***}$ | $-0.277^{***}$ | $-0.016^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| **Software*Alice** | $0.004^{+}$ | $0.211^{***}$ | $0.007^{***}$ | $0.130^{***}$ | $0.011^{***}$ |
| | (0.144) | (0.000) | (0.000) | (0.000) | (0.000) |
| Software | $0.033^{***}$ | $0.210^{***}$ | $0.007^{***}$ | $0.130^{***}$ | $0.011^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| NPL Citations | $0.004^{***}$ | $0.062^{***}$ | $0.002^{***}$ | $0.047^{***}$ | $0.003^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Age | $0.004^{***}$ | $0.084^{***}$ | $0.002^{***}$ | $0.041^{***}$ | $0.003^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Scope | $0.037^{***}$ | $0.719^{***}$ | $0.021^{***}$ | $0.332^{***}$ | $0.024^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Scope | $-0.014^{***}$ | $-0.285^{***}$ | $-0.008^{***}$ | $-0.120^{***}$ | $-0.009^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Litigation History | $0.072^{***}$ | $0.824^{***}$ | $0.035^{***}$ | $0.448^{***}$ | $0.049^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Post | $-0.004$ | $-0.027$ | | $-0.040$ | |
| | (0.481) | (0.668) | | (0.217) | |
| Alice | $-0.050^{***}$ | $-1.819^{***}$ | | $-0.792^{***}$ | |
| | (0.000) | (0.000) | | (0.000) | |
| Year-Quarter FE | Yes | Yes | | Yes | |
| Tech Field FE | Yes | Yes | | Yes | |
| $R^2$ | 0.071 | | | | |
| Adj. $R^2$ | 0.071 | | | | |
| McFadden Pseudo-$R^2$ | | 0.162 | | 0.158 | |
| Num. obs. | 828780 | 828780 | | 828780 | |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: P-values computed from robust standard errors are in parentheses. This table reports Linear, Logit, and Probit results on the relationship between being Software patent and the likelihood of PAE acquisition following heightened invalidation risks following AIA and Alice v. CLS Bank. Software patents are identified using the algorithm provided in Webb et al. (2018) and is used as the group treated by law changes due to their high ambiguity in patentability and validity in the practice of law. While the expected negative sign appears for Software*Post, Software*Alice is unexpectedly positive.

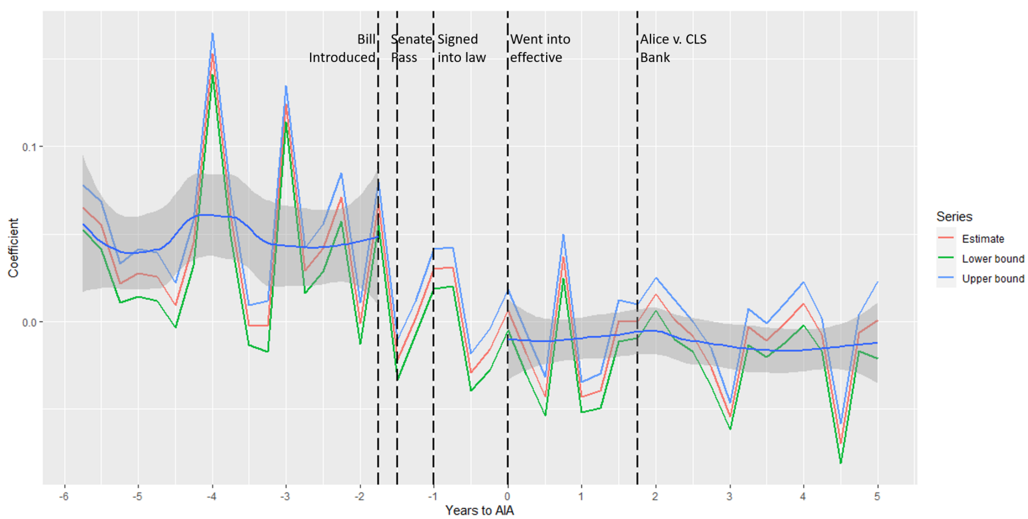



Figure 3.11.: Coefficient plot on Software Patents

Notes: Coefficients of Software*Quarter for each quarter, as well as upper and lower bounds of the 95%interval are plotted. This graph shows for the likelihood of a Software patent to be purchased by PAE in each quarter, as compared to a non-Software patent. The likelihood of PAE acquisition was positive prior to AIA, while became negative after AIA, indicating the heightened risk for invalidation makes the litigation-prone software patents less desirable for PAEs. Interestingly, Alice v. CLS Bank seems to have no further impact to PAEs' acquisition of software patents.

### 3.6.5 Intensive margin: Firm-level results on AIA and PAEs' acquisitions

As hypothesized, I argue that PAEs will acquire fewer patents due to the reduced litigating value of patents after the legal regime shift due to the AIA and use patent transaction-level data to test our hypothesis. To further validate our theoretical prediction that the PAEs will acquire fewer patents after the enactment of AIA, which represses PAEs' patent conventional monetization method, for firms with data availability, I aggregate their quarterly patent acquisitions and test the impact of the AIA on their patent acquisitions. Since most PAEs are small private firms, for which firm-level controls are lacking. But for public firms, I obtain their financial data from Compustat. Details regarding the firm-level data is given in Appendix B.3.6.

Table 3.10 gives results from OLS and Negative Binomial count models. As I can see, the strongly negative coefficient of $Post{*}TimeIndex$ suggests that after AIA, the increasing trend of listed PAEs' patent acquisition was stopped. Altogether, the analysis strongly supports Hypothesis 3 that after the AIA, the legal regime became less plaintiff friendly, which reduced the expected profitability of litigating monetization, resulting in PAEs significantly reducing their patent acquisition activity.

## 3.7 Additional Analysis

### 3.7.1 Family size, technological strength, and internationalization

The family size of a patent shows in how many jurisdictions' patent offices are the same invention protected (Lanjouw and Schankerman, 2001). Since filing for protection in multiple offices is costly and extra effort is usually needed to guarantee the quality of patent in different countries, a larger family size of the patent indicate a higher technological quality of the patents so that filing in multiple countries is worthwhile, at least from the inventor's perspective(Harhoff et al., 2003; Lanjouw and Schankerman, 2004; Squicciarini et al., 2013).[27] However, a larger size will not

[27] As a note on the limitation of using Citations as a measure of technological quality (Trajtenberg, 1990; Hall et al., 2005; Moser et al., 2018; Harhoff et al., 1999), Abrams et al. (2013) report that

Table 3.10.: Firm-Level PAEs' patent acquisitions

| | Model 1 OLS | Model 2 OLS | Model 3 NB | Model 4 NB |
|---|---|---|---|---|
| Post | 48.518 | 39.403 | 0.119 | 0.403 |
| | (0.263) | (0.392) | (0.562) | (0.053) |
| Time Index | 11.732 | 16.692 | $0.174^{***}$ | 0.091 |
| | (0.227) | (0.146) | (0.000) | (0.077) |
| Post*Time Index | $-22.882^{+}$ | $-27.823^{+}$ | $-0.504^{***}$ | $-0.410^{***}$ |
| | (0.092) | (0.067) | (0.000) | (0.000) |
| Net Income | | 0.153 | | 0.000 |
| | | (0.706) | | (0.848) |
| Current Assets | | 0.029 | | $0.001^{*}$ |
| | | (0.811) | | (0.034) |
| Total Assets | | −0.028 | | −0.000 |
| | | (0.613) | | (0.098) |
| Cash | | −0.113 | | $0.002^{**}$ |
| | | (0.546) | | (0.007) |
| Year-Quarter FE | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| $R^2$ | 0.017 | 0.017 | | |
| Adj. $R^2$ | −0.015 | −0.024 | | |
| Num. obs. | 520 | 492 | 520 | 492 |
| Log-Likelihood | | | −1655.041 | −1558.836 |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: P-values are in parentheses. As extra evidence for the negative impact of law changes following AIA, the table reports OLS and Negative Binomial regression results on the effect of the AIA on PAEs' firm-level patent acquisitions. The dependent variable is the number of patents a firm acquired in a quarter. Results of OLS and Negative Binomial count models are reported. In general, we observe a strong negative shift in public PAEs' patent acquisition after AIA, as shown by the sign of the interaction term of (Post*Time Index).

make a patent more profitable for litigating monetization, unless the PAE initiate lawsuits internationally.[28] Unlike PEs which can appropriate monopolistic value in internationally given legitimate patent rights (Harhoff et al., 2003; Lanjouw et al., 1998), PAEs' businesses are mostly domestic. Because the implementation of litigating monetization is highly dependent on a country's legal regime and most PAEs' businesses are primarily concentrated in the United States, so whether the patent is protected in other countries does not matter much for the value appropriation in U.S. courts.

Results using family size are reported in Table 3.11. The claim above suggests a negative and significant coefficient for $FamilySize$, which is found in Model 4-6. But, one interesting finding is that although $FamilySize$ is negative, the negative relationship between Family Size and PAE acquisition is almost neutralized during post-AIA periods. There are two potential explanations to this finding. The first is that after the AIA enactment, PAEs start to acquire patents with higher technological quality, which is claimed in the main analysis. The second possibility is that due to the less friendly institution in the United States, PAEs start to expand their activities to other countries. Regarding the international activities of PAEs, Thumm (2018) has documented the recent international expansion of PAEs to Europe.

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patents that generate medium value receive more forward citations than patents of either high or low value. Given that patent citations can be added by either the inventor or the examiner and represent the existing knowledge that the citing patent does not claim property rights on (Alcácer and Gittelman, 2006; Hall et al., 2005). So a higher citation can also be interpreted as the patent has claimed a wide scope so that many following patents have to cite it to acknowledge its boundary of property rights.

[28]As a matter of fact, protecting the invention in a greater geographical scope gives a patent owner the right to exclude rivals in more regions. But such exclusion scope is different from the exclusion scope that is discussed in this paper. With litigating monetization primarily jurisdiction-specific, protecting the patent in other countries does not directly lead to increased litigating value in the focal country. Instead, a large family size should demonstrate its high practicing value (Dechezleprêtre et al., 2017; Kabore and Park, 2019; Deng, 2007) due to high technological quality. However, when litigating monetization is international, greater family size does directly lead to higher litigating value.

Table 3.11.: Patent Family Size and the likelihood of PAE acquisition

| | Model 1 | Model 2 | | Model 3 | | Model 4 | Model 5 | | Model 6 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LPM | Logit | Margins | Probit | Margins | LPM | Logit | Margins | Probit | Margins |
| Family Size | 0.002*** | 0.022*** | 0.001*** | 0.008** | 0.001** | −0.008*** | −0.162*** | −0.005*** | −0.080*** | −0.006*** |
| | (0.000) | (0.000) | (0.000) | (0.002) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Family Size*Post | | | | | | 0.008*** | 0.153*** | 0.004*** | 0.076*** | 0.006*** |
| | | | | | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Family Size*Exposure | | | | | | 0.001*** | 0.012*** | 0.000*** | 0.006*** | 0.000*** |
| | | | | | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Family Size*Post*Exposure | | | | | | −0.000* | −0.002 | −0.000 | −0.001 | −0.000 |
| | | | | | | (0.083) | (0.103) | (0.106) | (0.331) | (0.332) |
| Post*Exposure | | | | | | −0.002*** | −0.017*** | −0.000*** | −0.009*** | −0.001*** |
| | | | | | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Post | | | | | | −0.001 | −0.106 | −0.003 | −0.082* | −0.006* |
| | | | | | | (0.906) | (0.110) | (0.114) | (0.016) | (0.019) |
| Exposure | | | | | | 0.000*** | −0.007*** | −0.000*** | −0.002* | −0.000* |
| | | | | | | (0.000) | (0.000) | (0.000) | (0.033) | (0.027) |
| Controls | Yes | Yes | | Yes | | Yes | Yes | | Yes | |
| Year-Quarter FE | Yes | Yes | | Yes | | Yes | Yes | | Yes | |
| Tech Field FE | Yes | Yes | | Yes | | Yes | Yes | | Yes | |
| $R^2$ | 0.071 | | | | | 0.073 | | | | |
| Adj. $R^2$ | 0.070 | | | | | 0.072 | | | | |
| McFadden Pseudo-$R^2$ | | 0.162 | | 0.158 | | | 0.164 | | 0.160 | |
| Num. obs. | 828780 | 828780 | | 828780 | | 828762 | 828762 | | 828762 | |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: P-values using robust standard errors are in parentheses. The table reports Linear, Logit, and Probit results on the relationship between the family size of the patent and the likelihood of PAE acquisition. Family size is a proxy for the technological strength of the patent. Overall, family size is positively related to the likelihood of a PAE as the buyer. However, a closer look reveals that before AIA, the relationship between was negative, but turned positive for later years in the sample. The positive relationship later on is probably due to the internalization of PAEs activities, which lead them to purchase patents protected in other countries. All models include litigation history, year quarter and technology field fixed effects.

### 3.7.2 Litigation history as a signal of litigating value

Litigation history is a control variable in all regressions, and it shows highly significant relationship with PAE acquisition. This is because litigation history is a direct signal of a patent's litigating value. Had a patent been involved in patent litigations, it indicate the patent has a high litigating value and the theory predicts that the patent will be more likely to be purchased by a PAE. For PEs, a patent involved in litigations may discourage acquisition. But when PAEs select patents to acquire, the ones that already have a history demonstrate their potential to initiate future patents. Figure 3.12 shows that PAEs' share in transactions of patents with litigation history is much higher than its share in transactions of patents without litigation history. Also, after the enactment of AIA, PAEs' share in transactions of litigated patents went higher, while its share in transactions of other patents went down.

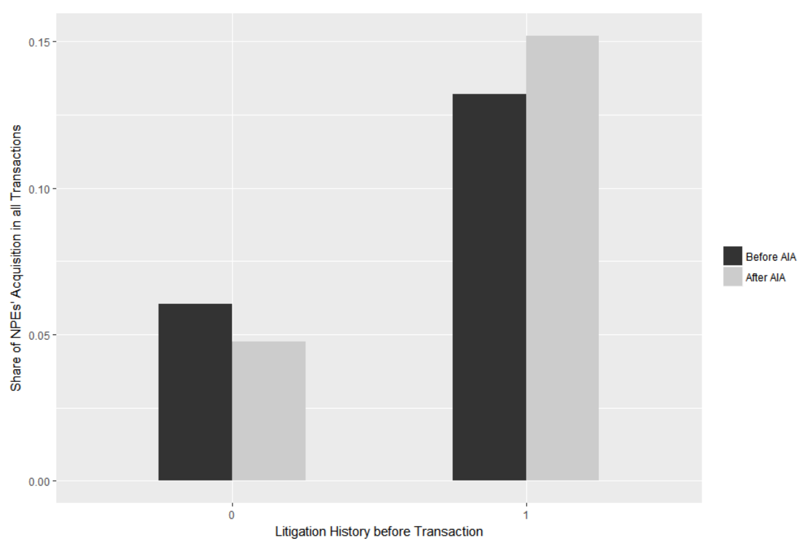


Figure 3.12.: Litigation History and PAE acquisition before and after AIA

Notes: This graph visualizes PAEs' disproportional interest in acquiring patents with a history of lawsuits, and the strengthened interests after AIA. PAEs' share in transactions for patents with litigation history is around 13%-15%, while their share in transactions for patents without litigation history is only around 5%. After AIA, PAEs' acquisition of litigated patents went up from 13.2% to 15.2%, while their share in transactions of never-litigated patents went down from 6.0% to 4.8%.

### 3.7.3 Litigation following PAE acquisition

I have argued that PAEs' patent monetization rely on patent litigations so that PAEs will purchase patents that have the potential to win lawsuits for them. To validate this assumption, we should observe a strong association between an acquisition made by a PAE and the likelihood the the patent being litigated in the future. We look at patents that were not litigated before transaction and examine how being purchased by a PAE relate to the patent's chance of appearing at patent court later on. Therefore, I change the dependent variable of models to the likelihood of litigation for a patent, and limit our sample only to patents with no prior litigations history. Our dependent variable is $LitFuture$ which is a binary variable that equals 1 if a patent were litigated after the transaction and 0 otherwise.

Table 3.12 reports results from linear, Logit, and Probit models on the likelihood of litigation after transaction. The coefficient of PAE Buyer is highly significant and positive in all models. On average, a patent purchased by PAE is 3.7-5.5 percentage points more likely to be litigated in the future, or 4.3 ($e^{1.457}$) times more likely to be litigated compared to a patent being purchased by an PE. After the AIA, with monetization method being discouraged, the association between PAE acquisition and litigation even strengthened, patents that acquired by PAEs are 8.5 percentage points higher, or 11.1 times ($e^{1.457+0.952}$) more likely to be litigated in the future. Taking evidence together, PAEs' patent acquisition became more parsimonious after the regime change, but PAEs also became more aggressive in actively monetizing the acquired assets.

## 3.8 Caveats and Boundary Conditions

First, for firms that intends to practice the technology, it is not necessary to acquire the patent. Instead, obtaining a license (exclusive or non-exclusive) of the patent shall be sufficient for practicing the technology. Thus, the data on patent acquisition of firms do not fully reflect firms' sourcing of external technologies and we do not intend

Table 3.12.: PAE acquisition and subsequent patent litigation

| | Model 1 | Model 2 | | Model 3 | |
|---|---|---|---|---|---|
| | LPM | Logit | Margins | Probit | Margins |
| PAE Buyer | $0.055^{***}$ | $1.457^{***}$ | $0.037^{***}$ | $0.643^{***}$ | $0.041^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| PAE Buyer*Post | $0.030^{***}$ | $0.952^{***}$ | $0.019^{***}$ | $0.388^{***}$ | $0.020^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Controls | Yes | Yes | | Yes | |
| Year-Quarter FE | Yes | Yes | | Yes | |
| Tech Subclass FE | Yes | Yes | | Yes | |
| $R^2$ | 0.020 | | | | |
| Adj. $R^2$ | 0.020 | | | | |
| McFadden Pseudo-$R^2$ | | 0.073 | | 0.072 | |
| Num. obs. | 820798 | 820798 | | 820798 | |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: P-values using robust standard errors are in parentheses. The table reports Linear, Logit, and Probit results on the association between PAE acquisition and the likelihood that future litigations. The sample contains all patent transacted from 2007-2017 but had no litigation history priot to transaction. Results show significant positive association between PAE acquisition and future litigation. On average, a patent purchased by a PAE is 4.3 ($e^{1.457}$) times more likely, or 3.7-5.5 percentage points higher, to be litigated compared to a patent purchased by an PE. The association is strengthened after the enactment of AIA, with patents that acquired by PAEs are 11.1 times ($e^{1.457+0.952}$) more likely, or 5.6-8.5 percentage point higher to be litigated. The results suggest the reliance on PAEs' business model on litigation and also the increased litigation intensity of acquired patents following law changes. Patent-level controls, year-quarter and technology area fixed-effects are included.

to. Since one of the key arguments of the paper is the different ways to appropriate the exclusionary strength of patents, non-exclusive licensing agreements fall outside of our research focus since a holder of non-exclusive licensing agreement cannot enforce the exclusion rights of patents. In addition, if a practicing firm owns an exclusive license, it reveals the firm's intention to appropriate value from exclusion by ruling out potential competitors. Since the firm is interested in both the technology and exclusion, it is often the negotiation with the selling party that determine whether the form of contract is either acquisition or exclusive licensing. Therefore, patents that firms obtained exclusive licenses shall not exhibit drastically distinctive characteristics compared to ones that firms acquired in the end. Thus, omission of exclusive licensing shall not add severe challenges to results in the paper. [29]

Second, regarding results on the impact institutional changes after AIA, it worth clarifying potential confounding factors. One such factor is the Supreme Court ruling *Bilski v. Kappos* case in June 2010 that sparked debates among law practitioners on patentability of software patents. This case clarified what kind of software methods are valid for patenting by redefining the "machine or transformation test," which basically tells that "a process is patentable if it is tied to a particular machine or it transforms a particular article into a different state or thing."[30] However, the *Bilski v. Kappos* is not likely to affect the patent acquisition of PAEs since it neither changed the odds of the defendant to win (unlike the enactment of AIA), nor clarified the patentability of business methods or software. Therefore, for PAEs, the invalidation risk and the value from litigating monetization of patents did not change. Figure 3.5 show the peak of PAE lawsuits and patent acquisitions arrived after *Bilski v. Kappos*.

Third, evidence suggests that AIA was anticipated to pass when it was introduced to the Congress again in 2011, after years of debate and failed bills. As PAEs are mostly law experts, it is highly likely that the expectation of the passage of the AIA

[29]However, firms may prefer acquisition to exclusive licensing to 1) limit future cash outflow to the patent owner, 2) eliminate uncertainties and potential disputes regarding the incomplete licensing contract, especially on clauses such as sublicensing and calculation of licensing fee, and 3) to retain the flexibility to sell or abandon the patent when the technology is no longer valuable to the firm.

[30]Source: https://www.law.com/insidecounsel/almID/4dcafbe1160ba0ad57002df0/?slreturn=20190617003230

and following changes to the patent law may arrive, before the actual enactment of AIA. Such anticipation may lead to PAEs early shift in patent acquisition, which may dampen our empirical results. So, our results is only a conservative measure of the impact of the Act.

Regarding boundary conditions, first, though I use a simple mapping of PEs to practicing monetization and PAEs to litigating monetization, firms may use a hybrid of two monetization methods. I use a strict definition of PAEs to refer to firms that has no stake in the product market, but many PEs, especially ones that hold large patent portfolios, also often have behaviors similar to those of PAEs. For example, the semiconductor giant Qualcomm has been reportedly using its troll-like strategy to "*impose unfair licensing terms on customers and drive out competing manufacturers.*"[31] In such cases, the litigating monetization may be used by firms with significant stake in the product market to strengthen their market power and to restraint rivalry. This hybrid business model is beyond the scope of this paper, our findings shed lights on what type of patents may be suited for litigating monetization by PEs.

In the aforementioned example, the outcome of Qualcomm's troll-like behavior, and of most litigating monetization, is licensing payments. Licensing, though is not explicitly discussed in the paper, its pricing can be explained by the value appropriation mechanisms behind. PAEs will price the licensing based on the litigating value of the patent while PEs will price the licensing based on the practicing value of the patent. Understandably, firms can apply both monetization logics together when negotiating the licensing payment and choose the higher to maximize value appropriation.

[31] But this practice causes controversies, Qualcomm was accused for "unfair" licensing terms. Source: Steven Titch, 2017, Forbes. Web: https://www.forbes.com/sites/realspin/2017/04/28/qualcomms-patent-trolling-habits-come-home-to-roost.

## 3.9 Concluding Remarks

This paper explore the litigating monetization of patents and how the implications in the market for technology. Firms' valuations of patents are revealed in their patent acquisitions, which are factor market behavior from which firms expect to create rents (Makadok, 2001; Barney, 1986). In this study, I present a theoretical perspective and empirical findings towards a broader understanding of monetizing patents, and provide insights explaining PAEs' patents acquisitions in the market for technology. Using patent transaction and litigation data and exploiting the enactment of the AIA, I find support for all hypotheses. Empirical evidence suggests that patents with good but old technologies are more likely to be acquired by PAEs. Second, there is an inverted U-shaped relationship between patents' exclusion scope and the likelihood of being purchased by PAEs. Third, I find evidence supporting that the heightened invalidation risk reduced PAEs' patent acquisition.

Scholars of the market for technology have invested significant effort discussing roles of different players during technology commercialization (Gans et al., 2008; Gans and Stern, 2003; Arora and Gambardella, 2010) and uncertainties (Gans et al., 2008; Hegde and Luo, 2017). Recently, the much neglected litigating monetization of patents and its implication on firms and innovation have received extensive attention (Cohen et al., 2020; Abrams et al., 2019), however its behavior in the market for technology is much less explored, this study contributes to the literature on by studying PAEs position in patent acquisitions and how they respond to invalidation risks.

This study also contributes to the general strategy literature. Strategic factor market (SFM) lies at the center of the theory of competitive advantage (Makadok and Barney, 2001). Firms that compete in the same SFM for the resources often have distinct business models (Schmidt and Keil, 2013). However, few studies have explored the implications of different business models for the SFM. Using a patent context, this study investigates how firms with distinct business models monetizing patents show different patterns in the factor market. Specifically, PAEs, with no stake in the product markets and expertise in litigating monetization, have different preferences for patents as compared to PEs. Besides, by comparing the two value appropriation mechanisms, this study also speaks to the growing literature of competing business models in the strategy (Casadesus-Masanell and Zhu, 2010, 2013).

The study has some limitations. First, we use a dichotomy of practicing and litigating monetization, but there are also other business models that are variants or hybrid of the two stylized models. Second, the USPTO patent transaction data is self-reported, though the reported patent transactions are sufficiently complete and representative (Marco et al., 2015) so that there should not be significant caveats regarding the selectivity issue. Third, though patent litigations play a vital role in patent assertion and litigating monetization, most patent assertions are settled even before the judicial filing of the case to the court (Hall, 2019). So the observable litigations may only be the tip of an iceberg (Lemley et al., 2019), and the number of patents used for litigating monetization may be much higher though the proportion of litigated patents is small. Fourth, due to the lack of financial information on the transactions, a direct measure of the litigating and practicing value of patents is lacking.

This paper suggests several avenues for future research. First, scholars can continue to study what are the consequences of PAEs' activities on threatened practicing firms. In terms of competitive strategy, will firms try lobbying to weaken the competitive advantage of the patent owners (Capron and Chatain, 2008) or will they learn to take advantage of the legal system and to assert patent rights against their rivals? As for innovation strategy, will firms change their directions of innovation and reduce their investment in the areas with PAE activities or will firms file patents that have high litigating value but low practicing value to exploit the litigating monetization? With PAEs' disproportional attention on software patents, the passing of AIA, and the emerging of open source software, what will be the impact on the rate and direction of the software innovations?

Second, while studies have looked at PAEs' direct impact on firms that are at the demand side of technologies, few have studied their impacts on inventors that are the supply side of technologies. One exception is is Chari et al. (2015) that found for individual inventors, small firms, and research institutions, the intermediation of PAEs increases their patent output, but at the expense of patent quality. The inventor, especially small firms and individuals, are often deterred from practicing the patent due to the lack of complementary assets (Arora and Gambardella, 2010). By enforcing patent rights, PAEs can incentivize inventors to conduct more innovation. However, there is also evidence that patents are roadblocks, and the invalidation of patents facilitate cumulative innovation (Galasso and Schankerman, 2015). It is yet to be examined how do PAEs change the incentive of innovation for different market players.

# CHAPTER 4 HOW DOES PATENT LITIGATION AFFECT ENTREPRENEURIAL VENTURE FINANCING?

## 4.1 Introduction

Financial constraint has been one of the most critical issues for entrepreneurial firms, and securing financial resources has been a vital task for startups' performance (Kerr and Nanda, 2011, 2015; Hall and Lerner, 2010). Extant studies of entrepreneurial finance have extensively studied how venture capitals (VC) influence startups' development, and the function of VC financing to startups is well-documented. VC financing helps entrepreneurial firms access complementary resources of other firms (Kortum and Lerner, 2000; Cumming, 2008; Blevins and Ragozzino, 2018; Dushnitsky and Shaver, 2009). From the perspective of startups, studies in entrepreneurship have examined how startups' value-creating activities build up their financial and human resources, technological capabilities, and complementary assets (Lerner, 2002; Serrano and Ziedonis, 2018; Barney, 2018). However, few studies have examined challenges for entrepreneurial firms that may destroy value and capabilities. Among such factors that affect performance, litigations have been one of the vital yet much neglected. Unlike other factors like financial and technological resources that startups constantly pay attention to, startups pay little attention to legal issues until when being hurt by lawsuits. Such events may bring astounding loss to firms and put the survival of entrepreneurial firms at risk (Chien, 2013). Existing literature have paid some attention to patent litigations (La Porta et al., 1997; Bessen and Hunt, 2007; Shane and Somaya, 2007). However, studies have mostly focused on the direct cost of litigation, while much neglected is the hidden cost of patent litigation. In addition to legal costs, damages, and settlement fees, patent litigation may change external stakeholders' views on the startup (Barney, 2018). One of the central questions to be answered is how will litigations affect entrepreneurial firms' external financing.

For entrepreneurial firms, patents and the enforcement of patent rights have been critical parts to maintain their incentive for innovation. However, the dark side of patent rights will reveal itself when firms are sued for infringing others' patents and showed up at court as the defendant. Given information asymmetry between new ventures and venture capitals, patents play a signaling role to demonstrate the venture's quality (Hsu and Ziedonis, 2013), though the signaling function diminishes as the information asymmetry reduces (Hoenen et al., 2014). Uncertainties surrounding litigations may cause a delay in VC investment (Cockburn and MacGarvie, 2009).

Both the patent application and examination processes generate information on the quality of new ventures that informs VCs (Haeussler et al., 2014). Studies have shown that while some degree of patent litigation activities is positively related to VC investment, excessive litigations dampen VC financing (Kiebzak et al., 2016). Knowing that patent litigation is a time- and resource-consuming task that distracts the limited resources of firms and impedes subsequent innovation (Mezzanotti, 2017), VCs, as maximizers of their interest, will have to be more cautious evaluating the future value of these defendant firms and figuring out whether what is behind the litigation is a hoax like the ex-Theranos CEO Holmes or just a smoke bomb slander from a competitor.

The stake of litigations is substantial: even without finding actual infringement, defendants often suffer from reputation discounts (Tan, 2016) and reduced innovation(**?**). In light of these negative impacts, as well as the ambiguity of defining the boundary of patents and infringement, patent litigation has emerged to be a non-market strategy that firms use to suppress competitors. Such reputation impact and publicity of patent litigations imply that patent litigations are able to change the attitude of external stakeholders, such as VC investors that already confront significant information asymmetry, drastically.

Given the theoretical significance and managerial relevance of VC financing and patent litigations, this paper is intended to fill in the gap in the literature by examining how do patent litigations affect VC financing to entrepreneurial firms and shed light on the mechanism through which the effect takes place. To investigate this question, we construct a novel dataset linking patent litigations to VC-backed firms. Using a carefully-matched sample, and exploiting variation in legal practices among regions, our analyses show that patent litigations negatively affect firms' probability of receiving follow-on VC investment and the amount of investment received. In addition, we find that heterogeneity in firms and plaintiffs affects the magnitude of such unfavorable impacts in that the litigation is less detrimental to startups if the startup possesses other quality signals and if the plaintiff's threat is weaker.

This paper makes several contributions. First, while most studies in entrepreneurship focus on how startups obtain resources and capabilities to build competitive advantages, few have examined potential caveats that can potentially ruin startups' effort. Adverse events, such as patent litigations, that can bring detrimental consequences to startups has received little attention among scholars. Second, this paper extends the theory of signaling and examines when the signal is negative due to an external agent, how the signal will affect audiences and what factors moderate the strength of such signals. Third, this is the first paper that examines the impact of patent litigation on startups' VC financing. Though past studies have examined multiple factors that affect entrepreneurial firms' VC financing (Hsu and Ziedonis, 2013), little attention has been given to the effect of patent litigations. It is well noted that investors have been sensitive to the legal environment (La Porta et al., 1997, 2000), but to what extent will VCs perception change after a firm is involved in patent lawsuits is still mostly unknown. Fourth, we contribute to the literature on litigations by deepening our knowledge on how heterogeneity among defendants and plaintiffs affects the consequences of litigations. Along this line, we add to the current discussion surrounding patent assertion entities (PAEs) when we further unveil heterogeneity among plaintiffs. We show that lawsuits initiated by PAEs, with their only interest in claiming monetary settlement fees, though notorious for frivolous lawsuits, are less detrimental to startup's financing as compared to lawsuits initiated by other plaintiffs.

## 4.2 Theory and Hypotheses

### 4.2.1 Patent litigation, Signaling, and Entrepreneurial Financing

In this section, we draw from information economics and argue that being sued is a negative signal to investors so that VCs will devalue the future profitability of the startup, resulting in negative consequences to the startups' achievements of obtaining external financing.

External financing plays a critical role in entrepreneurial firms' development. Entrepreneurial firms, though very often suffer from information asymmetry, try to signal to investors their quality. For entrepreneurial firms, one crucial signal they may send is the patents they own (Hsu and Ziedonis, 2013). Producing patents is a costly action that signals potential investors the technological capability and potential of the firm. In addition to the positive signals firms may send to VCs, there are also negative signals that firms may unintentionally send to investors. One of such signals is being involved in patent litigations. Knowing that VCs are also firms which seek to gain profit, while investing their limited resource in a firm, they expect the firm to be profitable in the future to recover their investment. As external stakeholders, patent conflicts raise investors' suspicion of the profitability of the firm, which shall negatively affect the likelihood of future investment in the focal entrepreneurial firm (Bessen and Meurer, 2012). Thus, a negative impact on the firm's future profitability will discourage investors from investing in the firm. Even when the case finally settles, possible reputation damage and subsequent licensing payments are additional costs to the firm (Lemus and Temnyalov, 2017; Meurer, 1989).

Patent litigations are referred to as the "Sport of Kings" (Kline, 2004). Patent litigations bring significant costs in forms of attorney fees and other legal fees up to millions of dollars to firms and consume lots of resources of firms. It is very often for patent litigations to take years to resolve (Bessen and Meurer, 2013). Instead, resources spent on patent litigation could have been used for developing a product or other activities related to the business. The empirical literature has shown that the results of such resource diversion can be the reduced function of patents as incentives for innovation (Lanjouw and Schankerman, 2001), which leads to reduced investment in R&D (Mezzanotti, 2017). In the long run, such underinvestment will negatively affect firms' future performance and social welfare (Jones and Williams, 1998).

Patent litigations are mostly initiated from strategic purposes by firms who seek to protect their product market profit or expand their market share, or by entities that merely seek to appropriate value from patent litigations (Hagiu and Yoffie, 2013). Either case, however, will translate to a significant cost on the part of the defendant. The plaintiff can be a competitor who initiates litigations as part of their competitive strategy against rivals (Agarwal et al., 2009). Studies have shown that, especially for large firms, filing patents have their value in establishing a legal fence that protects firms' focal technology while retaining the option to attach and disrupt competitors' technology and operation, resulting in the so-called patent thicket (Cohen et al., 2000; Paik and Zhu, 2016). In such scenarios, once a party initiates patent litigation, the other party can make use of its patent stock to start a counterclaim and fight back. The result is often a litigation war that lasts several years in different courts with different patents involved. Though the legal and non-legal cost is high, such cost is often unavoidable, since the plaintiff rival firm, would often seek for the injunction of the product to achieve competitive objectives in the product market that is hard to achieve through market strategies. Therefore, when a startup becomes the target of the non-market strategy of litigation, without deep technology pocket to fight back and related legal and financial resources, the startup may be severely disrupted, either resulting spending tremendous amount of time and money in settling the case, or even worse, has to respond by abstaining certain product and reorienting technological developments. Litigations as signals raise investors' expectations of the occurrence of such events, which negatively affect their likelihood to invest in focal litigated startups. Thus, we hypothesize:

**Hypothesis 1a.** *Being litigated in patent lawsuits will negatively affect firms' likelihood of receiving venture capital financing.*

**Hypothesis 1b.** *Being litigated in patent lawsuits will negatively affect the amount of venture capital financing that firms receive .*

### 4.2.2 Heterogeneity among startups: Alternative Quality Signals

While we discussed the main effect of being sued for patent infringement, the effect differs among the sued startups. Regarding the heterogeneity among startups, since being sued is a negative signal to potential investors, we argue that possession of other positive quality signals shall mitigate the negative impact of being sued. At first, the number of quality signals shall be positively related to the age of the firm, and when a firm is young, it has less information available to investors, thus being sued shall significantly change investors' attitude on the startup. However, for an entrepreneurial firm that is several years in the market, its information will be much more available to investors so that being sued is less a significant piece of information regarding its quality.

Having more quality signals reduces the severity of being litigated. Besides, younger firms are more vulnerable to negative consequences of patent litigations as well so that investors have reason to believe that litigation may more significantly impact the future profitability of the younger startup. It is known that young and small firms are usually more vulnerable in the face of external shocks (Freeman et al., 1983). Empirical studies on patent litigations have shown the detrimental effect of litigation to small firms (Appel et al., 2020; Chien, 2013; Smeets, 2014), through mechanisms of reduced VC investment and reduced innovation activities.

Compared to established firms, younger entrepreneurial firms are less experienced in handling patent litigations. Younger entrepreneurial firms, when facing litigations, suffer from the "liability of newness" (Bruderl and Schussler, 1990; Freeman et al., 1983). Thus, these startups have to initially spend time and money learning the information and knowledge about patent litigations. The treated firms in our sample, being a defendant only once, are mostly never exposed to the realm of patent litigations since they are also inexperienced in initiating litigations. If the firm chooses to settle but not fight, then it is likely that next time other plaintiffs will claim infringement using other patents. Thus, the inexperienced firm needs to learn how to formulate and implement their legal strategy, which is a procedure that more time and energy needs to be spent on, such that the effort that the firm can make in other fronts will reduce, subsequently negatively affecting the firm's chance of getting VC financing.

Then, even after getting acquainted with patent litigations, compared to established firms, younger firms have fewer resources to exploit to win a lawsuit. Unlike established firms that often employ their own legal team, younger firms have to be parsimonious and hire external lawyers to handle the lawsuit. During the process, the litigation will consume a lot of time and energy of the top managers in startups, which is a wasteful and unproductive way of allocating the precious human capital of top managers (Somaya, 2003). Though VC's involvement is vital to startup performance (Fitza et al., 2009), when the resource is limited, the startup firm may have to prioritize the litigations over other investment opportunities. The result is a combination of substitution and income effect that exhaust firm resources and impoverishes the young firm.

Second, a more direct quality signal entrepreneurial firms have is the number of previous rounds of investments it has successfully obtained. Endorsement by more investors shall signal to future investors the potential of the startup, and thus making being sued a less negative sign. In addition, from investors' perspective, having more previous rounds of investments means the startup has more resources to spare to defend itself from the consequences of the litigation. Furthermore, the additional investors in those rounds of investment can all lend resources to the startup to better handle the litigation, because of their own stake in the startup. The number of rounds of investment a firm received will affect venture capitalists' evaluation of the firm and thus affecting their investing decisions. A firm that already has a couple of investors, especially prominent investors, may look more attractive to future investors (Hellmann and Puri, 2002; Hsu, 2004; Kortum and Lerner, 2000).

Thus, we hypothesize:

**Hypothesis 2a.** *The negative effect of being litigated on the likelihood of receiving VC financing is smaller for firms with more substitute quality signals.*

**Hypothesis 2b.** *The negative effect of being litigated on the amount of VC financing is smaller for firms with more substitute quality signals.*

### 4.2.3 Heterogeneity among plaintiffs: Being sued by PAEs

We have argued how the characteristics of the defendant startup may moderate the strength of the negative signal of being sued, but not less important is the characteristics of the plaintiff. Among patent litigations, one of the most significant differences among plaintiffs is whether the plaintiff is a PAE (Patent Assertion Entity). A PAE, sometimes also called as NPE (Non-Practicing Entities) or patent trolls, are not competitors of startups. The business model of PAEs is to litigate or threat to litigate firms seeking for monetary settlement payments (Xu and Makadok, 2019). If being sued by a PAE, then the cost is mostly settlement fees of a certain amount, without further risking product market profit and the validity of the technology of the focal firm.

If the plaintiff is a PAE, which is a firm that does not seek to practice the patent but is trying to use the patent to assert patents rights and litigate, current literature has documented negative impacts of PAE litigations (Appel et al., 2020; Cohen et al., 2016), though a few studies also argue that PAEs can create value by improving the efficiency in the patent market (McDonough III, 2006). In our case, when the plaintiff is a PAE, due to their experience in patent litigations, PAEs can easily increase the defendants' cost to fight a case if these firms refuse to settle with the PAE and pay upfront. When the plaintiff makes strategic moves regarding how and when to finalize the patent litigation (Somaya, 2003), usually the defendant firm has no other choice but to compromise and settle (or incurring the high cost of defending its patent rights). Since PAEs are good at picking patents that are relatively broad, ambiguous, and litigation-prone, lots of firms are subject to the threatening of PAEs (Abrams et al., 2019).

To the extent that the venture capitalists are discouraged regardless of whether the plaintiff is a PE or a PAE, other things equal, investors may be hesitant in investing in firms that were involved as defendants of patent litigations and they may devalue these firms. Thus, litigations initiated by PAEs shall post smaller threats to the startup's future product market profits compared to litigations initiated by rivals. In the eyes of investors, being sued by a PAE is a less negative signal as compared to being sued by a practicing entity or a rival, whose intention for litigation may be beyond trolling. So we hypothesize:

**Hypothesis 3a.** *The negative effect of being litigated on the likelihood of receiving VC financing is smaller for startups sued by PAEs.*

**Hypothesis 3b.** *The negative effect of being litigated on the amount of VC financing is smaller for startups sued by PAEs.*

## 4.3 Empirical Strategy

### 4.3.1 Data and Sample Construction

We test our hypotheses using data on firms that were defendants of patent litigations in any of the ninety-one regional Federal district courts during the eighteen years from 2000 to 2019 using database provided by LexMachina. Then, to examine their receiving of venture financing, we obtain complete VC/PE investment data from 1995 to 2019 from VentureXpert database provided by ThomsonONE. From both databases, we retrieve firms' names and manually did a cleaning of firm names to match the two databases. Among the 130k+ firms that received venture financing, we found that there were around five thousand firms that were sued in patent litigations for at least once. Among those investee defendants, there are approximately 2,300 firms that were the defendant of only one lawsuit. It worth noticing that some large corporations, such as Apple and Samsung, are sued for patent infringement several dozen times every year. For these large corporations, on the one hand, many of them already have sufficient internal financing and are no longer seeking external investment; on the other hand, it is hard to identify the effect of litigations on those companies. For clear identification, we decided to focus on firms that were only litigated once and compare these firms that were never litigated. Thus, our treated sample consists of these 2300 firms. In the next section, we give details about procedures matching the treated firms to a comparable sample of control firms.

### 4.3.2 Matching Procedures

To identify the effect of patent litigations, ideally, we would want a group of firms that were identical to the treated firms prior to the patent litigation as the control group. The motivation for matching is because, among the more than 130 thousand companies that received investments during 1995-2019 in VentuerXpert, only around 5 thousand were sued. Thus, there exists a high level of uncontrolled firm heterogeneity that the litigated firm may differ from other firms in important dimensions. Thus, to identify the impact of patent litigations, we shall compare the set of litigated firms to a set of other firms similar in other dimensions but was not affected by litigations. Therefore, we select treated firms that were only sued once, and received 1-5 rounds of investments when sued. Also, the investments should be received within ten years of firm founding. Then we match this set of firms to firms that are in the same Industry Subgroup level 3 (the finest level in VentureXpert) and were founded in the same year as the matched firm. Also, the control firms should have received the same rounds of investment as the matched firm at the year when the treated firm was litigated. In addition, the control firm received its most recent "pre-litigation" investment in the same year as the treated firm. In addition to the above exact matching, we conduct a 1:2 Nearest Neighbor matching for the total amount of investment received before the year of litigation of the treated firm. The final matched sample consists of 409 treated firms, and are matched to 724 control firms. The period of study is five years before and after the treatment. In Figure 4.1, we summarize the above matching procedures.

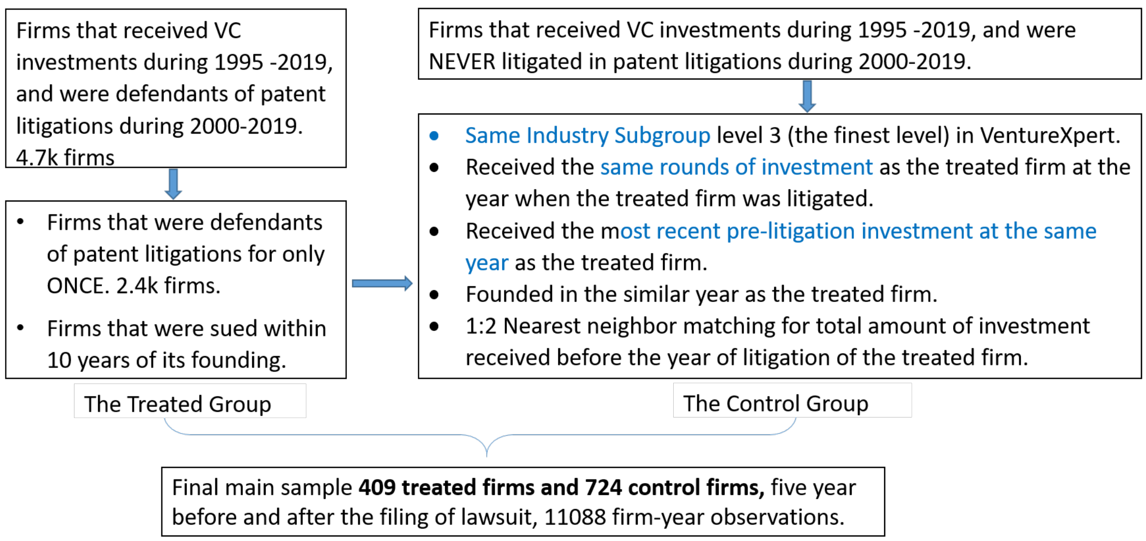


Figure 4.1.: Matching Procedures

### 4.3.3 Instrumental Variables

Though matching partially alleviate endogenous concern, there may still be some unobserved factors that affect both the treatment variable of being litigated and the outcome variables of VC investments. Thus, we further use the instrumental variable approach. Since the instrumented variable is binary (being a defendant or not), we need to avoid the forbidden regression (Angrist and Pischke, 2008; Balachandran, 2018).

In terms of operationalization, Step 1, we run a Probit model, using original exogenous variables to estimate the probability of being a Defendant; Step 2, we run the Stage 1 of 2SLS procedures, using estimated probability from Step 1 as the instrument in the formal 2SLS procedure and estimate OLS models; Step 3 is the Stage 2 of 2SLS, substitute the endogenous binary treatment variable with the fitted value from Step 2.

Thus, in Step 1, we can use multiple exogenous variables to estimate the Probit model. We exploit the location of firms and the variation in the legal environment of the local region. The United States has 91 district court to which firms can file patent lawsuits. Some districts are much friendlier to plaintiffs than others, thus attract lots of patent lawsuits, adding the risk of being litigated to local entrepreneurial firms. Specifically, variables we use include the numbers of patent lawsuits that were granted a plaintiff win, that were granted a defendant win, that were allowed to be transferred to another district, and that were put "on hold" (or "Stayed") to wait for the resolution of a parallel challenge towards the focal patents, as well as the mean number of days to the outcome at the venture's local district court in the three years prior to the year of litigation.

### 4.3.4 Variables

Dependent variables. Based on our hypotheses, we use two dependent variables in our statistical models. The first is the probability of receiving VC investment for firm i at year j. Empirically, our DV $Inv_{it}$ is a binary variable which equals one if firm i received VC investments in year j. Then, to test hypotheses on the amount of investment, our second DV is the logarithm of the amount of VC investment a focal firm i receive at year j. The variable is calculated as Log(Amount+1). Third, we also count the number of investments a firm i receive in year j.

Independent variables: For independent variables, $Post_{it}$ is a 0-1 binary variable that equals one for firm i at year t if it is after litigation was filed. Firms in the control group are assigned the same value as the treated firm that they were matched to. $Def_i$ is a dummy variable that equals one for firms in the treated group. Thus, the interaction term $Def_i * Post_{it}$ is our Diff-in-Diff variable that captures the main effect on being litigated. Then, $Age_{it}$ is a variable that equals the age of the firm at a year. Similarly, the heterogeneous impact on firms of different ages will be captured by the three-way interaction of $Def * Post * Age$. $Round_{it}$ is a variable that gives the number of rounds of investment firm i has raised at year t, so the moderating effect will be captured by the three-way interaction of $Def * Post * Round$. $PAE_i$ is a firm-level variable which equals 1 if firm i is sued by a PAE, and the three-way interaction $Def * Post * PAE$ captures how startups sued by PAEs may be affected differently compared to other ones. In addition, $CVCShare_{it}$ is a variable which captures the share of CVCs in an investment received by a startup in a year, it equals zero if the firm received no investment from CVCs in that year.

As to the time window of the study, instead of using data of each firm for the available years, we choose a time window of five years before and after the treated year. Our original dataset is an unbalanced panel of 11,088 firm-year observations. Table 4.1 reports summary statistics of variables.

Table 4.1.: Descriptive Statistics

| Statistic | N | Mean | St. Dev. | Min | Pctl(25) | Pctl(75) | Max |
|---|---|---|---|---|---|---|---|
| Investment | 11,088 | 0.28 | 0.45 | 0 | 0 | 1 | 1 |
| Ann. Rounds of Inv. | 11,088 | 0.32 | 0.58 | 0 | 0 | 1 | 6 |
| Ann. Inv. Amount | 11,088 | 3.35 | 16.96 | 0 | 0 | 0.9 | 900 |
| Post | 11,088 | 0.16 | 0.37 | 0 | 0 | 0 | 1 |
| Age | 11,088 | 4.89 | 3.04 | 0 | 2 | 7 | 10 |
| Round | 11,088 | 2.25 | 1.85 | 0 | 1 | 3 | 16 |
| PAE | 11,088 | 0.17 | 0.37 | 0 | 0 | 0 | 1 |
| CVC Share | 11,088 | 0.12 | 0.17 | 0 | 0 | 0.2 | 1 |

Notes: Firm-year observations of 1,133 firms, consisting of 409 treated firms and 724 control firms.

### 4.3.5 Regression Analysis

The regression equations that we estimate in the second stage of 2SLS are:

$$Inv_{it} = \beta_1 \widehat{Def_i * Post_{it}} + \beta_2 Post_{it} + \beta_3 \widehat{Def_i} + \delta X_{it} + \lambda_i + \epsilon_{it} \tag{4.1}$$

$$log(Amount)_{it} = \beta_4 \widehat{Def_i * Post_{it}} + \beta_5 Post_{it} + \beta_6 \widehat{Def_i} + \delta X_{it} + \lambda_i + \epsilon_{it} \tag{4.2}$$

where $\widehat{Def_i}$ and $\widehat{Def_i * Post_{it}}$ are fitted values from the first stage of the 2SLS. They are used in lieu of the endogenous binary variable of a firm $i$ being a defendant, $Def$, and the main effect $Def * Post$. $X_{it}$ indicates other time-variant controls such as the investment round information. $\lambda_i$ and $\epsilon_{it}$ are matched pair fixed effect and the error term respectively. To estimate the first equation on the extensive margin of whether the startup receive an investment in the year, we use Logit and Probit models. To estimate the second equation, we use two methods, a negative binomial model counting number of investment received in a year and a Tobit model with the dependent variable being the amount of investment the startup receive in a year and that account for the left- censoring of investment data.[1] The Tobit model will give consistent estimates of parameters and is technically similar to Heckman (1978) two-stage selection model, which include the fitted value of the first stage to the second-stage estimation. Among the 11,088 firm-year observations, there were 8,035 with zero investment amount data. For the main variable of interest $\widehat{Def_i * Post_{it}}$, we expect its coefficients to be negative. In addition, the coefficient of $\widehat{Def_i}$ shall be insignificant, indicating that the treated firms and control firms had no significant different in obtaining VC financing prior to the litigation of the treated firm.

[1] The Tobit model (Tobin, 1958) acknowledges there is an unobservable latent variable and estimate the parameters using Maximum Likelihood estimation.

## 4.4 Results

At first, Table 4.2 reports the first two steps of our operationalization testing the validity of the instruments. The first column reports the Probit model using exogenous court variables to estimate the probability of a startup being sued. As seen from the model, only the coefficient of Plaintiff Win is significant, meaning that if the district ruled more cases with plaintiff win, then it is positively related to the likelihood that the startup in the district is targeted for patent litigation. Second, since we have two endogenous variables $Def$ and $Def * Post$, two instruments are needed and they are $\widehat{Def}$ and $\widehat{Def * Post}$. Results show that the instruments are highly correlated to the endogenous variables. Since only Plaintiff Win significantly predicts the chance of a startup being sued, we only use that variable as the source of our exogenous variation in the 2SLS procedure.

Full results of models testing Hypotheses 1a and 1b are reported in Table 4.3. The Probit Model in the first column and only Plaintiff Win is used for exogenous variation. After obtaining our instrument $Prob\widehat{(Def)}$, it is used in the Stage 1 model. To test the validity of the instrument, we conduct F-tests to each of our Stage 1 models to test the significance of instruments in predicting endogenous variables. With a residual degree of freedom of 10,895, the F-statistics are beyond 100, which are far above the commonly used threshold of 10, lending confidence for the validity of the instrument. Our main variable of interest $\widehat{Def * Post}$ is negative with p-values smaller than 0.001 in both Model 1 Probit and Model 2 Logit models. Also, coefficients on $\widehat{Def}$ are all insignificant, indicating that the defendant firm and the matched firms are not statistically different in their obtaining of investment prior to the litigation. The results lend strong support to Hypothesis 1a. On average, the defendant firms are 7.4% less likely to receive investment in each year following the litigation as compared to firms that were not sued.

Moreover, in both Negative Binomial and Tobit specifications, $\widehat{Def * Post}$ are also significantly negative in predicting the amount of investment raised. The neg-

Table 4.2.: Validity of Instruments

| | Probit | Stage 1-1 | Stage 1-2 |
|---|---|---|---|
| | Probit | OLS | OLS |
| DV: | Probit(Def) | Def | Def*Post |
| $\widehat{Prob(Def)}$ | | 0.746*** | −0.093* |
| | | (0.000) | (0.007) |
| $\widehat{Prob(Def)}$*Post | | 0.001 | 1.004*** |
| | | (0.902) | (0.000) |
| Plaintiff Win | 0.009* | | |
| | (0.049) | | |
| Defendant Win | 0.004 | | |
| | (0.549) | | |
| Stayed Cases | −0.009 | | |
| | (0.453) | | |
| Transferred Cases | −0.000 | | |
| | (0.950) | | |
| Duration | −0.000 | | |
| | (0.594) | | |
| Age | −0.004 | 0.002 | −0.001 |
| | (0.799) | (0.220) | (0.376) |
| Round | 0.024 | −0.006* | 0.000 |
| | (0.406) | (0.014) | (0.843) |
| CVC Share | 0.175 | 0.009 | 0.002 |
| | (0.331) | (0.683) | (0.872) |
| PAE | 11.497 | 0.229*** | 0.084** |
| | (0.000) | (0.000) | (0.006) |
| $R^2$ | | 0.420 | 0.582 |
| Adj. $R^2$ | | 0.410 | 0.574 |
| Num. obs. | 3255 | 11088 | 11088 |
| F-statistic of Instruments | | 100.86 | 6312.3 |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: P-values reported in parentheses. In the Probit model, among five exogenous variables, only the number of Plaintiff Cases is statistically significant. Our instruments are $\widehat{Prob(Def)} * Post$ and $\widehat{Prob(Def}$, with $\widehat{Prob(Def}$ being the fitted value from the Probit model. Then, in OLS models of Stage 1, $Def$ and $Def * Post$ are instrumented using $\widehat{Prob(Def}$ and $\widehat{Prob(Def} * Post$ Results shows $\widehat{Prob(Def}$ and $\widehat{Prob(Def} * Post$ are valid instruments.

ative binomial tells that the defendant firm on average receives "0.3" fewer rounds of investment each year. The Tobit model tells that, on average, the defendant firm raises \$6.5 million less in VC investments compared to control firms. The results confirm our Hypothesis 1b that litigation negatively affects the amount of investment startups receive from VCs.

Further results of the dynamic impact of being sued are reported in Table 4.4. In these models, we re-estiamte Model 1 and Model 2 in Table 4.3 and interact $\widehat{Def}$ with Year dummies instead of a binary *Post* variable, with Year 0, the year of the litigation to the treated firms, being the reference year. As presented in the table, the difference between the treated firms and the control firms was insignificant statistically prior to the litigation. Then the likelihood of the treated firms receiving investments significantly dropped since the year they were sued. Over time, the effect even escalated in magnitude, giving us additional evidence of the negative effect of patent litigation on the startup's likelihood of receiving investments.

After verifying the main effect, we proposed factors that mitigate the negative impact of litigation, from the startup's aspect and from the plaintiff's aspect. When the startup has more alternative quality signals, and when the plaintiff is weak, the being targeted in patent litigations is less detrimental to the startup's VC financing. Results of models testing Hypotheses 2a and 3a are reported in Table 4.5. The sign of the three-way interaction terms of $Def * Post * Age$ and $Def * Post * Round$ are expected to be positive, meaning firms with more alternative quality signals are affected less by the litigation. We find evidence for Hypotheses 2a with the positive and highly significant coefficient across models. Then, regarding plaintiff heterogeneity, $Def * Post * PAE$ is positive and significant, meaning litigations initiated by weak plaintiffs, in this case, PAEs, are less detrimental to firm, lending support to Hypothesis 3a. Then results testing Hypotheses 2b and 3b are reported in Table 4.6. Still, the positive and significant coefficients on $Def * Post * Age$, $Def * Post * Round$, and $Def * Post * PAE$ verify that alternative quality signals from the startup and that

Table 4.3.: 2SLS Results on the Effect of Patent Litigation on VC Financing

| | Probit | Stage 1 | | Stage2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Model 1 | | Model 2 | | Model 3 | Model 4 |
| DV: | Probit(Def) | Def | Def*Post | P(Inv) | | P(Inv) | | Num Inv | Amount |
| | | | | Probit | Margin | Logit | Margin | Neg Binomial | Tobit |
| $\widehat{Prob(Def)}$ | | 0.746*** | −0.093* | | | | | | |
| | | (0.000) | (0.007) | | | | | | |
| $\widehat{Prob(Def)} * Post$ | | 0.001 | 1.004*** | | | | | | |
| | | (0.902) | (0.000) | | | | | | |
| Age | −0.008 | 0.002 | −0.001 | −0.244*** | −0.074*** | −0.440*** | −0.073*** | −0.298*** | −6.506*** |
| | (0.626) | (0.220) | (0.376) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Round | 0.025 | −0.006* | 0.000 | 0.377*** | 0.113*** | 0.674*** | 0.113*** | 0.413*** | 10.287*** |
| | (0.390) | (0.014) | (0.843) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| CVC Share | 0.161 | 0.009 | 0.002 | 0.527*** | 0.165*** | 0.984*** | 0.157*** | 0.610*** | 15.781*** |
| | (0.372) | (0.683) | (0.872) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| PAE | 11.496 | 0.229*** | 0.084** | 0.164 | 0.042 | 0.241 | 0.051 | −0.233 | 3.116 |
| | (0.000) | (0.000) | (0.006) | (0.638) | (0.710) | (0.689) | (0.659) | (0.594) | (0.798) |
| Def | | | | −0.101 | −0.024 | −0.145 | −0.030 | 0.294 | 1.651 |
| | | | | (0.797) | (0.836) | (0.831) | (0.802) | (0.551) | (0.905) |
| Def*Post | | | | −0.322*** | −0.088*** | −0.524*** | −0.096*** | −0.140+ | −5.693+ |
| | | | | (0.000) | (0.000) | (0.000) | (0.000) | (0.094) | (0.104) |
| Plaintiff Win | 0.009** | | | | | | | | |
| | (0.005) | | | | | | | | |
| Log(scale) | | | | | | | | | 3.543*** |
| | | | | | | | | | (0.000) |
| Matched Group FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Num. obs. | 3454 | 11088 | 11088 | 11088 | 11088 | 11088 | 11088 | 11088 | 11088 |
| Left-censored | | | | | | | | | 8035 |
| $R^2$ | | 0.420 | 0.582 | | | | | | |
| Adj. $R^2$ | | 0.410 | 0.574 | | | | | | |
| McFadden Pseudo-$R^2$ | | | | 0.183 | | 0.184 | | | |
| Wald Test | | | | | | | | | 1414.869 |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: P-values reported in parentheses. Independent variable of interest in Stage 2 $Def$ and $Def * Post$ are instrumented using $\widehat{Def}$ and $\widehat{Def * Post}$ with $\widehat{Def}$ being the fitted value from the Probit model.

Table 4.4.: Dynamic Effects of Patent Litigation on the Likelihood of VC Financing

| | Model 5 | | Model 6 | |
|---|---|---|---|---|
| DV: | P(Inv) | | P(Inv) | |
| | Probit | Margin | Logit | Margin |
| Def*Year-5 | $-0.502^{**}$ | $-0.128$ | $-0.786^{**}$ | $-0.149^{**}$ |
| | (0.002) | (0.136) | (0.004) | (0.003) |
| Def*Year-4 | $-0.347^{*}$ | $-0.086$ | $-0.530^{*}$ | $-0.103^{*}$ |
| | (0.014) | (0.174) | (0.027) | (0.019) |
| Def*Year-3 | $-0.116$ | $-0.027$ | $-0.166$ | $-0.035$ |
| | (0.379) | (0.493) | (0.456) | (0.381) |
| Def*Year-2 | 0.143 | 0.043 | 0.265 | 0.042 |
| | (0.259) | (0.309) | (0.214) | (0.259) |
| Def*Year-1 | 0.162 | 0.047 | 0.288 | 0.048 |
| | (0.181) | (0.278) | (0.160) | (0.191) |
| Def*Year1 | $-0.619^{***}$ | $-0.167$ | $-1.026^{***}$ | $-0.184^{***}$ |
| | (0.000) | (0.107) | (0.000) | (0.000) |
| Def*Year2 | $-0.980^{***}$ | $-0.271^{+}$ | $-1.658^{***}$ | $-0.292^{***}$ |
| | (0.000) | (0.096) | (0.000) | (0.000) |
| Def*Year3 | $-1.242^{***}$ | $-0.370^{+}$ | $-2.269^{***}$ | $-0.370^{***}$ |
| | (0.000) | (0.094) | (0.000) | (0.000) |
| Def*Year4 | $-2.102^{***}$ | $-0.634^{+}$ | $-3.882^{***}$ | $-0.626^{***}$ |
| | (0.000) | (0.091) | (0.000) | (0.000) |
| Def*Year5 | $-2.944^{***}$ | $-0.910^{+}$ | $-5.574^{***}$ | $-0.877^{***}$ |
| | (0.000) | (0.090) | (0.000) | (0.000) |
| Def | $-0.155$ | $-0.049$ | $-0.300$ | $-0.046$ |
| | (0.730) | (0.712) | (0.695) | (0.738) |
| Age | $-0.242^{***}$ | $-0.069^{+}$ | $-0.425^{***}$ | $-0.072^{***}$ |
| | (0.000) | (0.084) | (0.000) | (0.000) |
| Round | $0.434^{***}$ | $0.124^{+}$ | $0.759^{***}$ | $0.129^{***}$ |
| | (0.000) | (0.084) | (0.000) | (0.000) |
| CVC Share | $0.289^{**}$ | 0.091 | $0.558^{**}$ | $0.086^{**}$ |
| | (0.005) | (0.128) | (0.001) | (0.007) |
| PAE | 0.415 | 0.128 | 0.691 | 0.136 |
| | (0.291) | (0.410) | (0.301) | (0.342) |
| Matched Group FE | Yes | | Yes | |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: P-values reported in parentheses. *Post* is replaced by Year dummies with Year 0, the year of litigation, being the reference year.

the weak plaintiff mitigates the negative impact of being litigated on the amount of VC investment received.

## 4.5 Robustness

### 4.5.1 Time to the Next Round

In the main analysis, we have shown that being litigated may reduce the probability of the targeted startup receiving further investments. As a robustness check, we test whether being litigated will delay the startup's speed of reaching the next round of financing. When a startup is sued, the investors may wait for the resolution of the case and observe the consequences to the firm, thus causing a delay in obtaining the next round of VC investment. Since receiving investment is a recurrent event for firms, we use the Andersen-Gill model (Andersen and Gill, 1982), which is an extension to the widely used Cox proportional hazard model accommodating for recurrent events. To conduct the analysis, we restructured the data and counted the number of days to the next round (if there was one) of all 3,478 investment events of our firms in the main analysis. Had there was not follow-on investment, the end of observation period was set to Dec. 15th, 2019, which was the date of our latest update to data. On average, it takes a startup in our sample four yearsto reach the next round. Table 4.7 gives the summary statistics.

Table 4.8 reports results of hazard models. The dependent variable of is the number of days after an investment until the next round investment for a startup. The status code, "Next Round", is one if a follow-on investment is observed, the status code is zero if no follow-on investment is observed. We expect the coefficient of $Def * Post$ to be negative, meaning a decrease in the hazard of receiving the next investment. The hypothesis is verified by the negative and significant sign of $Def * Post$ and the insignificant $Def$ across Models 1-5. On average, after being sued, the hazard of receiving next round of investment of treated firms is merely 3.4% ($e^{-3.388}$) of the hazard of their control counterparts. In both Model 3 and 5,

Table 4.5.: Heterogeneous Effect of Patent Litigation on the Likelihood VC Financing

| | Model 1 | | Model 2 | | Model 3 | | Model 4 | | Model 5 | | Model 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DV: | P(Inv) | | P(Inv) | | P(Inv) | | P(Inv) | | P(Inv) | | P(Inv) | |
| | Logit | Margin | Probit | Margin | Logit | Margin | Probit | Margin | Logit | Margin | Probit | Margin |
| Def | −0.197 | −0.065 | −0.418 | −0.056 | −0.544 | −0.146 | −0.894 | −0.159 | −0.148 | −0.044 | −0.264 | −0.044 |
| | (0.624) | (0.562) | (0.545) | (0.637) | (0.172) | (0.218) | (0.198) | (0.192) | (0.172) | (0.218) | (0.198) | (0.192) |
| Def*Post | −0.694** | −0.169** | −1.093** | −0.196** | −1.165*** | −0.341*** | −2.085*** | −0.340*** | −0.563*** | −0.156*** | −0.941*** | −0.167*** |
| | (0.001) | (0.006) | (0.003) | (0.002) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| **Def*Post*Age** | 0.202*** | 0.054*** | 0.348*** | 0.057*** | | | | | | | | |
| | (0.000) | (0.000) | (0.000) | (0.000) | | | | | | | | |
| **Def*Post*Round** | | | | | 0.469*** | 0.133*** | 0.813*** | 0.137*** | | | | |
| | | | | | (0.000) | (0.000) | (0.000) | (0.000) | | | | |
| **Def*Post*PAE** | | | | | | | | | 1.363*** | 0.416*** | 2.511*** | 0.403*** |
| | | | | | | | | | (0.000) | (0.000) | (0.000) | (0.000) |
| CVC Share | 0.449*** | 0.124*** | 0.803*** | 0.127*** | 0.377*** | 0.117*** | 0.716*** | 0.110*** | 0.539*** | 0.166*** | 1.001*** | 0.159*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Age | −0.128*** | −0.037*** | −0.238*** | −0.036*** | −0.198*** | −0.059*** | −0.360*** | −0.058*** | −0.238*** | −0.071*** | −0.429*** | −0.070*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Round | 0.435*** | 0.119*** | 0.772*** | 0.123*** | 0.583*** | 0.165*** | 1.005*** | 0.170*** | 0.380*** | 0.112*** | 0.679*** | 0.112*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| PAE | 0.252 | 0.084 | 0.493 | 0.076 | 0.535 | 0.170 | 0.891 | 0.176 | 0.926 | 0.339 | 1.628 | 0.322 |
| | (0.479) | (0.477) | (0.417) | (0.519) | (0.127) | (0.214) | (0.145) | (0.180) | (0.127) | (0.214) | (0.145) | (0.180) |
| Def*Age | −0.054** | −0.015** | −0.095** | −0.015** | | | | | | | | |
| | (0.007) | (0.005) | (0.006) | (0.005) | | | | | | | | |
| Post*Age | −0.166*** | −0.046*** | −0.296*** | −0.047*** | | | | | | | | |
| | (0.000) | (0.000) | (0.000) | (0.000) | | | | | | | | |
| Def*Round | | | | | −0.077** | −0.023** | −0.138** | −0.023** | | | | |
| | | | | | (0.009) | (0.007) | (0.005) | (0.010) | | | | |
| Post*Round | | | | | −0.292*** | −0.079*** | −0.484*** | −0.085*** | | | | |
| | | | | | (0.000) | (0.000) | (0.000) | (0.000) | | | | |
| Def*PAE | | | | | | | | | −0.656 | −0.195 | −1.179 | −0.194 |
| | | | | | | | | | (0.009) | (0.007) | (0.005) | (0.010) |
| Post*PAE | | | | | | | | | −1.145*** | −0.197*** | −2.125*** | −0.209*** |
| | | | | | | | | | (0.000) | (0.000) | (0.000) | (0.000) |
| Matched Group FE | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Num. obs. | 11088 | | 11088 | | 11088 | | 11088 | | 11088 | | 11088 | |
| McFadden Pseudo-$R^2$ | 0.217 | | 0.219 | | 0.223 | | 0.222 | | 0.186 | | 0.188 | |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: P-values reported in parentheses. Independent variables of interest are Def*Post*Age, Def*Post*Round, and Def*Post*PAE. All two-way interactions are included. All models included matched pair fixed effects.

Table 4.6.: Heterogeneous Effect of Patent Litigation on VC Financing Amount

| DV: | Model 1<br>Num Inv<br>Neg Binom | Model 2<br>Amount<br>Tobit | Model 3<br>Num Inv<br>Neg Binom | Model 4<br>Amount<br>Tobit | Model 5<br>Num Inv<br>Neg Binom | Model 6<br>Amount<br>Tobit |
|---|---|---|---|---|---|---|
| Def | 0.201 | 1.084 | −0.181 | −10.277 | 0.345 | 3.699 |
| | (0.680) | (0.940) | (0.712) | (0.467) | (0.470) | (0.780) |
| Def*Post | −0.434 | $-11.966^{+}$ | $-1.026^{***}$ | $-29.326^{***}$ | −0.185 | $-16.472^{***}$ |
| | (0.059) | (0.176) | (0.000) | (0.000) | (0.224) | (0.008) |
| Def*Post*Age | $0.207^{***}$ | $5.071^{***}$ | | | | |
| | (0.000) | (0.001) | | | | |
| Def*Post*Round | | | $0.359^{***}$ | $12.154^{***}$ | | |
| | | | (0.000) | (0.000) | | |
| Def*Post*PAE | | | | | $1.441^{***}$ | $49.285^{***}$ |
| | | | | | (0.000) | (0.000) |
| CVC Share | $0.488^{***}$ | $14.036^{***}$ | $0.410^{***}$ | $12.599^{***}$ | $0.611^{***}$ | $16.015^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Age | $-0.158^{***}$ | $-2.848^{***}$ | $-0.244^{***}$ | $-5.137^{***}$ | $-0.291^{***}$ | $-6.233^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Round | $0.470^{***}$ | $11.601^{***}$ | $0.577^{***}$ | $15.318^{***}$ | $0.417^{***}$ | $10.336^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| PAE | −0.102 | 5.593 | 0.155 | 13.152 | 1.621 | $64.722^{*}$ |
| | (0.813) | (0.649) | (0.719) | (0.279) | (0.065) | (0.085) |
| Def*Age | $-0.069^{**}$ | $-2.087^{***}$ | | | | |
| | (0.003) | (0.004) | | | | |
| Post*Age | $-0.194^{***}$ | $-4.617^{***}$ | | | | |
| | (0.000) | (0.000) | | | | |
| Def*Round | | | −0.034 | $-1.839^{*}$ | | |
| | | | (0.212) | (0.035) | | |
| Post*Round | | | $-0.240^{***}$ | $-7.333^{***}$ | | |
| | | | (0.000) | (0.000) | | |
| Def*PAE | | | | | −1.796 | $-61.459^{*}$ |
| | | | | | (0.044) | (0.074) |
| Post*PAE | | | | | $-1.551^{***}$ | $-38.634^{***}$ |
| | | | | | (0.000) | (0.000) |
| Log(scale) | | $3.532^{***}$ | | $3.530^{***}$ | | $3.540^{***}$ |
| | | (0.000) | | (0.000) | | (0.000) |
| Matched Group FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Num. obs. | 11088 | 11088 | 11088 | 11088 | 11088 | 11088 |
| Left-censored | | 8035 | | 8035 | | 8035 |
| McFadden Pseudo-$R^2$ | 0.167 | | 0.148 | | 0.172 | |
| Wald Test | | 1520.156 | | 1637.662 | | 1425.849 |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: Only Stage 2 of 2SLS results are reported. P-values are in parentheses. Independent variables of interest are Def*Post*Age, Def*Post*Round, and Def*Post*PAE. Endogenous independent variables in Stage 2 are instrumented using $\widehat{Def}$ and its interaction terms obtained from Stage 1 models of 2SLS. All two-way interactions are included. All models included matched pair fixed effects.

Table 4.7.: Descriptive statistics for Hazard Models

| Statistic | N | Mean | St. Dev. | Min | Pctl(25) | Pctl(75) | Max |
|---|---|---|---|---|---|---|---|
| Days to Next Round | 3,478 | 1,317.66 | 1,738.60 | 0 | 276.2 | 1,435.8 | 7,288 |
| Next Round | 3,478 | 0.73 | 0.45 | 0 | 0 | 1 | 1 |
| Amount | 3,078 | 11.63 | 29.35 | 0.002 | 1.75 | 12.00 | 900.00 |
| Year | 3,478 | 2,009.42 | 5.10 | 2,000 | 2,006 | 2,014 | 2,018 |
| Round | 3,478 | 2.84 | 1.93 | 1 | 1 | 4 | 16 |
| PAE | 3,478 | 0.15 | 0.36 | 0 | 0 | 0 | 1 |
| Age | 3,478 | 3.76 | 2.46 | 0 | 2 | 6 | 9 |
| CVC Share | 3,478 | 0.10 | 0.14 | 0 | 0 | 0.2 | 1 |
| Post | 3,478 | 0.33 | 0.47 | 0 | 0 | 1 | 1 |
| Def | 3,478 | 0.34 | 0.47 | 0 | 0 | 1 | 1 |

Notes: Each row is an investment event to one of the firms in the matched sample used in the main analysis.

we find the interaction terms of $Def * Post * Round$ positive and significant, lending support to our hypotheses that alternative quality signals by having received more rounds of investment mitigates the negative impact of being sued. There is some evidence showing that lawsuits initiated by PAEs are less detrimental in reducing the hazard of receiving investments.

### 4.5.2 Matched Locations

One limitation of the main analysis is that since we exploit variation among district courts, we are not able to address other regional factors that potentially drive the results. To address this issue, we adopted another matching method and intentionally matched each treated firm with firms in the same metropolitan area. Thus, we have several criteria in the matching (Angrist, 1998). First, the control firm must be in the same Industry Subgroup as the treated firm in VentureXpert since different businesses and industries have quite different venture financing environment. Second, the control firm must be founded in the same State as the matched treated firm since the location is known to affect venture financing. (Sorenson and Stuart, 2001). Third, the control firm must have received the same rounds of investment as the treated firm at the year when the treated firm was litigated. It is well known that in venture financing, to invest or not and the amount of financing depends on how many series of financing have the company already gone through. Fourth, we would want control firms to be founded in similar years as the treated firms since firms are affected by the external environment when they were founded, and such an imprinting process can be long-lasting (Stinchcombe and March, 1965; Sydow et al., 2009). We operationalize by at first categorizing founding years into several bins, divided by major macroeconomic downturns such as the 2009 financial crisis, the 2000 internet bubble, and the 1990 Gulf war. Then, we require that control firms must be founded in the same year bins as the treated firm. After matching the bins, among the firms remained, we pick up to three firms with the closest founding years as the treated firm. Going through all

Table 4.8.: Time to Next Round: Hazard Model Results

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| Def | −0.513 | 0.164 | 0.301 | −2.934 | 0.380 |
| | (0.771 | (0.918) | (0.848) | (0.121) | (0.828) |
| Def*Post | $-3.388^{***}$ | $-3.540^{***}$ | $-3.516^{***}$ | $-8.342^{***}$ | $-4.385^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Def*Post*Age | | −0.065 | | | $0.477^{***}$ |
| | | (0.109) | | | (0.000) |
| Def*Post*Round | | | $1.198^{***}$ | | $0.752^{***}$ |
| | | | (0.000) | | (0.000) |
| Def*Post*PAE | | | | $11.524^{***}$ | 2.994 |
| | | | | (0.000) | (0.390) |
| Amount | $-0.006^{***}$ | $-0.010^{***}$ | $-0.008^{***}$ | $-0.009^{***}$ | $-0.009^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Age | 0.015 | 0.043 | 0.029 | 0.028 | 0.056 |
| | (0.724) | (0.462) | (0.606) | (0.596) | (0.348) |
| Round | $-0.080^{**}$ | −0.040 | $-0.073^{+}$ | −0.048 | $-0.063^{+}$ |
| | (0.007) | (0.167) | (0.072) | (0.132) | (0.091) |
| PAE | 0.520 | −0.077 | −0.229 | $13.947^{*}$ | 3.895 |
| | (0.682) | (0.947) | (0.841) | (0.039) | (0.836) |
| CVC Share | $-2.323^{***}$ | $-2.142^{***}$ | $-2.161^{***}$ | $-2.270^{***}$ | $-2.144^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Post*Age | | $-0.695^{***}$ | | | $-0.349^{***}$ |
| | | (0.000) | | | (0.000) |
| Def*Age | | $1.002^{***}$ | | | −0.075 |
| | | (0.000) | | | (0.377) |
| Post*Round | | | $-0.818^{***}$ | | $-0.396^{**}$ |
| | | | (0.000) | | (0.002) |
| Def*Round | | | −0.054 | | −0.119 |
| | | | (0.586) | | (0.288) |
| Post*PAE | | | | $-2.583^{***}$ | $-1.869^{*}$ |
| | | | | (0.000) | (0.043) |
| Def*PAE | | | | $-12.809^{+}$ | −4.178 |
| | | | | (0.056) | (0.830) |
| Matched Group FE | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes |
| Obs. | 3078 | 3078 | 3078 | 3078 | 3078 |
| Events | 2286 | 2286 | 2286 | 2286 | 2286 |
| $R^2$ | 0.361 | 0.361 | 0.550 | 0.463 | 0.560 |
| $Chi^2$ | 1183.08 | 2005.48 | 2116.30 | 1637.18 | 2154.08 |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: Andersen-Gill Model (Andersen and Gill, 1982) (An extension to Cox model with recurrent events) results are reported with the Dependent Variable being the number of days until the next round of investment. Results shows defendant firms experienced significant decrease in the hazard of receiving next round of investment as compared to the control firms, lending support to our hypothesized negative impact of patent lawsuits. When estimating models, if no investments observed after For one firm, then observation period ends on Dec. 15th, 2019. Only Stage 2 of 2SLS results are reported. P-values are in parentheses with standard errors clustered at firm-level. Endogenous independent variables that include $Def$ are instrumented using $\widehat{Def}$ and its interaction terms obtained from Stage 1 models that follows same procedures as previous analysis and that are not reported. All two-way interactions are included.

the procedures, we obtain a sample of 6,322 firms with 1,769 treated firms and 4,553 control firms. Table C.1 summarizes the data and Table C.2 reports the correlation between variables.

We report the results of Linear Probability Models on the likelihood of VC financing in Table 4.9. Across Models 1-4 in the Table, the coefficient of $Def * Post$ is negative and highly significant (three out of the four models have a p-value smaller than 0.001, the other is also smaller the 0.05), lending strong support to our Hypotheses 1a. On average, patent litigation leads to a drop of 2-3 percentage points in the probability of getting a VC financing. Then in Table 4.10, we report two sets of results on the effect of patent litigation on the logarithm amount of VC financing. Model 5-8 were estimated using fixed-effect panel regression, and Model 9-12 were estimated using the Tobit model with industry and year fixed effects. The Tobit model fixes the data censoring problem and produces consistent estimates of parameters (Amemiya, 1973). As we can see, in all models, $Def * Post$ is negative and highly significant with p-values smaller than 0.01, lending evidence supporting Hypothesis 1b.

We also find that the three-way interaction of $Def * Post * Age$ has positive coefficients in Table 4.9 and Table 4.10. The finding lends support to our hypotheses, while contradicting our findings in the main results. One plausible reason is that as startups mature, the value at stake for patent litigations is also larger, thus making the litigation more detrimental to investors as compared to litigations that target young startups. But further studies shall be conducted to reveal the mechanism behind the finding.

### 4.5.3 Placebo Test

Furthermore, we also conducted a placebo test that marked the original treated group as a part of the control group and randomly selected 25% of the original control group firm to be labeled as the treated company. Then, using this sample, we repeat

Table 4.9.: Effect of Patent Litigation on the Likelihood of VC Financing

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Def*Post | $-0.023^{***}$ | $-0.030^{***}$ | $-0.012^{*}$ | $-0.081^{***}$ |
| | (0.006) | (0.006) | (0.006) | (0.007) |
| Def*Post*Age | | | $0.003^{***}$ | |
| | | | (0.000) | |
| Def*Post*CVC | | | | $-0.086^{***}$ |
| | | | | (0.012) |
| Round FE | No | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| Yesr FE | Yes | Yes | Yes | Yes |
| $R^2$ | 0.001 | 0.156 | 0.157 | 0.158 |
| Adj. $R^2$ | $-0.112$ | 0.061 | 0.062 | 0.064 |
| n | 6322 | 6322 | 6322 | 6322 |
| Num. obs. | 62690 | 62690 | 62690 | 62690 |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: Standard errors reported in parentheses. The dependent variable is a binary variable which equals one if a firm i received a VC financing at year t and zero otherwise. The table report linear probability model results on the effect of patent litigation on the likelihood of VC financing. The negative and significant coefficients of $Def * Post$ show that the treated firms, after being sued are less likely to receive VC investments as compared to their matched counterparts, and lend support to our hypothesis. Further, the age of the startup mitigate the negative effect of being sued, and the negative impact is more severe for startups that were funded by CVCs.

Table 4.10.: Effect of Patent Litigation on the Amount of VC Financing

| | Model 5 OLS | Model 6 OLS | Model 7 OLS | Model 8 OLS | Model 9 Tobit | Model 10 Tobit | Model 11 Tobit | Model 12 Tobit |
|---|---|---|---|---|---|---|---|---|
| Def*Post | $-0.081^{***}$ | $-0.089^{***}$ | $-0.042^{**}$ | $-0.169^{***}$ | $-0.484^{***}$ | $-0.599^{***}$ | $-0.518^{***}$ | $-1.186^{***}$ |
| | (0.012) | (0.012) | (0.013) | (0.015) | (0.114) | (0.109) | (0.116) | (0.122) |
| Def*Post*CVC | | | $-0.233^{***}$ | | | | $-0.282$ | |
| | | | (0.026) | | | | (0.158) | |
| Def*Post*Age | | | | $0.004^{***}$ | | | | $0.057^{***}$ |
| | | | | (0.000) | | | | (0.004) |
| Age | | | | | | $-0.121^{***}$ | $-0.121^{***}$ | $-0.131^{***}$ |
| | | | | | | (0.003) | (0.003) | (0.003) |
| CVC | | | | | | | $0.204^{**}$ | |
| | | | | | | | (0.068) | |
| logSigma | | | | | $1.359^{***}$ | $1.245^{***}$ | $1.244^{***}$ | $1.244^{***}$ |
| | | | | | (0.017) | (0.015) | (0.015) | (0.015) |
| Industry FE | Yes | Yes | Yes | Yes | No | No | No | No |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| $R^2$ | 0.001 | 0.060 | 0.062 | 0.062 | | | | |
| Adj. $R^2$ | $-0.112$ | $-0.046$ | $-0.044$ | $-0.044$ | | | | |
| Left-censored | | | | | 56057 | 56057 | 56055 | 56057 |
| n | 6322 | 6322 | 6322 | 6322 | 6322 | 6322 | 6322 | 6322 |
| Num. obs. | 62690 | 62690 | 62690 | 62690 | 62690 | 62690 | 62690 | 62690 |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: Standard errors reported in parentheses. Dependent variable is Log(Amount+1), which is the logarithm of the amount of VC investment firm i received in year t. All models included firm and year fixed effects.

our analysis of the two dependent variables. As expected, our variables of interest showed no significance. Detailed results are not reported in the text.

## 4.6 Caveats

Though extant studies have exploited variations in regional court practices to instrument for focal firms' risk of being litigated (Kiebzak et al., 2016), the validity of such instruments is challenged if firms choose locations or relocate based on the friendliness of district court. However, given the overall small proportion of firms sued and the abundance of other factors that entrepreneurs consider deciding for locations, we do not think district courts practice in patent lawsuits post significant influence on entrepreneurial firms' location choice.

On the other side of the coin, another question to be asked is whether VCs tend to refrain from investing in firms located in those litigious and plaintiff-friendly districts. In the main analysis, we are not able to tell since locations are not matched. However, in the robustness section, comparing firms with proximate locations that were sued and not sued, we still find significant main effects of litigation, thus alleviating the above concern. However, it is yet to be tested whether the entrepreneurial firms or the VCs intentionally avoid districts with certain behavior in their legal practices.

In this study, we do not find conclusive evidence on whether the younger or older firm is affected more by the litigation, and have proposed potential mechanisms. Future studies can further explore more heterogeneity among defendant startups to unveil the reason behind such heterogeneous impact of patent litigations.

## 4.7 Concluding Remarks

Scholarships in entrepreneurship have primarily focused on the building of resources and capabilities. While securing access to resources and building capabilities are essential to entrepreneurial firms' competitive advantage, much less is known about the events and actions that potentially hurt firms' resources and capabilities, thus destroying competitive advantage. Patent lawsuits, when faced by an entrepreneurial firm, is one of such events that can potentially ruin the efforts of the startup.

In the past five years, patent litigations have received much attention from scholars of multiple fields. For entrepreneurial firms, while most studies focus on how litigations affect their development of technological capabilities and complementary assets, it is much neglected how litigations will affect their VC financing, which is one of the most central issues for entrepreneurial firms. VCs' involvement is even more critical than providing financial resources, as they also lend other valuable complementary assets to startups (Fitza et al., 2009; Teece, 1986).

This paper fills in the gap in the literature by looking into how patent litigations affect a firm's external financing from venture capitals. Using our matched firm-level data that combines VC investment and litigation records, we find evidence supporting the view that patent litigations on average, negatively affect a firm's chance as well as the amount of obtaining VC financing. In addition, contrary to the view that CVCs may provide complementary assets to the portfolio firm such that they will be better dealing with patent litigations, we find that the negative impacts of litigations are more prominent for firms that are backed by CVCs. Moreover, younger entrepreneurial firms, due to their liability of newness and limited resources, are also more affected by patent litigations.

With contributions of this paper, it also has some limitations, thus opening avenues for future extensions. First, we have not yet distinguished the patent litigations initiated by rival firms from the ones initiated by PAEs. PAEs are said to initiate frivolous litigations (Shrestha, 2010) based on low-quality patents and ambiguous infringement charges. Thus, it can be expected that when litigated by a PAE, the impact would be different from other situations. Future studies can further discuss how the plaintiff of patent litigation affects the impact of patent litigation on VC financing and other factors.

Another limitation of this study is that due to the scope of this paper, we do not pay much attention to the two-side matching of the investment, i.e., we focus on the firms receiving VC financing, but not on the VC/PE's willingness to invest in ventures. This limitation is also partly because we do not observe offers made by VC/PEs but were rejected by venture firms. In the future, it would be interesting to further the study by distinguishing the impact on the venture firms, as well as on the VC/PEs.

Yet another future avenues of study is that, in addition to the impact of the focal defendant firm, it worth exploring whether or how the impact of patent litigations will spillover to other firms and organizations. Lemus and Temnyalov (2014, 2017) argue that the litigation activities will, in the end, benefit the innovation of firms in the industry. In addition, how will technology suppliers such as universities (Shane and Somaya, 2007) be affected by patent litigations? When while VCs may be reluctant financing firms with legal disputes, will universities tend to be more likely to help firms with patent litigations. Future examination of the impact using firm-level data could be a fruitful direction of study.

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# APPENDIX A APPENDIX TO CHAPTER 2

## A.1 Proofs

### A.1.1 Proof of Lemma 1

It is clear that for the target PE firm, since $S^* \leq \theta_j D_j + L_j$, which is the expected payoff had it choose to fight at court, the PE is willing to settle with the NPE. We let $D_j \leq \tilde{\pi}_j^C$, meaning the court will not award a damage larger than the defendant firm's profit to the plaintiff.

Then from the perspective of the NPE, if the defendant PE decides to fight, even when the plaintiff NPE wins at the court, the payoff of the NPE will only be $\mathbb{E}(\pi_j^{court}) = \theta_j D_j - L^N < S_j^*$. The difference is the legal fee that the defendant has to pay under the American court rule that let each party bear their own legal fee.

This indicates that fighting at court is not to the plaintiff NPE's best profit either. So NPEs, with knowledge about the litigation cost of PEs and their odds at court, would demand the maximal monetary payment $S^*$ such that it can expect a PE to agree to settle other than fight.

### A.1.2 Proof of Proposition 1

Signs of relevant first-order and second-order derivatives are given below: $\frac{\partial \Pi_i^{pW}}{\partial v} = \frac{2(nx+1)^2 v + 2A(nx+1)}{(n+1)^2} > 0$, $\frac{\partial^2 \Pi_i^{pW}}{\partial v^2} = \frac{2(nx+1)^2}{(n+1)^2} > 0$, $\frac{\partial \Pi_i^{pC}}{\partial v} = \frac{2(n^2x^2+2nx)v+2Anx}{(n+1)^2} > 0$, $\frac{\partial^2 \Pi_i^{pC}}{\partial v^2} = \frac{2(nx+1)^2-2}{(n+1)^2} > 0$, $\frac{\partial \Pi_i^{pC}}{\partial x} = \frac{\partial \Pi_i^{pW}}{\partial x} = \frac{2n^2v^2x+2nv(v+A)}{(n+1)^2} > 0$, $\frac{\partial^2 \Pi_i^{pC}}{\partial x^2} = \frac{\partial^2 \Pi_i^{pW}}{\partial x^2} = \frac{2n^2v^2}{(n+1)^2} > 0$.

### A.1.3 Proof of Corollary 1

Using Proposition 1, we know that $\max\{\Pi^p\} = \Pi^p|_{x=1} = v^2 + \frac{2Av}{n+1} - C^p$. To guarantee that $\max\{\Pi^p\} > 0$ such that $x^p < 1$, we obtain: $C^p < v^2 + \frac{2Av}{n+1}$.

Let $\Pi^p = 0$, then we can solve for the minimum level of exclusivity that support profitable practicing monetization $x^p$:

$$x^p = \frac{-A - v + \sqrt{C^p(n+1)^2 + A^2}}{nv}$$

Thus we can obtain the signs of relevent first-order derivatives: $\frac{\partial x^p}{\partial v} = -\frac{\sqrt{C^p(n+1)^2+A^2}-A}{n}v^{-2} < 0$, $\frac{\partial x^p}{\partial C^p} = \frac{1}{2nv}\frac{(n+1)^2}{\sqrt{C^p(n+1)^2+A^2}} > 0$, $\frac{\partial x^p}{\partial n} = \frac{(v+1)\sqrt{C^p(n+1)^2+A^2}-C^p(n+1)-A}{vn^2\sqrt{C^p(n+1)^2+A^2}} < 0$.

### A.1.4 Proof of Proposition 2

The proof is straightforward by taking the derivative of $\Pi^l$ with respect to $x$. When the damage is positive ($D > 0$), the chance of a plaintiff win is positive ($\theta_0 - \alpha x > 0$), and the cost of the defendant to defend itself is sufficiently large in that $L \geq L^N + 2c^t$, we have $\frac{\partial \Pi^l}{\partial x} = (D(\theta_0 - \alpha x) + \frac{L-L^N}{2} - c^t)n > 0$ and $\frac{\partial^2 \Pi^l}{\partial x^2} = -\alpha D n < 0$.

### A.1.5 Proof of Corollary 2

From Proposition 2, we know that $\max\{\Pi^l\} = \Pi^l|_{x=1} = -\frac{1}{2}\alpha n D + (D\theta_0 - c^t + \frac{L-L^N}{2})n - C^l$. To guarantee $\max\{\Pi^l\} \geq 0$ such that $x^l \leq 1$, we obtain the necessary condition that: $n \geq \frac{C^l}{D(\theta_0 - \frac{\alpha}{2}) + \frac{L-L^N}{2} - c^t}$. The condition is also sufficient because the numerator is greater than zero by assumptions. In addition, the condition above is a sufficient condition that guarantees the existence of real colutions of $x^l$. Letting $\Pi^l = 0$, we can solve for the minimum level of exclusivity that support profitable litigating monetization $x^l$:

$$x^l = \frac{\theta_0}{\alpha} + \frac{L - L^N - 2c^t}{2\alpha D} - \frac{1}{\alpha}\sqrt{\left(\theta_0 + \frac{L - L^N - 2c^t}{2D}\right)^2 - \frac{2\alpha C^l}{nD}} \tag{A.1}$$

To prove properties of $x^l$, we define and use a tool $\Psi = \frac{\theta_0 + \frac{L-L^N-2c^t}{2D}}{\sqrt{\left(\theta_0+\frac{L-L^N-2c^t}{2D}\right)^2 - \frac{2\alpha C^l}{nD}}} > 1$. Then the corollary is straightforward by calculating $\frac{\partial x^l}{\partial D} < 0$, $\frac{\partial x^l}{\partial C^l} > 0$, $\frac{\partial x^l}{\partial n} = -\frac{C^l}{n}\frac{\partial x^l}{\partial C^l} < 0$, $\frac{\partial x^l}{\partial \theta_0} = \frac{1-\Psi}{\alpha} < 0$, $\frac{\partial x^l}{\partial c^t} = -\frac{1}{D}\frac{\partial x^l}{\partial \theta_0} > 0$, $\frac{\partial x^l}{\partial L^N} = \frac{1}{2}\frac{\partial x^l}{\partial c^t} > 0$ and $\frac{\partial x^l}{\partial L} = -\frac{\partial x^l}{\partial L^N} < 0$. The results also match with intuitions regarding variables that affect patent litigations and with findings in Lanjouw (1998) about the value of patent protection.

After simplifying by letting $L = L^N + 2c^t$, we obtain $\Pi^l = -\frac{1}{2}\alpha n D x^2 + D\theta_0 n x - C^l$. When $\Pi^l = 0$, we can solve for the minimum requirement for a patent's exclusivity: $x^l = \frac{\theta_0 - \sqrt{\theta_0^2 - \frac{2\alpha C^l}{nD}}}{\alpha}$.

### A.1.6 Proof of Proposition 3

(a) When $\Pi^p = 0$, we have $\underline{v}^p = \frac{\sqrt{1+C^p(n+1)^2} - A}{1+nx}$. Also, notice that $\underline{x}^l$ is $x^l$ after we made simplifications of $\theta_0 = 1$, $\alpha = 1$, and $L = L^N + 2c^t$. So we have $\underline{x}^l = 1 - \sqrt{1 - \frac{2C^l}{Dn}}$. When $x > \underline{x}^l$, $\Pi^l > 0$. Thus, when $x \leq \underline{x}^l$ and $v \leq \underline{v}^p$, a patent is in D region with $\Pi^l \leq 0$ and $\Pi^l \leq \Pi^p$.

(b) Solving $\Pi^p = \Pi^l$ for $v$, we obtain: $v^* = \frac{-A+\sqrt{1+(1+n)^2[(C^p - C^l) + nD(x - \frac{x^2}{2})]}}{1+nx}$. Thus, when $x > \underline{x}^l$ and $v < v^*$, a patent is in L region with $\Pi^l > 0$ and $\Pi^l > \Pi^p$.

(c) After specifying the L and D region, then what remains on the plane is the P region with is to the right of the D region and to the up of the L region, with $v > \underline{v}^p$ when $x \leq \underline{x}^l$ and $v > v^*$ when $x > \underline{x}^l$. It worth noticing that when solving $\Pi^p = \Pi^l$ for $x$, we obtain two solutions:

$$x^{*1} = \frac{D - \frac{2v(v+A)}{(n+1)^2} - \sqrt{\Lambda}}{\left(D + \frac{2v^2 n}{(n+1)^2}\right)} \tag{A.2}$$

$$x^{*2} = \frac{D - \frac{2v(v+A)}{(n+1)^2} + \sqrt{\Lambda}}{\left(D + \frac{2v^2 n}{(n+1)^2}\right)} \tag{A.3}$$

where $\Lambda = \left(D - \frac{2v(v+A)}{(n+1)^2}\right)^2 - 2\left(\frac{D}{n} + \frac{2v^2}{(n+1)^2}\right)\left((C^l - C^p) + \frac{v(v+2A)}{(n+1)^2}\right)$.

There are two real solutions to $x^*$ while there is only one solution to $v^*$, this is represented in Figure 2.5 by the fact that for each $x$ value on the curve that splits the P region and the L region, there is only one $v^*$; while for a $v$ value, it can have two intersections with the P-L boundary, corresponding to the two $x^*$ solutions.

### A.1.7 Proof of Proposition 4

Recall that: $x^{*1} = \frac{D-\frac{2v(v+A)}{(n+1)^2}-\sqrt{\Lambda}}{\left(D+\frac{2v^2n}{(n+1)^2}\right)}$, $x^{*2} = \frac{D-\frac{2v(v+A)}{(n+1)^2}+\sqrt{\Lambda}}{\left(D+\frac{2v^2n}{(n+1)^2}\right)}$, $x^l = 1-\sqrt{1-\frac{2C^l}{Dn}}$, and $x^p = -\frac{1}{n}-\frac{A}{nv}+\frac{\sqrt{C^p(n+1)^2+A^2}}{nv}$. In addition, from $\Pi^l \geq \Pi^p \iff x \in [x^{*1}, x^{*2}]$ and $x^l > 0$, we know that the Litigating region is a convex set on $\{x|0 \leq x < 1\}$, meaning there is only one segment on $[0,1)$ that the optimal monetization will be Litigating. Also, as $\frac{\partial \Pi^p}{\partial x} > 0$ and $\frac{\partial \Pi^l}{\partial x} > 0$ $\forall x \in [0,1)$, we know that if there exists a Dormancy region, it must be the first segment on $[0,1)$, before Litigating region or Practicing region. Therefore, exhausting all combinations of D, L, P giving the constraints yields nine possible equilibrium sequences in terms of patnets' exclusionary strength $x$: (P), (L,P), (P,L), (P,L,P), (D), (D,P), (D,L,P), (D,P,L), and (D,P,L,P).

### A.1.8 Proof of Proposition 5

The proof is straightforward by replacing $n^U$ in $\Pi^l$ with $\rho = \frac{n^U}{n}$. Then it is easy to find that $\frac{\Pi^l}{\Pi^p} \propto \rho$.

# APPENDIX B APPENDIX TO CHAPTER 3

## B.1 A Formal Framework

### B.1.1 Patent characteristics

In this section, I derive the hypotheses in the main text formally using a simple model following the basic framework in Xu and Makadok (2019). Let each patent be characterized by its technological strength $v$ and exclusion scope $x$. The technological strength measures to what extent will the patent raise consumers' willingness-to-pay (WTP) or reduce the marginal production cost. For example, if a patent can increase consumers' WTP for the focal firm's product or service by 10% , $v = 0.1$. The exclusion scope $x \in (0, 1)$ measures to what extent will the patent be effectively exclude rivals in the same industry from using the technology either by inventing around or simply disregard the patent since it is poorly written. For example, if a patent can exclude half of the firms in the industry from using the technology, the exclusion scope $x = 0.5$, and to an extreme when a hypothetical patent is so poorly written that it can exclude no firm, then $x \to 0$.

### B.1.2 Value capture

Let $\Pi^p$ be the expected profit gain from the product market assuming ownership of the patent, and let $\Pi^l$ be the expected profit gain from the serial threatening of litigating.

In the patent market, assuming a simple bidding model where a PE and a PAE bid for the patent independently based on their assessment of patent value. Thus, a firm's strategy is either buy (B) or not buy (N) a patent $i$, denoted as $\sigma_{ij} \in \Omega$, where $\Omega = \{B, N\}$. If the firm chooses to buy the patent, then either $\Pi^l$ or $\Pi^p$ will be realized based on the type of the firm, if the firm chooses not to buy, then its payoff will be zero. Then let the profit from practicing and litigating monetization follow a random utility structure:

$$\Pi^p = V^p - C^p + \epsilon_p \tag{B.1}$$

$$\Pi^l = V^l - C^l + \epsilon_l \tag{B.2}$$

where $\epsilon_p$ and $\epsilon_l$ are the unobservable random component of $\Pi^p$ and $\Pi^l$ respectively, $V^p$ is the value capture for practicing monetization and $V^l$ is the value capture for litigating monetization.

The product market profit ($\Pi^p$) is a function of both the technological value and the exclusion scope of the patent, as well as the number of rivals in the market, denote as $V^p(x, v, N^p)$. The equilibrium price and quantity (and thus the revenue and profit) of the focal firm's product are completely determined by the dynamics of the product market following an n-firm oligopoly structure. I write the value creation from practicing monetization as:

$$V^p = \frac{\alpha v^2}{N^{p2}} \tag{B.3}$$

where $\alpha > 0$ is a demand parameter and $N^p$ is the number of firms using the technology and competing in the product market. Thus, the profit from practicing the patent $\Pi^p$ has increasing return in terms of the technological strength and is negatively related to the number of rivals in the market. Formally, these mean: $\frac{\partial V^p}{\partial v} > 0$, $\frac{\partial^2 V^p}{\partial v^2} > 0$, and $\frac{\partial^2 V^p}{\partial N^p} < 0$.

For the litigating monetization business model, the profit does not directly depend on the technological value of the patent (I will explain the indirect relation later in the section), but directly the number of potential targets and the patent's exclusion scope. In addition, how much can litigating monetization appropriate from each firm depending on the friendliness (or tolerance) of the legal regime to the plaintiff and its serial threatening behavior. Considering the odds of winning at court and the damage to be awarded if the patent owner wins, let $D$ capture the expected damage award to the plaintiff patent owner, with a higher $D$ meaning a regime more friendly to patent owners. Hence, the function of $D$ is to affect the WTP of targets. Noticing that the PAE does not have the capability nor the resource to evaluate and differentiate by charging different $D$ to different firms, the PAE will only estimate one $D$ for each specific patent, and try to ask each target firm to pay $D$.

So the profit from litigating monetization, $\Pi^l$, is a function of $n$, $x$ and $D$, denoted as $V^l(x, N^l, D)$, where $N^l$ is the number of users of the PAE. The PAE will choose valid targets from these $N^l$ firms. At first, $\frac{\partial V^l}{\partial N^l} > 0$, meaning that the more potential target, the more profitable is litigating monetization. This highlights the key distinction between litigating monetization and practicing monetization that PAEs would want as many firms to use the technology as possible while the PEs want as few firms use as possible.

Second, as the exclusion scope of a patent increases, more and more firms can be potential targets of threatening since they cannot avoid the patent. However, when targeting on those additional firms, the business model of litigating monetization will have a decreasing margin. The patent owner will start from threatening some easy targets (entrepreneurial firms that lack legal and technological capabilities for example) and get paid, but as the targets gets more capable, the expected payment by will decrease. For example, if a patent is strong enough for a PAE threat Apple, even if the PAE proceed, it is very unlikely that the threatening will be successful, since Apple will not give in and pay settlement fee easily, and will use its strong legal team to counter the threat. Therefore, $\Pi^l$ has properties: $\frac{\partial V^l}{\partial x} > 0$, $\frac{\partial^2 V^l}{\partial x^2} < 0$, due to the decreasing margin nature of its business model.

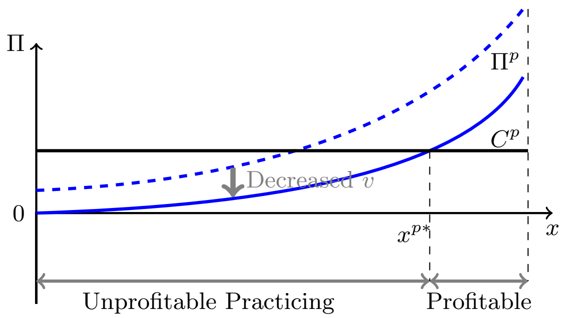
Third, let $\rho$ be the invalidation risk of patent so that the damage award $D$ reduces as $\rho$ increases $D = (1 - \rho)D_0$. Thus, we expect $\frac{\partial V^l}{\partial \rho} < 0$, reflecting the fact that a higher invalidation risk is detrimental for litigating monetization.

A patent with an exclusion scope of $x$ means the patent will exclude a portion of $x$ firms from using the technology. In another sense, had the patent be in stealth and all the firms are using the technology, then the patent will enable the PAE to target on $N^l x$ firms, who are infringing the patent. For each firm, the likelihood of yielding to the PAE is $(1 - 2\delta k)$, where $k$ is the firm's capability to avoid infringement. The stronger the firm's capability to avoid infringement, the less likely will it yield to threats of PAEs. Thus, we have the value generated by litigating monetization:

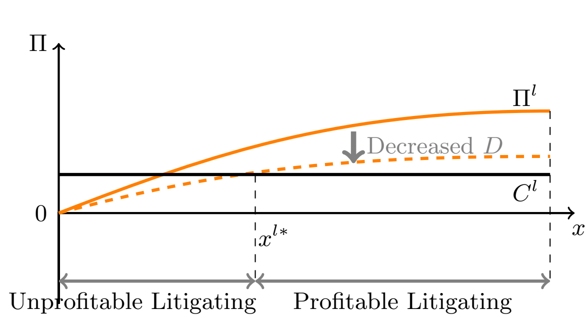
$$V^l = \int_0^{N^l x} D(1 - 2\delta k)dk = N^l x D(1 - \delta x) \tag{B.4}$$

in which $\delta \in (0, \frac{1}{2})$ is a parameter.

However, to implement either monetization method, there are some costs. Let $C^p$ and $C^l$ be the cost an owning party has to pay to realize the patent's practicing profit and litigating profit respectively. Further assuming that there is some uncertainty in both $C^p$ and $C^l$ so that $C^p$ and $C^l$ are two independent random variables with probability density function $f_{C^p}$ and $f_{C^l}$ respectively. Thus, the value of the patent to the PE is $\Pi^p = V^p - C^p$ and the value of the patent to the PAE is $\Pi^l = V^l - C^l$. The two panels in Figure B.1 plot the curves for $\Pi^p$ and $\Pi^l$.




(a) Practicing Monetization




(b) Litigating Monetization

Figure B.1.: Values from Practicing and Litigating Monetization

Notes: The horizontal axis is a patent's exclusion scope $x$ and the vertical axis is value Π. In Panel B.1a, the Blue curve is the value appropriation from practicing monetization ($\Pi^p$) and the Orange line in Panel B.1b is the value appropriation from litigating monetization ($\Pi^l$). Positions of costs maintaining the patent and implementing the strategy of practicing monetization $C^p$ and litigating monetization $C^l$ are shown in each panel. The dashed curve in Panel B.1a shows the impact when patents' technological strength ($v$) decreases. The dashed curve in Panel B.1b shows the impact when the expected damages awarded by the court ($D$) decreases. Regions of patents in terms of the exclusion scope for profitable and unprofitable monetization are marked accordingly.

### B.1.3 The diffusion of the technology and active user firms

Let the diffusion of the innovation be exponential and the number of firms using the technology and compete in the market be: $N_t = e^{\eta v t}$, where $\eta$ is a parameter. This expression reflects the facts that the number of users increases over time ($t$), and also that the stronger the technology (the higher $v$), the faster technological diffusion (the higher $N_t$). It is assumed that among the patents in the same cohort,[1] the better technology, the more firms will use the technology.

However, with the existence of the patent, in practicing monetization, a share of $x$ among the $N_t$ firms will be excluded so that the number of active competing firms is $N_t^p = (1-x)N_t = (1-x)e^{\eta v t}$. Let the length of the patent be $T$ and assume that when the patent expires, numerous firms will flood the market so that the profit becomes

[1]The same cohort means patents were granted around the same time and are in the same technology class

zero. Thus, at time $t$, the total product market profit that a firm can appropriate from a patent by holding it until expiration is:[2]

$$V_t^p = \int_t^T \frac{\alpha v^2}{N^p(s)^2} ds \tag{B.5}$$

$$= \int_t^T \frac{\alpha v^2}{(1-x)^2 e^{2\eta v s}} ds \tag{B.6}$$

$$= \frac{\alpha v}{2\eta(1-x)^2} \left(e^{-2v\eta t} - e^{-2v\eta T}\right) \tag{B.7}$$

With the above value function, we have: $\frac{\partial V^p}{\partial x} > 0$, $\frac{\partial^2 V^p}{\partial x^2} > 0$, which means that the return from practicing monetization is increasing in terms of the exclusion scope of the patent.

It worths noting that $V^p \mid_{x=0} > 0$, this reflects the fact that the technology has value in commercialization, even without any value from exclusion, i.e., the technology is an open innovation that diffuses fast among firms. Thus, we have:

$$\Pi_t^p = \frac{\alpha v}{2\eta(1-x)^2} \left(e^{-2v\eta t} - e^{-2v\eta T}\right) - C^p + \epsilon_p \tag{B.8}$$

However, in litigating monetization, with the patent exists in stealth, all the $N_t$ firms are using the technology until the PAE starts to assert patent rights, thus $N^l = N_t = e^{\eta v t}$. Also, instead of appropriating product market from a dynamic market with more rivals, litigating monetization will assert patents rights against available targets instantaneously:

$$V_t^l = N^l(t) x D(1 - \delta x) = e^{\eta v t} x D(1 - \delta x) \tag{B.9}$$

Thus, we have the profit from litigating monetization at time $t$:

$$\Pi_t^l = e^{\eta v t} x D(1 - \delta x) - C^l + \epsilon_l \tag{B.10}$$

[2]For the parsimony of the model, we do not include a discount factor. Nor do we use more complicated function forms of diffusion such as (Bass, 1969) because we only aim to capture the variation of numbers of users over time and among patents with different technological strength.

Then in the market for technology, the party whose bidding price is higher will acquire the patent. So when observing a transaction, the probability that the PAE wins the bidding is:

$$Pr_{PAE} = Pr\left(\Pi_t^l - \Pi_t^p > 0\right) \tag{B.11}$$

$$= Pr\left(e^{\eta v t} x D(1-\delta x) - \frac{\alpha v(e^{-2v\eta t} - e^{-2v\eta T})}{2\eta(1-x)^2} - C^l + C^p > \epsilon_p - \epsilon_l\right) \tag{B.12}$$

### B.1.4 Empirical hypotheses

For estimation, I use three specifications: Logit, Probit, and Linear Probability. When assuming both $\epsilon_p$ and $\epsilon_l$ follow type I extreme value distribution, we have the Logit equation below:

$$Logit(Pr_{PAE}) = log(\frac{Pr_{PAE}}{1-Pr_{PAE}}) = e^{\eta v t} x D(1-\delta x) - \frac{\alpha v(e^{-2v\eta t} - e^{-2v\eta T})}{2\eta(1-x)^2} - C^l + C^p \tag{B.13}$$

and when assuming $\epsilon_p - \epsilon_l$ is a standard normal random component in the Z-score of the Normal distribution, we obtain the Probit equation as:

$$\Phi^{-1}(Pr_{PAE}) = e^{\eta v t} x D(1-\delta x) - \frac{\alpha v(e^{-2v\eta t} - e^{-2v\eta T})}{2\eta(1-x)^2} - C^l + C^p \tag{B.14}$$

When we use the right hand side of Eq.B.14 to directly model the probability, we obtain the specification for linear probability model. Then, let $y_i$ be the dependent variable in those regressions, then the empirical models that I estimate will have the form:

$$y_{it} = e^{\eta v_i t} x_i D(1-\delta x_i) - \frac{\alpha v_i(e^{-2v_i\eta t} - e^{-2v_i\eta T})}{2\eta(1-x_i)^2} - C^l + C^p + \beta X_i + \epsilon_{it} \tag{B.15}$$

where $X$ is the matrix of control variables and $\epsilon_i$ is the error term. Also recall that $D = (1-\rho)D_0$, the hypothesized effects of patent characteristics and the legal regime can be written as the below FOCs:

$$\begin{cases} \dfrac{\partial y_i}{\partial v_i} & = Dx_i(1-\delta x_i)e^{\eta v_i t}\eta t + \dfrac{\alpha\left(\frac{2\eta v_i t-1}{e^{2\eta v_i t}} - \frac{2\eta v_i T-1}{e^{2\eta v_i T}}\right)}{\eta(1-x_i)^2} \text{ (Hypothesis 1a)} \\ \dfrac{\partial y_i}{\partial t} & = Dx_i(1-\delta x_i)e^{\eta v_i t}\eta v_i + \dfrac{\alpha v_i^2}{(1-x_i)^2 e^{2\eta v_i t}} \text{ (Hypothesis 1b)} \\ \dfrac{\partial y_i}{\partial x_i} & = D(1-2\delta x_i)e^{\eta v_i t} - \dfrac{\alpha v_i(e^{-2v_i\eta t} - e^{-2v_i\eta T})}{\eta(1-x_i)^3} \text{ (Hypothesis 2)} \\ \dfrac{\partial y_i}{\partial \rho} & = -e^{\eta v_i t}x_i(1-\delta x_i)D_0 \text{ (Hypothesis 3)} \end{cases} \tag{B.16}$$

I start by checking the sign of $\dfrac{\partial y_i}{\partial v_i}$. At first, $Dx_i(1-\delta x_i) > 0$ since $\delta < \frac{1}{2}$. Then, let $f(z) = \dfrac{z-1}{e^z}$. Then $\dfrac{df}{dz} = \dfrac{2-z}{e^z}$. When $z \geq 2$, $\dfrac{df}{dz} \leq 0$. Thus, when $\eta v t \geq 1$, meaning $N_t > e^{\eta v t} = e$, $\left(\frac{2\eta v t-1}{e^{2\eta v t}} - \frac{2\eta v T-1}{e^{2\eta v T}}\right) \geq 0$ such that $\dfrac{\partial y_i}{\partial v_i} > 0$. Hence, a sufficient but not necessary condition for $\dfrac{\partial y_i}{\partial v_i} > 0$ is that there are more than three firms that are potential users of the technology. From an economic perspective, this is likely to hold in most scenarios, which leads to our Hypothesis 1a that the likelihood of PAE acquisition is higher for patents which has stronger technology in the same cohort.

The logic of this result is that the likelihood of PAE acquisition increases with the potential "popularity" of the technology. The more firms using the technology, the more firms can PAEs target on, thus helping litigating monetization. However, if the technology is being used by many firms, from the perspective of practicing monetization, a PE cannot reap as much monopolistic product market profit. This explains the finding that PAEs tend to acquire more-cited patents among patents in the same cohort.

In addition, it is obvious to see that $\dfrac{\partial y_i}{\partial t} > 0$. This result leads to the argument underlying Hypotheses 1b that PAEs are not likely to outbid PEs for patents when the patent has high technological value. Only when the technology becomes well-established or obsolete (which imply that a patent is old), such that PEs' valuation of them depreciate, will PAEs outbid PEs and acquire those patents. In sum, PAEs tend to acquire those good but old patents.

Regarding Hypothesis 2, we want to examine the sign of:

$$\frac{\partial y_i}{\partial x_i} = D(1-2\delta x_i)e^{\eta v_i t} - \frac{\alpha v_i(e^{-2v_i \eta t} - e^{-2v_i \eta T})}{\eta(1-x)^3} \tag{B.17}$$

Let $g(x_i) = D(1-2\delta x_i)e^{\eta v_i t}$ and $h(x_i) = \frac{\alpha v_i(e^{-2v_i \eta t} - e^{-2v_i \eta T})}{\eta(1-x)^3}$. Then when $x_i \in [0,1)$, it is not difficult to see that $\frac{dg(x_i)}{dx_i} < 0$ and $\frac{dh(x_i)}{dx_i} > 0$. So $g(x_i)_{max} = g(0) = De^{\eta v_i t}$ and $\lim_{x \to 1} g(x_i) = D(1-2\delta)e^{\eta v_i t}$. Also, we have $h(x_i)_{min} = h(0) < \frac{\alpha v_i}{\eta e^{2v_i \eta t}}$ and $\lim_{x \to 1} h(x_i) = \infty$. When $e^{3\eta v_i t} > \frac{\alpha v_i}{D\eta}$, then $h(0) < g(0)$, such that there exists a $x_0$ which satisfies $\frac{\partial y_i}{\partial x_i} \geq 0$ if $x_i \leq x_0$ and $\frac{\partial y_i}{\partial x_i} < 0$ if $x_i > x_0$. These predictions regarding an invert U-shaped relationship between the likelihood of PAE acquisition and the exclusion scope of patents corresponds to my statements in Hypothesis 2.

For Hypothesis 3, since $\delta \in (0, \frac{1}{2})$, $x_i(1-\delta x_i) = x_i - \delta x_i^2 > 0$. Thus, $\frac{\partial y_i}{\partial \rho} = -e^{\eta v_i t}(x_i - \delta x_i^2)D_0 < 0$. The higher the risk of invalidation, the less likely will the patents be acquired by PAEs.

## B.2 PAE Data Collection

In this section, I give the procedures of obtaining a list of names of PAEs that involve in patent litigations. The data is from RPX Corporation[3] , but since RPX do not release their PAE list to non-enterprise subscribers, I use a more laborious route, steps are given below.

The litigation records are open to non-enterprise subscribers, I obtained all the litigations that involve PAEs. Then for each lawsuit, the party that was a PAE will be labeled by RPX in red. After clicking to enter the page of that specific PAE, if the entity had a parent company, then the name of the parent would also be given. At last, after clicking to enter the view of the parent company, its associated entities would be listed. Thus, I was able to obtain a list of PAEs that involved in patent litigations as well as their parent companies, if there was one.

[3] Some patent aggregators try to set themselves apart from NPEs to avoid being linked to the stigmatized public image. RPX is an example, though RPX is an NPE by definition, it calls the business model of NPEs is "Wasteful and Dangerous." See http://www.rpxcorp.com/network/patent-risk/

## B.3 Additional Tables

### B.3.1 Largest PAEs

In Table B.1, I list the 20 PAE entities with most patent acquisitions from 1970 to 2017. Entities are not aggregated to parent level.

Table B.1.: Top 20 PAEs with Most Patent Acquisitions

| Rank | Name | Patents | Rank | Name | Patents |
|---|---|---|---|---|---|
| 1 | Polaris Innovations | 3706 | 11 | Godo Kaisha IP Bridge 1 | 1327 |
| 2 | Round Rock Research | 3689 | 12 | North Star Innovations | 1294 |
| 3 | Rockstar Consortium US | 2483 | 13 | Ol Security | 1259 |
| 4 | Intellectual Ventures I | 2359 | 14 | Mosaid Technologies | 1225 |
| 5 | Callahan Cellular | 1914 | 15 | Level 3 Communications | 1152 |
| 6 | Rambus | 1720 | 16 | Gula Consulting | 1150 |
| 7 | Wi-Lan | 1543 | 17 | The Invention Science Fund I | 1131 |
| 8 | Industrial Technology Research Institute | 1538 | 18 | Intellectual Ventures II | 993 |
| 9 | Unwired Planet | 1374 | 19 | Empire Technology Development | 965 |
| 10 | Acacia Research Group | 1346 | 20 | Xylon | 952 |

Notes: 1. Names of PAEs come from RPX. Numbers are aggregated from patent transactions from the beginning of the USPTO patent assignment dataset until the end of 2017. Patent count are at entity level and are not aggregated to parents. 2. In the list, Intellectual Ventures I, Collahan Cellular, Ol Security, Gula Consulting, The Invention Science Fund I, Intellectual Ventures II, Empire Technology Development, and Xylon are all subsidiaries of Intellectual Ventures.

### B.3.2 Calculation of the Exposure Index

The exposure index is aimed to capture the variation in the exposure to the changes of the AIA among patent groups. While the AIA expanded channels for patent challenges, not all patents are subject to the challenge in the same degree. Patents of some patent groups were rarely involved in patent litigations before the AIA. Among a total of 663 CPC subclasses, patents of 603 patent subclasses were involved in litigations. And the index is computed as the share of a patent CPC subclass in all patent litigations at Federal district courts from 2000 to Spet. 15th 2012, the day before the enactment of the AIA. The distribution is described below in the table. Overall, the distribution is highly skewed, indicating the exposure to the AIA shall greatly differ among different patent groups. While the Top 9 CPC subclasses all has index more than 10, most CPC subclasses received very few litigations.

Table B.2.: Distribution of Exposure Index for CPC Subclasses

| N | Mean | St. Dev. | Min | Pctl(25) | Median | Pctl(75) | Max |
|---|---|---|---|---|---|---|---|
| 603 | 0.439659 | 1.94 | 2.57e-4 | 1.11e-2 | 4.07e-2 | 0.139 | 19.6 |

### B.3.3 Correlation Matrix of Patent-transaction-level Data

Table B.3 gives correlations between variables used in the analysis, as well as several raw variables before normalization. Except for the correlation between the raw variable and the normalized variable, there are not highly correlated variables, thus we do not concern about collinearity.[4]

[Insert Table B.3 about here]

### B.3.4 Exploratory Analysis

Table B.4 reports exploratory results on the relationship between patents' technological strengths and the likelihood of PAE acquisition conditional on being traded.

[Insert Table B.4 about here]

[4]As the data show, there is a relatively high correlation between Patent Age and the Number of Independent Claims, we pay attention this correlation and watch out for whether this affects empirical estimates.

Table B.3.: Correlation Matrix

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | PAE | | | | | | | | | | | | | |
| 2 | Post | −0.06*** | | | | | | | | | | | | |
| 3 | Age | 0.10*** | 0.15*** | | | | | | | | | | | |
| 4 | Tech Quality | 0.02*** | −0.02*** | −0.06*** | | | | | | | | | | |
| 5 | NPL Citation | 0.00 | −0.02*** | −0.10*** | 0.08*** | | | | | | | | | |
| 6 | Scope | 0.00* | −0.01*** | −0.10*** | 0.14*** | 0.09*** | | | | | | | | |
| 7 | Family Size | 0.01*** | −0.05*** | −0.05*** | 0.18*** | 0.09*** | 0.21*** | | | | | | | |
| 8 | N Ind. Claims | 0.07*** | −0.09*** | 0.34*** | 0.01*** | 0.00* | −0.02*** | 0.02*** | | | | | | |
| 9 | Generality | 0.01*** | −0.04*** | −0.04*** | 0.16*** | 0.08*** | 0.35*** | 0.10*** | 0.03*** | | | | | |
| 10 | Lit. Future | 0.12*** | −0.03*** | 0.01*** | 0.05*** | 0.02*** | 0.02*** | 0.03*** | 0.04*** | 0.03*** | | | | |
| 11 | Lit. History | 0.04*** | 0.01*** | 0.09*** | 0.03*** | 0.01*** | 0.01*** | 0.03*** | 0.08*** | 0.02*** | −0.01*** | | | |
| 12 | Exposure | 0.07*** | 0.06*** | 0.05*** | 0.03*** | 0.06*** | −0.03*** | −0.04*** | 0.01*** | −0.03*** | 0.04*** | 0.02*** | | |
| 13 | Software | 0.05*** | 0.01*** | 0.05*** | 0.03*** | 0.02*** | 0.00** | −0.03*** | 0.03*** | 0.01*** | 0.04*** | 0.03*** | 0.25*** | |
| 14 | Year-Quarter | −0.06*** | 0.86*** | 0.19*** | −0.02*** | −0.02*** | −0.01*** | −0.05*** | −0.11*** | −0.04*** | −0.04*** | 0.01*** | 0.09*** | 0.02*** |

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

Table B.4.: Exploratory analysis on Technological Strengths and the Likelihood of PAE acquisition

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 | Model 8 | | Model 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | LPM | Logit | Probit | LPM | Logit | Probit | LPM | Logit | Margins | Probit | Margins |
| NPL Citation | 0.001*** | 0.011** | 0.010*** | | | | 0.001*** | 0.023*** | 0.066†*** | 0.017*** | 0.126†*** |
| | (0.000) | (0.002) | (0.000) | | | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Age | | | | 0.004*** | 0.082*** | 0.040*** | 0.004*** | 0.083*** | 0.002*** | 0.040*** | 0.003*** |
| | | | | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Litigation History | 0.096*** | 1.235*** | 0.647*** | 0.073*** | 0.848*** | 0.462*** | 0.073*** | 0.844*** | 0.037*** | 0.459*** | 0.051*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Year-Quarter FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | Yes | |
| Tech Field FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | | Yes | |
| $R^2$ | 0.060 | | | 0.070 | | | 0.070 | | | | |
| Adj. $R^2$ | 0.060 | | | 0.070 | | | 0.070 | | | | |
| McFadden Pseudo-$R^2$ | | 0.137 | 0.135 | | 0.161 | 0.157 | | 0.161 | | 0.157 | |
| Num. obs. | 828780 | 828780 | 828780 | 829751 | 829751 | 829751 | 828780 | 828780 | | 828780 | |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: † The NPL citation variable used to calculate marginal effects is multiplied by 100 for better presentation in the table. P-values calculated using robust standard errors are in parentheses. The table reports LPM, Logit, and Probit results for testing the relationship between technological strength and the probability that a traded patent or an application is acquired by a PAE. I use the normalized proportion of non-patent backward citations (NPL Citation) of a patent to capture the cross-sectional variations of the technological strength, and use the age of the technology when being acquired to capture the temporal changes in technological strength . The main effect of both NPL Citations and Age are highly significant and positive, supporting the hypotheses that PAEs are more likely to acquire patents of good but old technologies. All models include a dummy variable of whether a patent was litigated before the transaction, as well as year-quarter and technology field fixed effects.

### B.3.5 Alternative measures of the Exposure index and regression results

In the main analysis, I use each patent subclasses' share in PTAB patent complaints as the measure patents' exposure to changes introduced by AIA.Other measures of the Exposure index are also calculated, including taking the maximum value of the subclasses that a patent is associated with as the patent's value instead of taking the mean (Alternative Measure 1), using patent subclasses' actual shares in PTAB petitions instead of pre-AIA patent lawsuits (Alternative Measure 2), and normalizing the exposure index by the share of the number of each patent subclass in all granted patents (Alternative Measure 3). Results from all the other measures of exposure do not qualitatively differ from what reported in the main analysis.

Results using the three alternative measures are reported in Table B.5. In calculating Alt Measure 2, I measure the exposure at patent subclass level as the share of PTAB petitions of the subclass in all patent litigations from Sept 2012 to March 2019. In calculating Alt Measure 3, I normalize the original exposure index by the share of the number of patents in each subclass' in all granted patents in year 2006, which is the middle year of 2000 and 2012. For all measures, a higher Exposure will mean that patents in that subclass has received or the potential to receive more patent challenges after AIA, which indicate high impact by the AIA.

[Insert Table B.5 about here]

### B.3.6 Firm-level data

For data regarding public PAEs, I aggregate patent acquisitions of entities to their parent companies, and then match with corporate information from COMPUSTAT. Table B.6 shows total patent acquisitions for PAEs that are publicly traded in NYSE or NASDAQ. For the subsample of publicly-traded PAEs, our data contains a total of 29,225 transacted patents.

Table B.5.: Alternative measures of Exposure and he impact of AIA

| | Alternative Exposure Measure 1 | | | Alternative Exposure Measure 2 | | | Alternative Exposure Measure 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 | Model 8 | Model 9 |
| | LPM | Logit | Probit | LPM | Logit | Probit | LPM | Logit | Probit |
| **Post*Exposure** | $-0.002^{***}$ | $-0.012^{***}$ | $-0.005^{***}$ | $-0.003^{***}$ | $-0.023^{***}$ | $-0.011^{***}$ | $-0.002^{***}$ | $-0.003$ | $-0.002$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.098) | (0.078) |
| Post | 0.004 | $-0.011$ | $-0.033$ | 0.005 | 0.036 | $-0.008$ | $-0.004$ | $-0.090$ | $-0.067^{*}$ |
| | (0.304) | (0.868) | (0.327) | (0.000) | (0.111) | (0.111) | (0.327) | (0.159) | (0.046) |
| Exposure | $0.001^{***}$ | $0.010^{***}$ | $0.007^{***}$ | $0.001^{***}$ | $-0.002$ | 0.001 | $0.001^{***}$ | $0.007^{***}$ | $0.005^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Quarter FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Tech Field FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| $R^2$ | 0.072 | | | 0.072 | | | 0.071 | | |
| Adj. $R^2$ | 0.071 | | | 0.072 | | | 0.071 | | |
| McFadden Pseudo-$R^2$ | | 0.163 | 0.159 | | 0.164 | 0.160 | | 0.163 | 0.159 |
| Num. obs. | 829723 | 829723 | 8297323 | 829723 | 829723 | 829723 | 829722 | 829722 | 8297322 |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Notes: P-values are in parentheses. The table reports LPM, Logit, and Probit results on the impact of the AIA and the likelihood of a PAE acquisition. All models use a specification of difference-in-differences with a continuous treatment intensity. The variable of interest is the interaction term Post*Exposure.

Table B.6.: Patent Acquisitions by Public PAEs 2007-2017

| Name | Patents | Name | Patents |
|---|---|---|---|
| Quarterhill (Wi-LAN) | 8777 | SITO Mobile Ltd | 141 |
| RPX Corp | 5849 | Universal Display Corp | 106 |
| Acacia Research Corp | 3414 | Network-1 Technologies Inc | 32 |
| TiVo Corp | 2912 | MGT Capital Investments Inc | 20 |
| MOSAID | 1951 | Inventergy Global Inc | 19 |
| Xperi Corporation (Tessera) | 1827 | Patriot Scientific Corp | 13 |
| Great Elm Capital Group (Unwired Patents) | 1498 | Worlds Inc | 9 |
| Rambus Inc | 1179 | Endeavor IP Inc | 5 |
| Walker Innovation Inc | 422 | Finjan Holdings (Vringo) | 5 |
| Spherix Inc | 330 | Asure Software Inc | 2 |
| InterDigital Inc | 278 | Axogen Inc | 2 |
| Marathon Patent Group Inc | 225 | VirnetX Holding Corp | 2 |
| Document Security Systems Inc | 207 | Total | 29225 |

Notes: The list of publicly listed PAEs is based on Maurer and Haber (2017). All numbers of patents are aggregated to parent company and include patent acquisitions of associated entities. Some PAEs changed their names, and their former names of those PAEs are given in parentheses.

The two tables below give more details regarding firm-level data. Descriptions for variables in the firm-level panel are given in Table B.7. Then, descriptive statistics for the firm-level panel are given in Table B.8.

Table B.7.: Firm-Level Variable Definitions

| Variable | Definition |
|---|---|
| Post | A binary variable which equals 1 when the time is after the implementation of AIA, 0 otherwise. |
| Time Index | Time to AIA (in years), a variable that captures time trend. |
| Total Acquisition | A firm's total number of patents acquired in a quarter |
| Current Assets | A firm's current assets, which includes cash, short-term investments, inventories, and receivables |
| Net Income | A firm's net income, which is obtained by subtracting a firm's loss and expenses from all revenues and gains. |
| Total Assets | A firm's total assets, which is current assets plus noncurrent assets, including intangible assets. |
| Cash | A firm's cash, which represents a firm's cash and all securities readily transferable to cash. |

Notes: Firm-level financial data are from Compustat.

Table B.8.: Firm-Level Descriptive Statistics

| Statistic | N | Mean | St. Dev. | Min | Pctl(25) | Pctl(75) | Max |
|---|---|---|---|---|---|---|---|
| Patents Acquired | 520 | 52.24 | 247.68 | 0 | 0 | 24 | 3,706 |
| Net Income | 516 | 1.24 | 29.57 | −208.62 | −5.86 | 7.37 | 235.67 |
| Current Assets | 504 | 268.35 | 273.82 | 0.18 | 49.00 | 405.59 | 1,420.30 |
| Total Assets | 505 | 570.02 | 745.22 | 0.19 | 68.93 | 690.97 | 3,534.48 |
| Cash | 494 | 111.42 | 116.40 | 0.002 | 17.95 | 154.03 | 687.20 |
| Post | 520 | 0.56 | 0.50 | 0 | 0 | 1 | 1 |
| Time Index | 520 | 0.12 | 3.13 | −5.75 | −2.50 | 2.75 | 5.00 |

Notes: The last nine public listed PAEs in Table B.6 are not included due to their extremely small number of patent acquisitions. The time period is the 44 quarters from 2007 Q1 to 2017 Q4. There are missing firm-quarter observations because some firms went public after 2007 Q1.

### B.3.7 Descriptions of CPC classes and subclasses

Table B.9 gives descriptions of the nine Cooperative Patent Classification (CPC) patent subclasses that appeared in more than 600 patent challenge petitions filed to PTAB from September 2012 to March 2019. They combined consist of more than 80% of all the 10k PTAB complaints. All descriptions of CPC codes come from USPTO website. The top two categories are G06F and H04L.

Table B.9.: CPC class and subclasses that received most PTAB petitions

| CPC Code | CPC Code Description | Number of Petitions |
|---|---|---|
| G06 | Computing; Calculating; Counting. | |
| • G06F | Electric digital data processing | 1940 |
| • G06Q | Data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes; systems or methods specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes, not otherwise provided for. | 1131 |
| H04 | Electric Communication Technique | |
| • H04L | Transmission of digital information, e.g. telegraphic communication | 1918 |
| • H04N | Pictorial communication, e.g. television | 879 |
| • H04W | Wireless communication networks | 774 |
| • H04M | Telephonic communication | 644 |
| Y10 | Technical Subjects Covered by Former USPC | |
| • Y10S | Technical subjects covered by former USPC cross-reference art collections [XRACs] and digests | 757 |
| • Y10T | Technical subjects covered by former US classification | 623 |
| A61 | Medical or Veterinary Science; Hygiene | |
| • A61K | Preparations for medical, dental, or toilet purposes | 663 |

Notes: One complaint can involve multiple patents and each patent can have multiple patent classes. Number of complaints are counted at the level of complaint-patent-subclass observations.

# APPENDIX C APPENDIX TO CHAPTER 4

## C.1 The Role of CVC

From the perspective of investors, CVCs differ from other independent venture capitals in their unique strategic motive in investing. CVCs very often offer additional complementary assets to the invested firm (Alvarez-Garrido and Dushnitsky, 2016; Teece, 1986) in exchange for the invested entrepreneurial firms advantage in producing radical innovations, which give opportunities for new firm creation (Henderson, 1993; Shane, 2001). Through CVC, new ventures provide established firms innovative ideas and windows to boost their own innovation (Dushnitsky, 2012; Dushnitsky and Lenox, 2005). CVC investment has a higher option value compared to acquisitions and grants the parent company more flexibility in developing new technologies (Tong and Li, 2011). However, CVC are also cautious about their investment decisions; for instance, when the intellectual property right (IPR) regime is weak, CVCs are less likely to invest in new ventures (Dushnitsky and Shaver, 2009).

While the CVC bears its responsibility from the parent corporation to explore new opportunities and gain a preview of the threats, when the venture that the CVC invested in gets involved in patent litigations, rather than proactively respond and fight side by side with the venture in the patent lawsuit for the portfolio firm, the CVC and the corporation behind may be better off back out to the safe area and keep some distance from the venture to avoid further exposure when necessary. If the CVC is dragged into patent litigations of its portfolio companies, then these fights may not be worth fighting since it does not align with the primary objective of the CVC. For example, if one giant sued a peripheral venture that another giant has a stake in, other than fight a full-blown litigation war, the other giant may save the cost and try to move cautiously and reevaluate the venture instead.

On the other hand, with the involvement of the CVC before, other VCs and CVCs will be less likely to have a major control right of the venture and thus be reluctant to chip in, especially when the venture is recently facing a patent litigation. When a VC invests, since its goal is to maximize the capital return, it will likely push the venture to be acquired or go IPO (Cumming, 2008). However, from the perspective of the existing CVC, it is not likely that either way will satisfy its interest in retaining the control while exploit the innovation of the venture. As to another CVC, the knowledge spillover to the previous CVC can be a potential concern (Henderson and Cockburn, 1996). Thus, when a CVC is in place, the litigation will only exacerbate the situation for the venture. Other potential investors would be even more prudent viewing the focal venture. In addition, although the CVC may be capable of carrying the invested venture to go through the patent litigation, we argue that doing so is not to the best interest of the CVC.

## C.2 Alternative Matching Procedures

Table C.1.: Descriptive Statistics of Alternative Matched Sample

| Statistic | N | Mean | Median | St. Dev. | Variance | Min | Max |
|---|---|---|---|---|---|---|---|
| Def | 62690 | 0.28 | 0 | 0.45 | 0.20 | 0 | 1 |
| Post | 62690 | 0.53 | 1 | 0.50 | 0.25 | 0 | 1 |
| Invl | 62690 | 0.16 | 0 | 0.36 | 0.13 | 0 | 1 |
| Log(Amount) | 62690 | 0.23 | 0 | 0.76 | 0.58 | 0 | 9.27 |
| Amount | 62690 | 2.28 | 0 | 48.39 | 2341.59 | 0 | 10618 |
| CVC | 62690 | 0.18 | 0 | 0.38 | 0.15 | 0 | 1 |
| LitAge | 62690 | 16.69 | 11 | 18.24 | 332.84 | 0 | 214 |
| Year | 62690 | 2010.06 | 2011 | 4.98 | 24.76 | 1995 | 2018 |
| Round | 62690 | 2.47 | 2 | 2.42 | 5.85 | 0 | 20 |
| Founding Year | 62690 | 1993.51 | 1998 | 18.74 | 351.10 | 1801 | 2016 |
| Treatment Year | 62690 | 2010.19 | 2011 | 4.35 | 18.88 | 2000 | 2017 |

Table C.2.: Correlation Table of Alternative Matched Sample

| Index | Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Def | 1 | | | | | | | | | | |
| 2 | Post | 0 | 1 | | | | | | | | | |
| 3 | Invl | 0.04 | −0.11 | 1 | | | | | | | | |
| 4 | Log(Amount) | 0.05 | −0.09 | 0.69 | 1 | | | | | | | |
| 5 | Amount | 0.02 | −0.01 | 0.11 | 0.27 | 1 | | | | | | |
| 6 | CVC | 0.03 | −0.01 | 0.08 | 0.12 | 0.01 | 1 | | | | | |
| 7 | LitAge | 0.06 | −0.03 | −0.12 | −0.13 | −0.01 | −0.14 | 1 | | | | |
| 8 | Year | −0.01 | 0.45 | −0.07 | −0.06 | 0 | 0 | −0.02 | 1 | | | |
| 9 | Round | 0.02 | 0.16 | 0.18 | 0.16 | 0.02 | 0.33 | −0.13 | 0.22 | 1 | | |
| 10 | Founding Year | −0.06 | 0.01 | 0.12 | 0.12 | 0.01 | 0.14 | −0.97 | 0.21 | 0.16 | 1 | |
| 11 | Treatment Year | −0.01 | −0.09 | 0 | 0 | 0 | 0.01 | 0 | 0.8 | 0.12 | 0.23 | 1 |

To examine the heterogeneous effect on firms that were backed up by CVCs, we add the interaction term $Post_{it} * Def_i * CVC_i$ to the baseline model. Model 3 in Table 3 confirms our hypotheses that CVC-backed firms, compared to firms invested by independent VCs, suffer more in receiving venture funding. On average, after litigation, the probability of a CVC-backed firm receiving a VC funding in a year is 0.086 lower than that of other firms. Similarly, Model 3 and Model 11 in Table 4 also show evidence that the amount of investment received by firms is also smaller than other firms. On average, CVC-backed firms only received 75% -80% of the investment that was received by other firms. Taken together, our results tend to support the backing off of CVC.

To test the moderating effect of firm age, we add the three-way interaction to the model $Post_{it} * Def_i * LitAge_i$. If as hypothesized, patent litigations have a more negative impact on less- established firms, then we should be able to observe a negative coefficient. Model 4 in Table 4.9 shows a highly significant positive coefficient on $Post_{it} * Def_i * LitAge_i$. While being litigated results in a drop-in investment probability of 0.081. On average, the negative impact is 0.003 lighter with one-year increase of the firm age when experienced the first patent litigation being the defendant. So, the result strongly supports Hypothesis 3a. Then we turn to Model 8 and Model 12 in Table 4.10. In both models, $Post_{it} * Def_i * LitAge_i$ has a highly significant positive coefficient of p-value smaller than 0.001. As the magnitude of the moderating effect, compared to the coefficient of $Post_{it} * Def_i$, one-year increase in the age when being the defendant for the first time, the negative impact of the litigation reduced by 4.5% to 12.9% (0.004/0.031– 0.057/1.574).

## C.3 Further refining of the matched sample

In addition to the main matched sample, we also did a stricter one to one matching of firms. Instead of choosing up to three firms with similar founding years, in this sample, we only match the treated firm to one firm that was founded at a year closest to the treated firm. In addition, we only choose litigated firms with a litigation year no later than 2013. The reason is that since the American Invents Act (AIA) was enacted in September 2012. The Act established the Patent Trial and Appeal Board (PTAB) and reformed Post-Grant Patent Review (PGR) and Inter Partes Patent Review (IPR) procedures for easier challenges towards patent validity. The influence on patent litigations could be substantial and since the enactment of AIA. Many defendants of patent litigations started to choose to make a challenge to the litigated patent at the PTAB. This could possibly complicate the treatment effect of the litigation itself. By choosing litigation years until 2013 and adopted a stricter rule of matching, we hope to further validate our findings reported before. In the end, we were able to match 1231 litigated firms to 1257 control firms. This sample of 2488 firms is out the sample to check the robustness of our finding.

We replicate the analysis on the likelihood of venture funding and the amount of venture funding using the new sample and report in Table table:litvcemr the results from LPM with firm and year dummies. The three variables of interest are marked in bold. The main effect $Post_{it} * Def_i$, showed a reduced level of significance due to the correlation among variables. But the two interaction terms still strongly support our hypotheses that while CVC investment exacerbates, firm age mitigates the adverse impact of patent litigations.

Then Table table:litvcimr reports the fixed-effect model and Tobit model results on the logarithm of the investment amount. The main effect in most models, except ones with interaction terms with CVC was significant. Again, this confirms and support Hypothesis 1b. The interaction terms with CVC and firm age are also highly significant, thus lending additional support to Hypothesis 2b and Hypothesis 3b. The reason that the main effect of the two models that include the CVC term is due to the high correlation between the two interaction terms.

Table C.3.: Robustness: Effect of Patent Litigation on the Likelihood of Receiving VC Financing

| | Model 13 | Model 14 | Model 15 | Model 16 |
|---|---|---|---|---|
| Post | $-0.031^{***}$ | $-0.043^{***}$ | $-0.043^{***}$ | $-0.042^{***}$ |
| | (0.010) | (0.009) | (0.009) | (0.009) |
| Post*Def | $-0.011$ | $-0.010$ | 0.009 | $-0.057^{***}$ |
| | (0.008) | (0.008) | (0.008) | (0.009) |
| Post*Def *CVC | | | $-0.091^{***}$ | |
| | | | (0.014) | |
| Post*Def *LitAge | | | | $0.003^{***}$ |
| | | | | (0.000) |
| Round 1 | | $0.508^{***}$ | $0.504^{***}$ | $0.508^{***}$ |
| | | (0.009) | (0.009) | (0.009) |
| Round 2 | | $0.602^{***}$ | $0.597^{***}$ | $0.601^{***}$ |
| | | (0.011) | (0.011) | (0.011) |
| Round 3 | | $0.627^{***}$ | $0.621^{***}$ | $0.630^{***}$ |
| | | (0.014) | (0.014) | (0.014) |
| Round 4 | | $0.591^{***}$ | $0.589^{***}$ | $0.598^{***}$ |
| | | (0.015) | (0.015) | (0.015) |
| Round 5+ | | $0.603^{***}$ | $0.606^{***}$ | $0.615^{***}$ |
| | | (0.015) | (0.015) | (0.015) |
| Round 10+ | | $0.599^{***}$ | $0.613^{***}$ | $0.611^{***}$ |
| | | (0.032) | (0.032) | (0.032) |
| Firm FE | Yes | Yes | Yes | Yes |
| Yesr FE | Yes | Yes | Yes | Yes |
| $R^2$ | 0.001 | 0.156 | 0.157 | 0.159 |
| Adj. $R^2$ | $-0.104$ | 0.067 | 0.068 | 0.070 |
| n | 2488 | 2488 | 2488 | 2488 |
| Num. obs. | 26384 | 26384 | 26384 | 26384 |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: Standard errors reported in parentheses. Dependent variable is Invl, which is a time-variant dummy variable which equals one if a firm i received a VC funding at year t.

Table C.4.: Robustness: Effect of Patent Litigation on the Amount of VC Financing

| | Model 17 OLS | Model 18 OLS | Model 19 OLS | Model 20 OLS | Model 21 Tobit | Model 22 Tobit | Model 23 Tobit | Model 24 Tobit |
|---|---|---|---|---|---|---|---|---|
| Def | | | | | 0.407*** | 0.565*** | 0.557*** | 0.577*** |
| | | | | | (0.110) | (0.109) | (0.109) | (0.109) |
| Post | −0.036 | −0.048* | −0.048* | −0.046* | −1.020*** | −1.547*** | −1.539*** | −1.569*** |
| | (0.020) | (0.019) | (0.019) | (0.019) | (0.131) | (0.130) | (0.130) | (0.130) |
| Post*Def | −0.049** | −0.046** | 0.001 | −0.124*** | −0.333* | −0.376* | −0.243 | −0.755*** |
| | (0.018) | (0.017) | (0.018) | (0.020) | (0.159) | (0.152) | (0.159) | (0.166) |
| Post*Def*CVC | | | −0.237*** | | | | −0.483* | |
| | (0.030) | | | | (0.199) | | | |
| Post*Def*LitAge | | | | 0.004*** | | | | 0.035*** |
| | | | | (0.001) | | | | (0.005) |
| LitAge | | | | | | −0.077*** | −0.077*** | −0.087*** |
| | | | | | | (0.003) | (0.003) | (0.004) |
| CVC | | | | | | | 0.192 | |
| | | | | | | | (0.109) | |
| logSigma | | | | | 1.333*** | 1.219*** | 1.218*** | 1.218*** |
| | | | | | (0.026) | (0.024) | (0.024) | (0.024) |
| Industry fixed effects | Yes | Yes | Yes | Yes | No | No | No | No |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| $R^2$ | 0.001 | 0.063 | 0.066 | 0.065 | | | | |
| Adj. $R^2$ | −0.104 | −0.036 | −0.033 | −0.034 | | | | |
| Log Likelihood | | | | | −13329.983 | −12144.871 | −12141.471 | −12135.903 |
| Left-censored | | | | | 23481 | 23481 | 23481 | 23481 |
| Uncensored | | | | | 2903 | 2903 | 2903 | 2903 |
| Right-censored | | | | | 0 | 0 | 0 | 0 |
| n | 2488 | 2488 | 2488 | 2488 | 2488 | 2488 | 2488 | 2488 |
| Num. obs. | 26384 | 26384 | 26384 | 26384 | 26384 | 26384 | 26384 | 26384 |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{+}p < 0.1$

Notes: Standard errors reported in parentheses. Dependent variable is Log(Amount) which is the logarithm of the amount of VC investment firm i received in year t, and is calculated as Log(Amount+1).

# VITA

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  - Purdue Strategy Area Proseminar, 2017.
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Faster but More Fragile? Organizational Learning in the Presence of Machine Learning, with Natarajan Balasubramanian and Yang Ye, **Resubmitted to *Academy of Management Review***.

- Presentations:
  - SMS Hangzhou Conference, 2020 (Scheduled).
  - SMS Virtual Annual Conference, 2020 (Scheduled).

How Does Patent Litigations Affect Entrepreneurial Venture Financing?

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