Essays on the U.S. Patent System

by

Matthew D. Henry

(Under the direction of David B. Mustard)

Abstract

This dissertation examines various aspects of the U.S. Patent System. The first chapter reviews the literature and traces the development of U.S. patent law with an eye toward recent reform proposals. In the second chapter, I measure the value of patents to firms and identify factors that contribute to that value by observing the abnormal change in firms' stock market values following court decisions. I find that firms lose .85% (about $19 million) of their value following a decision that one of their patents is "Invalid." Firms only gain about .7% of their value following a "Valid & Infringed" decision. I find that factors that that affect the expectations of investors as to the enforceability of patent rights are at least as important in determining the contribution of the patent to the firm's market value as are characteristics of the patent. Most prominently, "Invalid" decisions caused a .7% (about $15.5 million) greater loss of firm value after the Court of Appeals for the Federal Circuit was created. I conclude that patents are substantially more valuable to firms because of this change in the legal landscape. The third chapter examines the impact, on market competition and efficient bargaining over a license, of three regimes used to calculate damages in patent cases. I focus on product patents in a differentiated, duopoly setting. I find that regardless of the damage regime, the per-unit royalty under efficient bargaining is not unique. As a result, the "reasonable royalty" damage regime's application of a "hypothetical negotiation" gives the court significant discretion in assigning damages. If firms expect the court to choose

reasonable royalty damages to maximize incentives to innovate, and patent enforcement is certain, then the reasonable royalty regime generates higher incentives to innovate than the "lost profits" or "unjust enrichment" regimes. However, if patent enforcement is uncertain, the "lost profits" regime yields better incentives to innovate for patents covering the most valuable products, as it is the only regime that may deter infringement. The "unjust enrichment" regime is the weakest of the three. My results offer an efficiency argument for abandoning it.

INDEX WORDS: Patents, Legal Reform, Event Study, Damages, Hotelling

Essays on the U.S. Patent System

by

Matthew D. Henry

B.A., Washington & Jefferson College, 2001

J.D., The University of Georgia, 2005

A Dissertation Submitted to the Graduate Faculty

of The University of Georgia in Partial Fulfillment

of the

Requirements for the Degree

Doctor of Philosophy

Athens, Georgia

2007

Essays on the U.S. Patent System

by

Matthew D. Henry

Approved:

Major Professor: David B. Mustard

Committee: John L. Turner
Jeff M. Netter

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
August 2007

Acknowledgments

I thank my parents and siblings for their constant and unwavering support. I also thank my committee for their tireless efforts to improve my research and writing. I am also grateful to my fellow graduate students who were always willing to discuss my ideas. Chapter 2 of this dissertation benefited from the comments of seminar participants at the 2005 Southern Economics Association Conference and the 2005 UGA Summer Seminar Series. Chapter 3 benefited from the comments of seminar participants at the 2007 International Industrial Organization Conference, the 2006 Southern Economics Association Conference, and the 2006 UGA Summer Seminar Series.

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction and Literature Review

When the framers of the U.S. Constitution met in Philadelphia in 1787, the granting of the power to create a patent system to the federal government was largely uncontroversial. But the system that subsequent Congresses would create has generated far more debate. The U.S. system has been criticized in many circles as hindering, rather than promoting, technological progress. In particular, two recent books, Jaffe and Lerner (2004) and Bessen and Meurer (2007) are vocal critics of how patents operate in today's economy, but for different reasons. The complaints made of the patent system are similar to arguments that have been made for the past two hundred years. But the specific problems in today's system can mainly be traced back to the creation of the Court of Appeals for the Federal Circuit in 1982. The Federal Circuit's creation was justified, at least in part, as a way to maintain (or restore) the United States competitive advantage in the creation of new technology. But it is unclear whether its creation has been a net positive for the economy. This paper examines the controversy that is brewing in light of the theoretical underpinnings and the history of the patent system. It then addresses current proposals for reform.

Since the first patent laws were passed in 1790, the law has constantly been in flux. The situation faced today, with numerous "imprudent" patents being issued, is most closely analogous to the time from 1793 to 1832, when the patent system resembled a registration system, with examination by the Patent Office only to make sure that formalities were followed. The solution at that time was to define what qualified as a "new" invention, require that the patent be "useful and important," and to require an examination by a patent official before issuance. Jaffe and Lerner (2004) argue that the examination process has

become meaningless due to lack of resources and improper incentives given to examiners. Additionally, the Federal Circuit has strengthened the presumption of validity and reduced the nonobviousness test for patentability,[1] meaning that it is harder to invalidate patents. Thus, we find ourselves back in the pre-1832 predicament. However, most proposals for reform don't advocate the abolishment of the Federal Circuit or overturning of its decisions, but wish to once again refine the way patents are handled, such as by creating an opposition procedure within the PTO. The question remains as to what the best design is for a patent system.

This article will analyze the argument that the patent system is currently broken and various proposals for reform. More importantly, it will identify work that still needs to be done to inform this debate. Hopefully, it will serve as a call-to-arms for economic and legal experts as to the direction towards which the field must move. My primary conclusion is that the "right" patent system is not a fixed concept, but depends largely on perspective. Thus, stronger patents are advocated when patent protection is perceived to be weak, and vice-versa. Typically, arguments that patents are too weak focus on the lack of induced investment into research and development, while the arguments that they are too strong focus on the deadweight loss of monopolies or the potential legal costs of inventing in fields where patents have been granted. Additionally, there are competing theories as to the purpose of patents, and a unifying theory has yet to emerge. Perhaps the discussion herein will point towards an explanation for the trends observed in the legal system.

1.1 Theoretical Arguments for Patents

Before discussing the modern-day problems and proposals for reform, it is important to understand the philosophical underpinnings behind the patent system and the historical developments in the patent system that have led to where we are today. Most people would

[1] See also Lunney (2004) for this later point.

readily accept the idea that innovation is a crucial component of economic development.[2] An effective patent system will encourage this innovation and thereby promote economic progress. The traditional view of patents is that an inventor is granted a monopoly for a limited time to secure for them enough profits to make engaging in research and development a rational choice *a priori*.[3] Additionally, protecting an inventor's ideas will encourage the inventor to release their ideas into the public domain, where they may be improved upon by others. This disclosure will therefore help move technological progress forward. However, this argument is not universally accepted. For instance, von Hayek (1949) argues, "In the field of industrial patents in particular we shall have seriously to examine whether the award of a monopoly privilege is really the most appropriate and effective form of reward for the kind of risk-bearing which investment in scientific research involves." As Lemley (2005, p. 1031) states, "the proper goal of intellectual property law is to give as little protection as possible consistent with encouraging innovation."

However, there are other rationales for offering patent protection. Machlup and Penrose (1950) discuss four historical justifications for patents (not necessarily mutually exclusive arguments) that were debated in the 19th century, at a time when patent systems were heavily contested throughout Europe. One justification is that a man has a natural property right in his own ideas that patents are necessary to protect. Under this view, a patent is similar to a fence surrounding your land, and the enforcement of the patent is similar to suing someone for trespassing. This argument was embodied in the preamble to the French patent law passed in 1791. Detractors from this argument cite the differences between ideas and real property. For instance, they argue that ideas are non-rival, whereas real property is a rival good. Furthermore, inventions aren't even ideas because they can be perfectly replicated.

[2]According to Nordhaus (1969, p. 8) the idea that "technological change is the major source of growth of per capita income" has become a generally accepted belief. See his discussion for a description of prior studies. See also, Romer (1990, p. S72), who argues "that technological change...lies at the heart of economic growth."

[3]See, e.g., Plant (1934, p. 32).

Finally, patents, unlike other property laws, can deny someone the ability to use their own ideas, which may have been developed independently.

Second, people argue that patents are necessary to give inventors their just reward for their services. Thus, patent law is grounded in equity. To counter this argument, John Lewis Ricardo in 1851 said, "nearly all useful inventions depend less on any individual than on the progress of society."[4] Under Ricardo's view, the inventor is owed nothing by society, because without society, he would not have been able to make the invention anyhow. Additionally, had he not made the invention, it would have been invented by someone else nonetheless. Others would counter this justification for patents by citing studies that show inventors enjoy a powerful first-mover advantage, even absent patent protection.[5] For instance, competitors of the inventor may not recognize the market opportunities of the invention. Further, by the time they are able to imitate the invention (which may come at substantial cost), the inventor's product may already be well-seated in the marketplace. The brand name that has been established can allow the inventor to reap economic profits even absent the protection of a patent.

Building on the just reward argument, a third justification for patents is that they provide the best incentives for innovation. Critics of this view either disagree with (1) the proposition that not enough inventions will be made or used unless incentives are provided or (2) that patents are the cheapest and most effective way to provide those incentives. Critics find the patent system socially costly because it could steer resources toward unproductive activity,[6] the bureaucratic costs of administering the system, the deadweight loss associated with

[4]Machlup and Penrose (1950, p. 18).

[5]See, e.g., Scherer (2006), and his discussion of his previous work, as well as the results of the Carnegie-Mellon (Cohen, Nelson and Walsh, 2004) and Yale (Levin et al., 1987) surveys of industries. See, additionally, Levin (1986).

[6]These unproductive activities may stem from duplicative research by firms engaged in patent races, or by researching profitable inventions rather than socially important ones (for instance, developing Viagra instead of a cure for malaria). Patent protection enhances the incentive to find the profitable invention. Machlup and Penrose (1950, p. 23) notes, "To the extent that the stimulus of the patent system is effective, in the sense of causing people to do what they would not do otherwise, its effectiveness may consist chiefly in diverting existing activity into different, perhaps less productive, channels."

monopolies, and the cost of preventing others from producing by the most efficient process or making further improvements or refinements to existing processes. Further, critics argue that the inventors don't get much of the profits from their ideas, which are often captured by the capitalist who licenses their ideas to bring it to market.[7] Alternative incentive systems may produce innovations at a smaller social cost. For instance, governments could reward inventors with cash prizes, rather than monopoly rights. Advocates of cash prizes, however, need to answer for how the size of the prize is to be determined and find a way to pay for it that is more equitable. As Say (1803, p. 263) noted, "The costs (of patent monopolies) are paid only by those who do not mind paying them; their wants...are not less fully satisfied than before."[8] The profits earned by the inventor come directly from the consumers who are enjoying the fruits of their labor. Additionally, accounting for the monopoly deadweight loss as a social cost of the patent system presupposes that the invention would have been made (or made at the same time in history) absent the assurance of patent protection, which may not be the case.

Ultimately, whether patents provide the best incentives to innovate depends on how innovation occurs. Under what Nordhaus (1969) calls the "Schumpeterian tradition," inventors are either driven by their own curiosity or inventions are stumbled upon (for instance, the discovery of penicillin). In this view, patents are largely useless for spurring innovation. However, as Nordhaus notes, this position is inconsistent with the fact that the number of patents issued to individuals has declined relative to firms.[9] Conversely, the view that innovation occurs as the result of a deliberate process, which elevates the importance of strong patent protection, is becoming more accepted.

A final justification for patents discussed by Machlup and Penrose (1950) is that they give the best incentive for inventors to disclose their secrets. Under this view, patents have

[7]This criticism may have made more sense in 19th century economies, which lacked the well-developed and competitive markets for capital that exist today. Additionally, more patents are issued to firms today than to individuals, although these firms may not produce for themselves.

[8]Cited from Machlup and Penrose (1950, p. 8)

[9]This argument relies on the assumption that patent counts accurately reflect inventive activity.

arisen as a type of contract between society and the inventor. Opponents argue that it is practically impossible to keep things secret forever, and if that was possible, firms would do it regardless of patent protection.[10] In fact, firms are more likely to patent things if there is a greater likelihood that the product or process will be developed independently prior to the patent expiring. Finally, detractors say, having a patent system in place could actually slow the release of ideas because inventors will keep their ideas secret while they are in the developmental stage. Absent patents, it is possible that people will publicize their ideas earlier to get the accompanying recognition.

The arguments presented above formed the majority of economic and legal thought on patents for over 500 years after the first patent was issued. Kitch (1977, p. 265) proposed that the "patent system performs a function not previously noted: to increase the output from resources used for technological innovation." Under Kitch's novel "prospect theory," patents were similar to the mineral rights system that was developed in the American west. The patentee was staking out a claim to a given area of technology, which then allows them to direct the exploitation of the new innovations in that area. To support this argument, Kitch points to three features of the patent system that are justifiable under the prospect theory rather than the traditional "reward function." First, the scope of patents is usually greater than what the reward would require. Second, many rules of the patent system encourage early application, possibly before a marketable (and therefore, profitable) reduction of the technology to practice has been found. Finally, many important patents are issued before it is even possible to exploit them commercially. In his view, the protection of intellectual property rights results from the scarcity of resources with which to exploit information, rather than a scarcity of information (as is the case with the protection of real property). Prospect patents promote efficiency by economizing the direction of research, preventing duplicative research, allowing for the transferability of ideas, and protecting investments to exploit new technologies. The prospect theory has many implications for patent policy. For instance,

[10]This criticism is also supported by the Yale and Carnegie-Mellon surveys cited earlier.

the test of novelty, under the Court's decision in *Cuno Engineering v. Automatic Devices Corp.* (1941),[11] required "a flash of creative genius." This test was hard to justify under the reward theory, which would imply a patent should only issue if the inventor toiled over the discovery. The prospect theory would suggest that the flash of genius opened up a new area of technology that could then be cordoned off and exploited. Also, the commercial success rule would, under the prospect theory, be viewed as protecting the inventor's investment in the exploitation of their ideas, which simplifies issues such as the role that marketing played in making an invention commercially successful. This theory has been met with large amounts of both praise and condemnation.

A similar, but distinct, view of patents was developed by Duffy (2004). Duffy views patents as analogous to the rewards of winning a government auction of a natural monopoly franchise, as proposed by Harold Demsetz. Duffy considers a patent a special case of a natural monopoly. Granting the exclusive franchise to one person allows for efficiency gains in exploiting the technology. Unlike the usual auction, where monopoly rents are dissipated by increasing quality or lowering price to have the winning bid, patentee's rents are dissipated by the competition to be the first to file and win the patent. Because a patent is filed before a commercial product is created (as under the prospect theory), filing for the patent sooner, and hence, having it expire sooner, will allow less monopoly rents to accrue to the patentee. Therefore, even with patents, there will be a small social cost imposed by the monopoly.

The underlying question that must be asked in evaluating a patent system is whether its existence enhances or harms social welfare and progress. This question also can be used to illuminate certain policy questions. For instance, Forman (1967) suggests that patents resulting from government funded research should only be granted if the technology is utilized by the inventor. This argument could be extended to the grant of any patent if what we value is enhancing total welfare (of course, this would contrast with the property rights argument). Additionally, enhancing social welfare is an important motivation behind the argument for

[11] 314 U.S. 84

granting compulsory licenses (whether to increase competition to diminish deadweight loss or to ensure that the invention is brought to market).

The optimal design for a patent system will depend largely on the objective for that system. While it is debatable as to which justification for the patent system is most important, the reward theory is the underlying justification for most theoretical work. Typically, the reward theory is the easiest to study because the costs and benefits can be clearly defined. Additionally, other theories, such as the natural right theory, invoke absolute principles that can shut off debate, and are therefore not worth studying. Nonetheless, ignoring the alternative ways that patents can impose costs or generate value causes a deviation between theoretical findings and reality.

1.2 The Genesis of the U.S. Patent System

Patents granting monopolies can trace their history to circa 1400 in the mining regions in eastern Germany and in maritime and mining districts of Venice.[12] Early patents were granted by the monarch in an arbitrary fashion. Because of the perception of abuse of this power, the legislatures of both Germany (1512) and England (1624, Statute of Monopolies) had to eventually step in. Early patents shared some basic characteristics. They were issued only after the examination and testing of a model. They were considered personal property. The monopoly rights granted were of a limited duration (10-20 years) and scope. And courts could void the monopoly rights if it was shown that the patented product was not newly imported or newly invented.

Patents were generally opposed by the existing artisan guilds. These guilds felt that the grant of monopoly rights to one individual was unfair because it was difficult to show that prior art existed at the time a patent was granted. Also, it was possibly the case, as found by Scherer (2006) for businesses over two centuries later, that patents were most important

[12]The discussion that follows is based largely on the more extensive writings of Prager (1961) and Machlup and Penrose (1950).

for start-ups (the new patent holder) against well entrenched rivals (the guilds). Regardless of the reasons for the artisan guilds' discontent, it is probable that the lack of established industries and guilds was a contributing factor for the generally favorable impression that most Americans have had towards patents. Early western European economists, such as Bentham, Smith, and Mills, mostly thought that patents were good for society, but early German economists were less enthused.

By the late 18th century in America, "(m)ajorities of the people began to see that human progress is possible and that it can promoted."[13]. Benjamin Franklin was foremost in advocating the idea that state action could encourage innovation. After achieving independence, most states passed copyright acts in the 1780's, and at least one state had a patent act. When the Constitutional Convention convened in 1787, allowing the government the power to grant patents was generally accepted.[14] The Constitution that was eventually ratified avoided using the language the government, in approving patents, was "granting" anyone rights. Rather, the Constitutional language reflected the view that patents were designed "to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."[15] The framers probably chose this language to distance themselves from the idea that Congress would be able to give away rights to anyone, which could lead to the skepticism of patents as being given to the politicians' political cronies, as was the case in the European systems. This language also reflected the equity and natural rights justifications for patents. Federalist Paper #43 recognized that the rights of patents came from common law and stated "the utility of this power will scarcely be questioned." President Washington, in his first message to Congress, stated, " 'I cannot forbear intimating to you the expediency of giving

[13]Prager (1961, p. 316)

[14]A cursory search of the Avalon Project at Yale Law School's collection of debates recorded by Madison reveals little discussion of this provision. According to Federico (1993, p. 163), the provision related to patents and copyrights "was adopted without any dissenting voice."

[15]Art. I, $\oint 8$.

effectual encouragement...to the exertions of skill and genius in producing' new and useful inventions."[16]

The first patent law was enacted by Congress in 1790. Rather than passing individual private laws for each patent, Congress decided to delegate that power to a special Patent Board created for such purpose. The Patent Board consisted of the Secretary of State, the Attorney General, and the Secretary of War. Although the Senate tried to add a provision into the law creating compulsory licenses, it did not ultimately make it into the bill that passed. The law provided the first clearly regulated procedure for examination. It also was the first patent system to prescribe that the patents' specifications were to be developed through negotiations between the inventor and the government, to protect the interests of both the inventor and the public. The law also gave the patent a presumption of validity. Perhaps the most important contribution of the new law was that it "made clear that American patents would exist as a matter of law, not as a matter of sovereign favor or grace."[17]

1.3 Developments in the first 200 years

Thomas Jefferson, who at the time was the Secretary of State and the leader of the Patent Board, imposed important rules for what was patentable that laid the foundation for the subsequent development of American patent law. Specifically, Jefferson thought that giving new forms to old tools, mixing new proportions of old compositions, and using old processes for new purposes were all unpatentable ideas. However, creating these standards for patentability required thorough examinations. Additionally, the provision of the law that required negotiation between the applicant and the Board to write the specifications of the patent was time consuming for the Board members. Thus, the Board was soon overwhelmed, especially in light of their other official duties.

[16]Federico (1993, p. 164).
[17]Prager (1962, p. 45).

Spurred by Jefferson, Congress changed the law a mere three years after the original bill had passed. The most prominent change was making the granting of patents largely a clerical function through a new Patent Office, with applicants just having to comply with certain formalities and pay the requisite fee. The new law rejected the idea of the examiner insuring that invention was new, and left novelty for the courts to decide.[18] Thus, the novel characteristics of the American system were dispatched with soon after they were created. Under the new law, the specification was good "so long as no one was able fully to show a concealment therein which was made for the purpose of deceiving the public."[19] It also abolished the presumption of validity that had been originally contemplated. Finally, the new law trebled the recovery for infringement.

Again, the new law soon proved unworkable. Because of the complete lack of review in the Patent Office, worthless and imprudently granted patents flooded industries and litigants found that court proceedings were an expensive form of review of patents.[20] Yet courts would typically overturn patents on the grounds of formalities, rather than on the novelty of the invention. The Court's decision in *Grant v. Raymond*[21] proved to be a watershed in the development of the U.S. patent system. In dicta in that decision, Chief Justice Marshall suggested ways to balance the equities of the inventor and the public, and Congress was once again spurred into action. Reforms to the existing law were passed nearly immediately in 1832, and a whole new code was passed in 1836 and amended further in 1839.

The reformed patent statute finally provided a definition of what comprised a "new" invention; an invention is new if it "has never been described in a public work and has not more than two years been used in public."[22] It also returned the requirements of invention to their pre-1793 status. The invention had to be "sufficiently useful and important." The new

[18]Note the similarity between this concept and the "rational ignorance" of Lemley (2005) discussed later.

[19]Prager (1962, p. 48).

[20]Recall these arguments in the discussion of the modern patent system.

[21]6 Pet. (31 U.S.) 218 (1832)

[22]Prager (1962, p. 53).

statute also reimposed an examination in the patent office, but eliminated the requirement that the government write a separate description of the invention. Unlike the 1790 law, the examination function of the government was delegated to a lower-level executive. Even though examination was reinstituted, the presumption of validity was not. The new law also provided for the publication of patents, which facilitates the disclosure function of patents. Finally, the new law abolished punitive damage awards in normal patent cases.

The era that followed the passage of the new law was characterized by an anti-patent attitude. For instance, in the case of *O'Reilly v. Morse*,[23] the majority rejected the pioneering patent of the Morse telegraph. The dissent in the case criticized the decision as "looking at a monument through a microscope," which was a general condemnation of the view courts had taken of pioneering patents. Nonetheless, America largely avoided the patent abolition movement that was occurring throughout Europe, reaching its peak in the 1860's. Despite the *Morse* case, the anti-patentee tide began to turn in the U.S. in 1853. Other court decisions in that year reintroduced the presumption of validity for granted patents and established the doctrine of equivalents, which effectively expanded the scope of patents. Prager (1962) estimates that the Supreme Court held patents valid about fifty percent of the time in the 1860's and 1870's, which was greater than previous eras. The number of patents applied for also grew steadily during this time period. A new patent act was passed in 1861. This act provided for an appeal to a panel of three examiners-in-chief within the Patent Office. The law also abolished patent-term extensions, but raised the standard term to seventeen years.[24] The only other notable legislative changes occurred in 1870, but most of these reforms were procedural, like dropping the requirement of submitting a model with the application and providing for the publication and distribution of the Patent Gazette (previously, only expired patents had been published). The wave of pro-patentee decisions continued through the 1920's. Around the turn of the century, "regulators could not block multiple patent-holding firms from coming together to form patent pools that were used to collectively restrict output

[23]15 How. (56 U.S.) 62 (1853).

[24]Previously, patents were granted for fourteen years, with a possible seven year extension.

and control prices. In 1902, the U.S. Supreme Court went so far as to state 'the general rule is absolute freedom in the use or sale of patent rights under the patent laws of the United States.'"[25] The Supreme Court allowed patent holders to engage in various anti-competitive activities, including price maintenance by their licensees.

It wasn't until the 1930's and the Great Depression that the movement was once again reversed. The Depression brought with it a hostility toward monopolies, which were viewed as an exacerbating factor preventing recovery. Courts began to enforce anti-trust laws, even against patentees. This led to numerous compulsory licenses being issued, both by court rulings and mutual consent. Patent holders were nonetheless awarded a reasonable royalty in most such cases.

As part of an effort to revise and codify the laws of the United States into the new United States Code, a new Patent Act was passed in 1952. But the new act did contain a few major additions. The first major change was the new $\oint 103$, the requirement of nonobviousness for patentability. The accompanying Committee Report to the new bill points out that this condition had existed in the common law for the previous hundred years, but it had yet to be enacted by Congress. Additionally, the legislative history of the bill explains that it doesn't matter whether the invention was the product of long toil or a flash of genius as to whether the idea was obvious. The second major addition of this legislation was that it was the first to define what constitutes infringement, and, in particular, a clarification of the law on "contributory infringement," which had previously been unclear in light of court decisions. Other important changes to the law include the addition of $\oint 120$, which formulated the process for "continuing" patent applications, and $\oint 121$, which formulated the "division" of applications procedure. The new law also added the "best mode" requirement for the specification and codified the Patent Office's practice on secrecy of applications. The new act also added $\oint 282$ to grant the patent a presumption of validity, and placed the burden of proving invalidity on the party asserting it. As noted above, this was the law prior to

[25] Jaffe and Lerner (2004, p. 96).

the act, but was not in the statutes. Finally, the new statute overruled court precedent that determined a patentee would have to disclaim, within a reasonable time, any individual claims that were found to be invalid to preserve the remaining claims of the patent. It is also worth noting that $\oint 5$ of the new act, which repeals the previous statutes, states, "Any rights or liabilities now existing under such sections or parts thereof shall not be affected by his repeal." As Federico (1993) points out, this statement reflects three principles relating to Congress's ability to legislate patent law. First, Congress has the ability to affect pending patent applications any way it pleases. Second, unless given just compensation if the rights are taken for a public purpose, Congress cannot adversely affected patent rights that have already been granted. Third, Congress retains the power to validate invalid patents, although this ability is limited by the rights of potential infringers, who probably cannot be held liable for activities that took place during the period of invalidity.

Prior to 1964, when infringement was found, damages were typically assessed on the basis of the infringer's profits attributable to the infringing activities. In that year, the Supreme Court ruled that when Congress had amended the law in 1946, the intended to proscribe this method for determining damages.[26] Since 1964, damages can only be assessed based on the patentee's lost profits or by applying a reasonable royalty rate. Chapter 3 of this dissertation provides an efficiency justification for this change in the law.

Around the time of the passage of this Act, public perception of patents was also beginning to turn back around. In particular, two 1956 court decrees ordering the licensing of patents held by AT&T and IBM drew intense public scrutiny. By the late 1970's, the emergence of other high-tech economies led to a widespread belief that increased patent protection was needed for the U.S. to keep its competitive advantage on the world stage and end its recent economic malaise. This feeling prevailed despite research finding that patent protection was largely meaningless to most firms.[27] This atmosphere led to the most drastic change

[26] *Aro Manufacturing Co. v. Convertible Top Replacement Co.*, 377 US 476 (1964).

[27] This research is summarized in Scherer (2006).

in the two hundred year history of patent protection in United States, the creation of the Court of Appeals for the Federal Circuit.

1.4 The creation and effects of the Federal Circuit

In 1977, the Office of Improving the Administration of Justice (OIAJ) was created to examine the functioning of the legal system, particularly the appellate functions.[28] In this task, they were aided by two previous commissions set up by the Congress, the Freund Committee (1972) and the Hruska commission (1975).[29] The OIAJ concluded that patent and tax law were the areas suffering the most from lack of uniformity. In considering reforms, the OIAJ identified three primary concerns. First, the reforms should not cut off anyone from access to the Supreme Court. Second, the reforms should not create a "fourth tier" in the judicial system. Finally, both the bench and the Bar were against the creation of "specialized courts." Generally, specialized courts are disfavored because of fears that they will fall subject to tunnel-vision and the risk that they could be captured by special interests. After much consideration, they decided the best course of action would be to merge the Court of Claims and the Court of Customs and Patent Appeals into a new court with jurisdiction over tax and patent appeals, and certain environmental disputes. This solution was particularly attractive from a logistical perspective because the Ct. of Claims and the CCPA already shared the same building in Washington D.C. Additionally, the proposal satisfied the concerns listed above. However, due to widespread opposition, jurisdiction over environmental concerns were soon dropped. Additionally, because of opposition from the Treasury Department (among others), jurisdiction over tax appeals was also dropped.[30] Generally, the proposal (which was introduced as S. 677 on March 15, 1979) was supported by corporate patent lawyers, but was

[28] Much of this account was taken from Meador (1992), who was the head of the OIAJ when it was created.

[29] The Hruska Commission had recommended the creation of a new court, but only for cases referred to them by the relevant appeals court to render decisions in cases involving precedential decisions. Although they did identify lack of uniformity leading to forum shopping as a problem, they explicitly rejected creating a new court to hear all patent cases.

[30] A seperate bill to create the Court of Tax Appeals was eventually introduced.

opposed by trial attorneys. Opinions of the public were still sharply divided. Against the bill were people who thought the new court wasn't sufficiently diversified and/or the problem of forum shopping was overblown.[31] In the other camp were those who thought the new court would strengthen the patent system, which would improve the growth of technology and innovation.

A new bill had to be introduced in the next Congress, and this bill gave the new court jurisdiction over patent appeals and appeals of government contract claims. By this time, the OIAJ had organized the corporate patent counsel into an effective support group in favor of the Federal Circuit.[32] The bill passed through both the House and the Senate easily,[33] and largely with bipartisan support. Regression analysis by of the House vote by Scherer (2006) reveals that Democrats were more likely to vote in favor of the bill, as well as representatives from states with more intensive industrial research and development expenditures and states with more pro-patentee circuit appeals courts. In response to the concern that the judges of the new court would have tunnel-vision, the enabling legislation attached to the Federal Courts Improvement Act suggested that the judges appointed to the new court come "from a broad range of qualified individuals." However, the Reagan committee on productivity slowdown suggested appointing "experienced patent lawyers to vacancies" on the Federal Circuit. Although the judges that have been appointed to the court appear to be from mixed backgrounds, Allison and Lemley (2000) found that 63% of validity decisions were written by judges who had a patent background despite these judges only comprising 38% of the judges on panels hearing the cases.

In the floor debate in the Senate before the passage of the bill, Senator Dole said "the bill will not substantively affect current law."[34] While the bill didn't change any patent laws, its

[31]The recent work of Turner, Atkinson and Marco (2007) finds that forum shopping by patentee-plaintiffs (on the basis of validity rates) actually ceased several years before the Federal Circuit was established.

[32]Scherer (2006, p. 23).

[33]The votes were 321-76 and 83-6, respectively. *Id.* at pg. 24.

[34]Scherer (2006, p. 25).

implementation dramatically changed the patent system. According to Landes and Posner (2004, p. 26), the Federal Circuit "has defined its mission as promoting technological progress by enlarging patent rights." In their view, the specialized courts are more mission-oriented than generalist courts. As a result, the Federal Circuit's creation can be attributed to the lobbying activity of those who wanted intellectual property rights to be expanded. Similarly, Jaffe and Lerner (2004, p. 2) find, "The new court of appeals has interpreted patent law to make it easier to get patents, easier to enforce patents against others, easier to get large financial awards from such enforcement, and harder for those accused of infringing patents to challenge the patents' validity." Henry and Turner (2006) found that the introduction of the new court caused a profound and statistically significant change in the share of appellate decisions affirming a ruling of invalidity, with an accompanying structural break in the number of "invalid" decisions rendered by district courts. The structural breaks occurred in 1983 and 1982 respectively, corresponding to the Federal Circuit's first decision in October of 1982. Specifically, Scherer (2006, p. 25) finds that the Federal Circuit was "more generous than the decentralized appellate courts in ruling that patents whose validity was challenged on the basis of insufficient novelty or utility were in fact valid." One way that the court brought about this change was by raising the presumption of validity for granted patents to a "clear and convincing evidence" standard, which is a greater burden than some of the geographical circuits had applied.

The Federal Circuit has made numerous other changes to patent law. It approved (or led the way) to the granting of new types of patents (i.e., business methods, life sciences, etc.), sometimes overturning prior court precedent directly. The court has also been more amenable to accepting jury findings, which are probably less accurate and more pro-patentee than judges. The court is more willing to grant preliminary and final injunctions. Furthermore, it has revised damage principles so that lost profits would be more generous and greater than reasonable royalties, and even allowing the award of both types of damages. This change brings the damage calculation more in line with the statutory language, and with the

theoretical findings in Chapter 3, but is nonetheless an obviously pro-patentee move. Finally, the court, by its decision in *Madey v. Duke*, severally limited the "experimental use" defense to infringment.

At least one early commentator concluded that the creation of the Federal Circuit was a positive step in patent law. Dreyfuss (1989) evaluated the Federal Circuit in terms of its "precision" and "accuracy". The law is "precise" if the law is articulated in a way that permits the PTO, lower courts, and practitioners to apply it with greater ease. As Dreyfuss notes, "Greater certainty and predictability would foster technological growth and industrial innovation and would facilitate business planning." The law is "accurate" if, in line with purpose of the Patent Act, it promotes the national goal of encouraging innovation. Dreyfuss concludes that the Federal Circuit has been both accurate and precise. For instance, the new court has brought nonobviousness inquiry out of chaos by elevating the "secondary" factors in importance and requiring a "nexus" between these factors and the innovation. This may not be the "right" solution (and many people disagree in light of the Supreme Court's opinion in *Graham v. John Deere*, which the Federal Circuit directly contradicted), but it provides an objective criteria, which should add to certainty. Dreyfuss does note that the new court has been less precise in regards to the infringement inquiry (though, this might have changed since 1989). As to accuracy, Dreyfuss finds that the court's decisions reflect a sound understanding of business and the process of innovation and a fidelity to the purposes of certain provisions of the law. However, the Federal Circuit may not have accomplished its goal of greater efficiency in patent litigation. Greater certainty should result in less litigation and quicker (and cheaper) dispensation of cases, but Dreyfuss is unable to find this effect in the first five years of the court's operation. Reassessing this earlier study, Dreyfuss (2004, p. 800) concludes, "Overall, observers largely agree that in its twenty years of existence, the Federal Circuit has vastly improved the patent system."

Many commentators attribute the rapid rise in patenting activity beginning in 1983 to the fundamentally pro-patentee shifts in the legal system. In Chapter 2, I find that firms

experience a greater loss in market value following a decision of "invalidity" after the new court was created. It follows that patents were much more valuable to the firm after the Federal Circuit was created. I argue that the increased value of patents, attributable to the institutional change in patent law, is one channel through which the Federal Circuit encouraged the increase in patent applications.

1.5 Criticisms of Today's Patent System

The rapid rise in patenting activity has led many commentators to conclude that many areas of industrial technology are too crowded for new innovations to occur. Exacerbating this problem, at least according to Jaffe and Lerner (2004), is the relative ease with which applicants can get their patents granted. Congress, in the early 1990's changed the funding of the PTO to make it cover its own costs (and contribute surpluses back to fund other government programs). As a result, the PTO has the incentive to churn though as many applications as possible (to generate greater revenue). At the same time, the PTO is unable to offer its examiners salaries to compete with the lure of private businesses, making retention of experienced examiners nearly impossible. Further, the incentive structure for individual examiners within the PTO favor granting patents with minimal examination. Finally, because there have been new areas of technology opened up to patents, the court has made it harder for examiners to do their jobs. Because the field is new, there is little prior art in the form of patents in these fields. The majority of the relevant prior art in these fields is found in other sources, and is more difficult for the examiner to discover. This leads them to grant patents that would not have been granted if the prior art from these other sources had been discovered. Thus, not only are more patents being granted, many of them are "imprudently" granted. The flood of weak patents leads directly to two problems. First, larger firms with

established patent portfolios can prevent small firms from engaging in innovation. Second, small-time inventors can hold-up large firms.[35]

Further, the same factors that led to the increase in patent applications make it harder for the court system to weed out the "imprudently" granted patents. The first problem for alleged infringers is the higher burden to overcome the presumption of validity. Secondly, as noted by Merges (1988) and others, the Federal Circuit has weakened the nonobviousness inquiry (which previously was the most common cause of patent invalidity) and elevated the "secondary factors" (such as commercial success) compared to its predecessors. Finally, the costs of litigation have become overly burdensome. According to Jaffe and Lerner (2004) (citing others), the cost of defending a large (greater than $25 million) patent suit is $2-4.5 million; for small suits (less than $1 million), the cost is $300-750 thousand.

However, the criticism of the patent system is not monolithic. For instance, Lemley (2001) explains at least part of the granting of "bad" patents as a result of "rational ignorance" in the PTO. Most critics ignore the additional costs that a more stringent prosecution of the patent in the PTO would create. Because a very small percentage of patents will ever be asserted, it doesn't make sense to spend these extra resources. A key assumption that he makes, however, is that the validity of nonlitigated patents is irrelevant. Jaffe and Lerner (2004) argue that there is the additional cost to society of potential inventors not entering a market due to the presence of many illegitimate patents. Lemley considers this a good criticism, but says the effect is smaller than it looks at first. Ghosh and Kesan (2004) expand on Lemley's idea, saying that in his cost benefit analysis, Lemley ignores who is paying the cost. In their view, what we need is "optimal ignorance" rather than rational ignorance. Optimal ignorance means that the PTO gathers "sufficient information regarding novelty, utility, and nonobviousness to balance the risks of Type I (false rejections) and Type II (false acceptances) errors."[36]

[35]This second situation is often the case with so-called patent "trolls," which will be discussed more extensively later.

[36]Ghosh and Kesan (2004, p. 1243).

The increase in the overall number of patents (both good and bad) will not necessarily detract from future innovation. For instance, as noted by Lunney (2004), the Federal Circuit has fundamentally changed the patent system from one with few valid patents with broad scope to one with many valid patents with narrow scope.[37] The net result on how much "innovative space" is covered by previous patents is unclear. Thus, it may still be possible for inventors to operate within uncovered (by previous patents) areas of technology. A competing criticism, or a refinement of, Jaffe and Lerner's criticism is promoted by Bessen and Meurer (2007). They argue that what is causing the patent system to break down is the blurring of the boundaries of patents. This explanation is consistent with the fact that there are more numerous patents (creating additional boundaries), and with Dreyfuss's (1989) conclusion that the Federal Circuit has not been successful in defining the infringement inquiry. However, the Supreme Court's recent decisions in *Warner-Jenkinson*[38] and *Festo*[39], which largely affirmed the narrowing of the scope of the doctrine of equivalents, should allow for a more clear delineation of what is covered by previous patents, and should ameliorate some of this problem.

A recent trend that augments the problems of the patent system is the emergence of patent "trolls." Trolls are loosely defined as patentees that remain undercover (this is done more easily if they do not produce a final good using their invention) until a firm with deep pockets engages in an arguably infringing act. When faced with the possibility of an expensive suit, the infringing firm will often choose settlement to litigation, allowing the troll to profit from their surreptitious behavior. Reitzig, Henkel and Heath (2006) explore the conditions necessary for a patentee to favor "being infringed" over negotiation, concluding that trolls can exist as long as it is possible for a patent to remain undetected and courts award damages greater than what the patentee could obtain through negotiation. To a degree, new disclosure

[37]This interpretation is also consistent with the empirical evidence of Henry and Turner (2006).
[38]520 U.S. 17 (1997).
[39]535 U.S. 722 (2002).

rules[40] and technology make being a troll somewhat more difficult, but the increase in patent applications and grants also makes the prior art search more costly.

Some also argue that even if industries are flooded with weak patents, companies have a remarkable ability to adapt to the conditions they face. For instance, a patent pool emerged from a bitter dispute between the Wright brothers and Glenn Curtiss, another aviation pioneer. The pool was created in 1917 among aircraft manufacturers in preparation for World War I, spurred by request from the secretaries of war and the navy. With only one major amendment in 1928, the pool lasted until 1975 when it was broken up by the Department of Justice. The DOJ alleged "that the cross-licensing agreement of 1928 hampered competition in research and development and that the amount of research and development in the aircraft industry would have been greater without the agreement."[41] But Bittlingmayer argues that other forms of intense competition (e.g., non-price competition) still existed among the participants. According to Bittlingmayer, "the agreement seems poorly designed to redistribute the gains of trade from consumers to producers."[42] And even if research and development in the fields covered by the patent pool was somewhat blunted by decreasing the race to be first to develop a new technology in that area, the agreement (and the amelioration of the dispute) freed resources for research into the non-covered fields. Additionally, resources may have been saved by preventing duplicate research. In any case, the agreement is one example of how an industry can adapt to particular circumstances despite numerous conflicting patents so that production and research and development can move forward. Hall and Ziedonis (2001) find extensive use of cross-licensing agreements in the semiconductor industry. Thus, few resources are wasted on litigation or negotiating individual royalty rates in an industry that is heavily dependent on cumulative innovation. Other industries have adopted industry-wide standards, with the holder of the patent covering that standard waiving their rights to sue for infringement, so that technological innovation can progress.

[40] Disclosure is required 18 months after an application is filed.
[41] Bittlingmayer (1988, p. 235).
[42] *Id.* at 238.

Nonetheless, even where such alternative arrangements can be worked out, there may still be a blunting effect on innovation. Scotchmer (1991) examines a theoretical model of two firms engaged in cumulative research. She finds that even with a licensing agreement, the full social value of each invention cannot be allocated to the inventor. Thus, some projects that would be socially efficient to undertake will be left undone. However, joint ventures can be efficient in Scotchmer's model, similar to how vertical integration can solve the problem of "double marginalization" in standard industrial organization models. Similarly, Jaffe and Lerner (2004) find that extensive cross-licensing agreements are also inefficient. The inefficiency found by Jaffe and Lerner stems from the fact that even within the agreement, no firm can stop patenting because doing so would leave them at a disadvantage in their future negotiation (and express limits would raise anti-trust concerns). This makes the use of patent system inefficient for everyone. Additionally, the licensing agreement might blunt incentives to invest in developing useful new technologies if the firms have access to all other firms' new patents. However, these two arguments that Jaffe and Lerner make seem to directly conflict with each other. One could argue that firms race to make the substantial improvements in the state of the art quicker under the cross-licensing agreement in order that they may have the upperhand in future negotiations. Furthermore, the agreement allows the firms to pursue these major breakthroughs without concern of being subsequently found guilty of infringing a prior minor patent held by one of its competitors.

1.6 Proposals for Reform

Many proposals for reforming the patent system have focused on the problems within the PTO. In 2000, the PTO undertook a new "Business Methods Patent Initiative" to figure out how to best deal with the patent applications from new industries. Part of this initiative was an effort to seek more input from the industries to figure out the best way for examinations to proceed. The PTO also committed to enhance the technical training for its examiners. A similar, more general, proposal is to simply hire more examiners, which would allow them

to spend more time examining each application, and to pay them more, to allow for greater retention.[43] Another simple change that can be made with regard to examiners is to change their incentive structure. The current practice is that bonuses and promotions are based on productivity, which is measured by how many applications that they examined have reached their final disposition. Approving an application is much quicker than rejecting it, because, following a rejection, the applicant may revise their claims again and again before a patent is finally granted or the application is withdrawn. A further refinement, though much more costly, is upgrading the tools available for examiners to conduct prior art searchers. The PTO has been upgrading its systems and databases numerous times over the past three and half decades, usually coming in over budget and under performing, or creating even more chaos. The PTO's "21st Century Strategic Plan" planned to increase fees and change the ways they were assessed to increase the resources available for some of these improvements. Another way to ease the burden on examiners would be to augment the applicant's duty to disclose by having a mandatory prior art search conducted by a third party. Critics fear that this proposal might produce too much prior art for the examiner to consider.

Other reform proposals are more drastic. One idea is to change the patent system back to a registration system (like we had 1793-1836). Given that the problems we had back then would probably be worse today (especially with litigation being more expensive), this proposal garners little support. Another idea, would be to allow applicants to self-select into a more thorough review, which would give them a higher presumption of validity if they ever subsequently litigated the patent. In a similar proposal, Benjamin and Rai (2007) suggest that patent law should be brought in line with the broader field of administrative law. Even though the PTO is an administrative agency, it had always been treated separately under the law. Typically, decisions made by other administrative agencies are given a degree of deference that is dependent on the process that the agency went through in rendering the decision. Under this view, if the patent application went through a very thorough review in

[43]These are issues the PTO have faced since its founding.

the PTO, it would be granted a higher presumption of validity. This is a sharp contrast to the state of the law today, where the Federal Circuit has ruled that the imitator cannot introduce evidence detailing the circumstances surrounding the prosecution of patent or of examiner incompetence. But this idea is reflected in the history of U.S. patent law. The presumption of validity was included with the procedure for examination in the patent legislation passed in 1790, but was done away with in 1793 when the law was changed to a registration system. Even when examination procedures were reestablished in 1832, the presumption of validity wasn't recognized until a court decision in 1853. Thus, in the beginning, the deference given to the Patent Office was reflective of the scrutiny the patent faced before being granted.

The majority of commentators favor creating an opposition system, like exists in most other industrialized nations. Although we currently have a interparte reexamination procedure, it has gone largely unused because the limitations on how the challenge is to take place and the estoppel effect it has on future litigation. Although particularities can be debated (for instance, whether it should be pre-grant or post-grant, etc.) the goal of the opposition proceeding should be to bring all relevant prior art to light so that the PTO official(s) can make an informed decision about the patentability. The operation of most proposals involve publishing the application 18-months after it was filed, and allowing a certain time period for the public to raise objections. Some proposals allow only written objections, others provide for an argument before the relevant official. Two key features make the opposition proceeding attractive to competitors: the process must be less expensive than a potential trial, and any estoppel created by a failed opposition should only apply to issues that are raised in the opposition. The proposed "Patent Reform Act of 2007," which is currently in committee in both the House and Senate, would create a post-grant opposition system. Under this law, anyone could challenge a granted patent within twelve months of the grant, or after that if they can show a "substantial reason to believe" the patent is "likely to cause significant economic harm," or they have received a notice letter from the patentee, or if the patentee consents. The opposition trial would take place before the Patent Trial and Appeal Board,

with appeals going directly to the Federal Circuit. A failed opposition means the losing party would be barred from later challenging validity based on any ground they raised in the opposition. During the opposition, there would be no presumption of validity.

Thomas (2001) advocates creating a patent "bounty" system. Under his plan, the PTO would offer a reward for people to bring forward relevant prior art that was not disclosed by the applicant nor discovered by the examiner. His hope is that such a system would create an army of private patent examiners, made up mostly of the applicant's competitors (who usually have the best knowledge of the prior art) and, possibly, retired PTO examiners (with limits). Furthermore, if applicants had to pay the bounty rewards, they would have a greater impetus to do a thorough search before applying. Thomas argues that this system would be better than an opposition system because it eliminates the potential for collective action and free-rider problems.[44]

Another way that the patent system could be reformed would simply be to change the fee structure for renewal. Currently, a patent is relatively cheap to maintain. If renewal fees escalated more quickly, it would be much more expensive for patent trolls to operate. Additionally, other useless patents would quickly be abandoned. A more general approach to reform is currently debated about the legal system as a whole. In many areas of the law, people advocate switching to "loser pays" system for assessing legal fees. Doing so would cause the parties to more actively engage in alternative dispute revolution and could prevent suits with little chance of success from being filed. This should reduce some apprehension for potential innovators.

At the extreme, some would argue that the patent system should be scrapped altogether.[45] It could be replaced (as has been done in some countries at various times in history) with a government prize system for sought-after inventions. Such a system suffers from numerous complications. The first is how to determine the size of the prize. One attractive feature of

[44]The opposing party creates a public good for other mutual competitors. It is also possible, Thomas argues, that potential opponents and the applicant could collude to not bring the opposition and let the patent be granted.

[45]See, e.g., **?**).

patents is that the "reward" given to the inventor is based on how valuable their contribution is, determined by the willingness to pay by the users of their product. Secondly, such a system may be expensive to implement. In the U.S. patent system today, the PTO generates a surplus of revenue, and the costs of the system (both in acquiring the patent and the litigation costs) are borne by the interested parties (the patentee, their competitors, and consumers of the product). Finally, the arbitrariness of a prize system is likely to direct research and development expenditures in a direction that is not the most economically efficient.

1.7 Conclusion/Future Work to be Done

One salient fact emerges in studying the history of the United States patent system - the law has constantly been in flux between varying degrees of patent protection. As pointed out here, and recognized by most critics, arguments for patent reform made today sound identical to arguments made for reform over 170 years ago. Particularly in the 20th century, the fluctuations in the law seemed to stem from changing underlying economic conditions and attitudes in the country.[46]

Yet, it is unclear whether the degree of patent protection necessary to promote innovation varies over time. The best argument that can be made in this regard is that in times of recession, firms have less expendable cash to invest in research and development, so an increase in the returns to R & D is needed in such periods to encourage more investment. This argument would certainly support the reforms circa 1980, but would cut against the policy changes during the Great Depression, which were motivated by a desire to limit monopoly rents. It could also be the case that changes in the patent system are necessary as businesses adapt to changes in the marketplace. Particularly in the last half of the 20th century, there has been a movement toward increased globalization. Many recent changes in the U.S. system

[46]But see Posner (1988), which criticizes the idea that patent policy is high on the list of factors which determine economic problems. I don't take a position on this issue, but that doesn't mean the public at large has not.

were spurred by the "Agreement on Trade-Related Aspects of Intellectual Property Rights" (TRIPS) and the desire for greater worldwide uniformity in patent protection.[47] Meanwhile, domestic courts have been strengthening patent rights. However, it seems contradictory that as business expand into broader markets, that stronger patent rights would be necessary to spur the same amount of innovation.

If there is an optimal level of patent protection, economic theory has not been able to identify it satisfactorily yet.[48] To conduct empirical analysis and determine some sort of "optimum," policy makers (or economic researchers) will need to identify the purpose of the patent system, and properly characterize all the social costs and benefits. As discussed earlier, there are numerous explanations for why we need patents. And while, in general, it can be said that the purpose is to promote innovation and, thereby, economic progress (notwithstanding the natural rights argument), the proper channel for promoting innovation is still undefined. Survey evidence reveals that patents are a relatively poor way of protecting intellectual property (except in a few industries),[49] which would effectively undercut the reward theory behind patent protection. This evidence also augments the theory that the increase in patent applications following the creation of the Federal Circuit was due to the pro-patentee changes in the law. The increase in applications may be attributed to changing firm stratagem, as opposed to simply allowing for greater monopoly rents.[50] Additionally, other theories for patents, such as the prospect theory and Demsetzian auction theory,[51] would seem to be diametrically opposed to the recent changes in the law by the Federal Circuit, which has held more patents valid, but decreased the scope of the patents.

[47]For example, the change of the patent term from 17 years from the time the patent was granted to 20 years from the time the application is filed.

[48]This is not to say that respectable efforts have not been made. Nordhaus (1969, p. 76) gives the classical treatment of the optimal life of a patent. Klemperer (1990*a*) characterizes the optimal scope of the patent. However, both works only consider the costs of monopolies, and ignore other social costs.

[49]Levin (1986) and Scherer (2006).

[50]Hall (2005). These strategic sources of value should also be captured in the market values found in Chapter 2 and other similar works.

[51]Kitch (1977) and Duffy (2004), respectively

In light of this uncertainty, the patent system may be more efficient if it didn't treat all patents exactly the same. For instance, one could argue that different rules should apply to product and process patents. Additionally, we may wish to separate pioneering patents from marginal improvements. Finally, it may make sense to treat different industries or patent classes differently. The problem, particularly with this last case, is that inventors would try to tailor their applications into the classification that is most favorable to them. This problem may be ameliorated by having very few broad classifications, making it impossible to bend the application in all but a few marginal cases.

Similarly, the way damages are awarded may also need to be changed. The simplest alteration would be to take more factors into account in determining reasonable royalties, so that the hypothetical bargain may better reflect reality.[52] The hypothetical bargain formulation that is currently prescribed by courts creates a circularity because the bargaining position of the parties is dependent on the expected damages.[53] It might also be appropriate to grant greater leniency when the infringement was inadvertent, particularly in cases involving surreptitious actions by the patentee. This would reduce some of the apprehension potential inventors may feel before venturing into new technological areas. Creating compulsory licenses would be another radical solution to the problem innovators face, but sacrifices the notion that patents are personal property. But a greater empirical study of the effects of compulsory licenses, which was done with regularity in the 1940's and 1950's but was abandoned thereafter, on inventive activity should be conducted.

Nonetheless, it may be the case that the Supreme Court has already recognized some of the "problems" with the current system and has sought to curb the expansion of patent protection.[54] In *KSR International Co. v. Teleflex Inc.*, the Court overruled the Federal Circuit's requirement that for a combination of patents to be considered within the obviousness

[52]See Reitzig, Henkel and Heath (2006).

[53]For a more thorough description of this problem, see Schankerman and Scotchmer (2001) and Chapter 3.

[54]For a more detailed description of the *KSR* and *Microsoft* cases, see Seidenberg (2007). Both those cases were decided April 30, 2007. The *eBay* case was decided May 15, 2006.

inquiry, there must have existed a "teaching, suggestion, or motivation" to combine the elements. The Court indicated that combinations had to be more than mildly creative to be patentable. This ruling should make it much easier for defendants to prove invalidity. The ABA had filed an amicus brief in support of the Federal Circuit's position. In *Microsoft Corp. v. AT&T Corp.*, the Court limited the liability for software manufacturers to software made or sold in the U.S. (and exempting that made and sold abroad). Finally, in *eBay v. MercExchange*, the Court found that the grant of a permanent injunction wasn't a necessary remedy upon the finding of infringement. This decision could eliminate potential hold-up problems that face imitators that fear they will be sued for infringement. Additionally, paired with the abandonment of unjust enrichment as a method of assessing damages in 1964, this ruling could create a situation of *de facto* compulsory licenses if the patentee is a small firm or not engaged in production at all. Because the infringer will never have to turn over their entire profit, producing (and infringing) could be more profitable than staying out of a market.[55]

Finally, proponents of reform have yet to firmly establish that the current patent system is "broken." Jaffe and Lerner (2004) present examples of ridiculous and "imprudently" granted patents, a few anecdotes aren't sufficient evidence to warrant radical changes in the law. Furthermore, the extreme cases of "bad" patents should be easily invalidated. Presumably, the cost of litigation is an increasing function of the closeness of the decision. If it is that obvious that a patent is invalid, it should be relatively cheap to resolve the dispute. The legal system has long allowed for summary judgements precisely to deal with such "easy" cases in a low-cost manner. Empirically, Jaffe and Lerner (2004) point to the fact that "important" inventions (defined as patents granted in Japan, Europe and the U.S.) originating in the U.S. increased by 51% between 1987 and 1998, while the total number of granted patents has increased 105% as evidence that U.S. patent quality is declining. But just because the average patent may not be as valuable doesn't mean the system is broken. In fact, I argue that a 51% increase in "important" inventions in only 11 years is *primae facie* evidence that

[55]If the patentee is small or doesn't produce, they will have a low level of lost profits, and therefore, the infringer would only have to pay a reasonable royalty.

the patent system is nonetheless still encouraging important innovative activity. A better test of whether the U.S. patent system is broken would compare the growth in "important" inventions originating in the U.S., versus those originating in Europe and Japan. Additionally, according to their own Figure I.1, it appears that the percentage of patents granted per application has fallen, particular since 1975. Finally, even if it is true that more "dubious" patents are granted (i.e., Type 1 errors) today in nominal terms, it could be a result of the increase in applications, with the rate of errors remaining the same. Given the broader fields of patentable materials, these "dubious" patents may not crowd any one industry.

Bessen and Meurer's (2007) main evidence of the failing of the patent system compares the annual aggregate costs to firms defending against litigation to the worldwide profit flow derived from U.S. patents. Their cost measure includes "business costs such as loss of market share or the costs of management distraction," which they find through stock market reactions to the lawsuit.[56] However, this estimate probably substantial overestimates the true cost. If the firm was engaged in infringing activity, their stock price would be artificially inflated. Thus, had the infringement never occurred, there would be no value for the firm to "lose." Additionally, profits do not account for the consumer surplus created by the new invention, and therefore understates the social benefits to patent protection, if you assume that at least some invention is induced by the promise of such protection.

Further evidence that the increased number of patents stifles further research is provided by Lerner (1995), which finds that biotechnology firms with high litigation costs (proxied by low financial resources and the lack of previous litigation activity) are less likely to patent in crowded classes of patents, particularly if the incumbents have low litigation costs (greater resources, previous litigation experience). However, many of these results could be driven by endogeneity. Smaller firms are often start-ups that will naturally be found in new industries (i.e., industries with few prior patents). Additionally, firms with more resources are likely to have greater ability to patent in many subclasses, rather than just look for an individual

[56]Bessen and Meurer (2007, p. 10).

niche of the market that hasn't been filled yet. This would break the connection between expected litigation costs and the selection of research projects. A better proxy of expected litigation costs could be the number of patents in that class that have been litigated as a percentage of the total number of patents in that class.

In addition to defining the role patents play in encouraging innovation, the optimal degree of patent protection, and testing whether the U.S. system is indeed broken, the discussion above also raises other interesting work to be done in studying the functioning of the patent system. First, it would be interesting to compare the approval rate of patent applications to subsequent validity rates. This would show whether stricter standards in the PTO imply more accurate examinations. It would also be interesting to redo the Dreyfuss (1989) tests of efficiency created by the Federal Circuit now that more than four times the amount of observations are available.[57] It is possible that it took more time for the efficiencies to be realized. Additionally, this work could help explain the increase in litigations as a decrease in costs due to the more efficient judicial system.[58] Another study could attempt to explain whether part of the surge in patenting over the last two decades was reflection of changing the ways patents were written as opposed to other potential causes. The way the Federal Circuit has interpreted the doctrine of equivalents makes patents with less claims more likely to be infringed, ceteris paribus. Thus, it is likely that patent applicants responded by filing two or more patents covering the various aspects of an invention, were previously one patent would suffice. A fourth idea involves examining the responsiveness of patent applicants and patentees to changes in the fee structure of the PTO and renewal fees. If patentees are sensitive to fee changes, one possible way to prevent the application for and to weed out "worthless" patents would be to increase the real cost of these fees. Finally, further study of the innovative productivity of firms that are engaged in patent pools, joint research ventures,

[57]Dreyfuss (2004) does not use the same methodology.

[58]Bessen and Meurer (2007) find that the rate of litigation (and therefore, costs of litigation) has roughly tripled since the 1980's.

and cross-licensing agreements is needed to determine whether such arrangements should be allowed to persist or encouraged.

The following two chapters of this dissertation are an attempt to answer some of the unresolved questions about the current U.S. patent system. The first demonstrates the effect that the legal regime will have on the value of intellectual property rights. The second analyzes the effect that the choice of damage regime will have on market competition.

Chapter 2

The Market Effects of Patent Litigation[1]

[1]To be submitted to the *Journal of Law and Economics*.

2.1 Introduction

Accurate patent valuation has been a troubling question for researchers and intellectual property managers for some time. Unlike a tangible asset with well defined property rights, the patent conveys to its owner a "negative right" of exclusion of others.[2] This right may be valuable to the firm for numerous reasons, including protection of a market for the firm's product, generating licensing revenue, or as a defense from suits from competitors. It is impossible to quantify the value to the firm of these various uses of a patent individually. Assuming that the stock market is efficient, the value of the patent as a whole should be reflected in the total market value of the firm. Changes in the firm's market value can reveal important information about the company.

I develop a model of how a firm's market value should react contingent on a court ruling on one of the firm's patents. I then test this model using a subset of data originally gathered for and published in Henry and Turner (2006). The subset has rulings on 544 patents that were published in the United States Patent Quarterly between 1962-2002. I find that the average firm loses about .85% of its market value following a decision that one of their patents was "Invalid", and firms gain about .7% in market value following a "Valid & Infringed" decision. I also conduct a cross-sectional analysis of the changes to the market values, in which I consider two types of factors that can determine the value of a patent: the expectations of enforceability of the patent and the characteristics of the patent. I find that the expectations aspect is at least as important in determining value as the characteristics of the patent. Importantly, the creation of the Court of Appeals for the Federal Circuit (CAFC), which is generally thought to be decidedly pro-patent, substantially increased the value of patents to firms.[3] For instance, I find that while a firm, on average, loses .85% (about $19

[2] See Burge (1999, p. 27).

[3] The CAFC was created by legislation in 1982 (and started hearing cases in 1983) to unify intellectual property law and, ostensibly, to end forum shopping in patent cases. The CAFC hears cases appealed from any federal district court in the nation. Prior to its creation, appeals would be heard by the circuit court of the circuit in which the district court was located and the outcome of the case could have been contingent on where it was litigated. Since its creation, the CAFC has

million) of its market value following a court decision that a patent is "Invalid", the average decline in firm value was .7% greater after the establishment of the CAFC. Thus, patents were, on average, about $15.5 million more valuable because of the creation of the CAFC. Additionally, there is some evidence that a measure of a court's "friendliness" toward patent holders may also affect the change in market value of the firm.

Previous researchers have only focused on the characteristics of the patent. Allison et al. (2004) study litigated patents, which they argue are more valuable. They find litigated patents are typically younger, owned domestically, issued to individuals or small companies, cite more prior art and are cited more by others, have longer prosecution times, more claims, and are concentrated in certain industries, such as the mechanical, computer and medical device industries.[4] Moore (2005) compares the characteristics of patents that are maintained longer[5] to conclude that more claims, more citations made and received, longer prosecution times, having related patent applications (continuations and divisions), a greater number of inventors, foreign ownership, and being in the computers classification all contribute to more valuable patents. Hall, Jaffe and Trajtenberg (2005) study the relationship between the value of intangible assets of firms (stock market value minus tangible assets) and research and development expenditures, patents, and patent citations. In particular, the authors find that firms whose patents are more frequently cited by subsequent patents have a higher market valuation.

Focusing only on the characteristics of the patent ignores an important aspect of property rights — for property rights to be valuable, the rights must be enforceable. No one would

garnered a reputation as being "pro-patentee". The evidence supports this conclusion as to the question of validity, but not for the infringement question. For a more thorough description of the court and the changes in outcomes over time, see Henry and Turner (2006).

[4]Lanjouw and Schankerman (2001) also find that the number of claims in a patent and the number of citations of the patent are important determinants of whether a patent will eventually be litigated.

[5]To maintain a patent, fees must be paid four, eight, and twelve years after they are granted. If the fees are not paid, the patent is deemed expired. Patent holders will only keep the patent current if the value of the patent is greater than the fees. Therefore, more valuable patents should be maintained longer.

invest in property if others could infringe upon it without recourse. Likewise, patents would be worthless and inventors wouldn't disclose new technology if their intellectual property rights were not enforceable.[6] Therefore, characteristics of the legal system are also important in determining the ultimate value that a firm may derive from a patent.

Many papers use event studies to study litigation, usually focusing on the filing of the suit.[7] However, only two previous papers use event studies to examine patent litigation exclusively.[8] Marco (2005*b*) studies the effect of 475 court decisions (in 295 adjudications) published in the United States Patent Quarterly (USPQ) between 1977 and 1997. The goal of this paper is the same as the present study, but the methods used differ significantly, and the results are therefore not directly comparable. Rather than separating the different types of decisions prior to presenting the results, Marco finds the abnormal returns (using an event study) for all the decisions and then regresses the returns on dummy variables for the decision rendered ("Valid", "Not Valid", "Infringed", and "Not Infringed").[9] Doing so assumes independence of the types of decisions, and allows for intermediate decisions (for instance, in a bifurcated trial) to count the same as final decisions. Clearly, this is problematic

[6]The lack of an enforceable patent system wouldn't completely destroy incentives to innovate, it would certainly diminish the incentive. Additionally, this would slow down the diffusion of ideas, which would slow technological progress in general.

[7]Engelmann and Cornell (1988) give an in-depth study of five suits in which both the plaintiff and defendant were corporations and find significant leakages of the value for the two firms involved. Bhagat, Brickley and Coles (1994), as part of a more comprehensive study, find that upon filing of a patent infringement suit, the 31 defendant firms lost an average of 1.2% of their market value, while plaintiff firms showed little change in value. Bhagat, Bizjak and Coles (1998) expand on this earlier work by considering more lawsuits. The authors find that upon filing the lawsuit, the defendant firm (with 33 observations) lost an average of 1.5% of firm value and the 51 plaintiff firms lost an average of .31% of their value. Bhagat and Romano (2002*a*) and Bhagat and Romano (2002*b*) survey event studies that have been conducted on various aspects of corporate litigation. They find only one study that showed that the plaintiffs benefit (in terms of increasing firm value) at the time a lawsuit was filed, and that study ((Bizjak and Coles, 1995)) was limited to private antitrust suits. Although I don't consider the filing date in this paper, I assume, based on the prior work, that the plaintiffs have not experienced any change in firm value on the filing date.

[8]Austin (1993) uses an event study to find the returns to patent issuance.

[9]The results for each type of decision are also reported independently, but each observation could fall into multiple categories, for instance, both valid and infringed. Conversely, I treat each decision separately in reporting my results, and therefore, each observation only appears once.

and I focus only on final adjudications. Additionally, he uses a bootstrap procedure allowing the return for each observation selected to be defined by a randomly drawn event window. Thus, I can not compare my results from each event window directly to his.

Another refinement in his paper is the use of the Expectation-Maximization Algorithm to separate the effects of decisions on multiple patents in the same suit. As he acknowledges, the use of this technique assumes independence of the decisions. Because this assumption is problematic, I choose not to follow the same technique, but attempt to control for other decisions in the same case in my cross-sectional analysis. Finally, he compares the results of various sub-samples to analyze the effect of the creation of the CAFC, whether the decision was by a district court or appellate court, and whether the plaintiff in the case was the patentee or the alleged infringer. Although he does not find a statistically significant difference in district and appellate decisions, lumping both types of decisions together in presenting his main results is problematic. The expectations of investors should be far different facing an appellate decision than they are facing the initial district decision, especially given that one judge has already ruled on the case. However, Marco doesn't have any way to control for the underlying district court decision when the appellate decision is rendered. Thus, he values a reversal from "Invalid" to "Valid" the same way he values an affirmation of a "Valid" decision, despite the fact that investors should react to the former situation in a much more dramatic way. Because of this problem, I use only decisions by district courts. Finally, this technique of comparing two sub-samples ignores other conflating factors that could be influencing the results. Therefore, I choose to use a cross-sectional regression analysis to analyze the effect of the creation of the CAFC and control for whether the patentee was the plaintiff.

Marco (2005*a*) uses abnormal returns to determine whether court decisions were "correct". Since investors can form some *a priori* judgment of the validity of a patent, the more shocking a judge's decision in the case is, the more the value of the firm drops. Therefore, he uses the abnormal return as a independent variable in a maximum likelihood estimation

to calculate the change in beliefs about the validity of a patent. This estimation also allows him to conclude how often judges get the decision "wrong". He finds that invalid patents are rarely held valid, but valid patents are often declared invalid. In addition to the other estimates, Marco presents the results of the event study (which was an intermediate step for him). Using the same data as in his other paper, he finds that valid decisions (with 55 observations) result in a 1.52% increase in firm value over an 11-day event window (five days prior to the decision until five days after). The result for a two day window (day of the event until the day after) for valid decisions was insignificant. The return on invalid decisions (45 observations) was -.64% for the two day event window and -.82% for the 11-day event window (though the later figure is less statistically significant). These figures will be useful to compare to my findings later.

In addition to the differences noted above, the current study is distinct from Marco's in several fundamental ways. First, I have a larger data set to consider. I have almost twice as many district court decisions. Additionally, the decisions I consider are more balanced on the creation of the CAFC, allowing for a more precise study of the effect of the new court. Second, I more precisely define the decision that is being rendered and consider the various decisions separately to avoid conflating results. Marco (2005*b*) uses intermediate decisions and separates the validity and the infringement inquiries in his analysis. Marco (2005*a*) excludes infringement decisions altogether because of the additional noise that they introduce into the system. An infringement decision must also consider the actions of the alleged infringer, rather than just the patent. However, excluding infringement decisions discounts the fact that a court's interpretation of the scope of a patent may significantly alter its value and the difference in returns possible between a "Valid & Infringed" decision and a "Valid, but Not Infringed" decision. Third, I consider both expectation factors and characteristics of the patents to explain the observed changes in market values.

In addition to being the most comprehensive study of the market effects of patent litigation to date, my finding that the creation of the CAFC increases patent value also sheds light

on the debate as to why there was a surge in patenting activity in the early 1980's. Kortum and Lerner (1998) argue that an increase in the productivity of R & D was responsible for this surge; Hall (2005) concludes that the CAFC was part of the cause. My findings tend to confirm the later opinion. The marginal cost of patenting remained relatively the same, while the marginal benefits (in terms of increasing firm value) were apparently increasing. Therefore, there were more patent applications filed.

2.2 Theory

The first step in litigation occurs when the patent holder files the suit. Previous work has shown that there is no significant change in the plaintiff's market value based on this filing.[10] The decision to file suit may also be made by the alleged infringer through the use of declaratory judgment action asking the court to find a patent invalid or not infringed. To entertain a declaratory judgment action, the court must find that an actual controversy exists between the parties. For instance, the patent holder may have sent a "cease and desist" letter or threatened judicial action prior to the filing of the suit. Because there may be differences in the selection of patents for litigation based on who files the suit, I control for this variable in the cross-sectional analysis.[11]

For tractability, I ignore the decision of whether to appeal and assume that the district court decision terminates the litigation. This assumption is inconsequential in considering the market reaction to the district court's decision because investors probably do not know whether the decision will be appealed during the event window. I also ignore the costs of the litigation because the costs will be paid regardless of the outcome of the suit (and should therefore, already be incorporated in the market value of the firm).

[10] See, e.g., Bhagat, Brickley and Coles (1994) and Lerner (1995).

[11] The decision to file suit can also be used strategically. For instance, particularly in the pre-CAFC era, the ultimate outcome of the suit may have been contingent on the forum, making naming the forum an important strategic decision.

Let V be the payout to the firm if the patent is declared to be "Valid & Infringed". This includes retaining the value of the patent, damages that are won in this trial, and any increase in expected damages from future suits. The payoff to the firm following a "Not Infringed" decision will then be αV, where α is between 0 and 1. The simplest explanation for this reduction to V is that it excludes the damages that would have been awarded if the patent had been found to be infringed. However, it may also be the case that the court has narrowed the scope of the patent in declaring it to be not infringed, which would necessarily reduce the value of the patent to the firm. The payout to the firm following an "Invalid" decision is 0 because the value of the patent is completely lost.

Let β be the *a priori* probability that the patent will be found "Invalid" and γ be the *a priori* probability that the patent will be found "Not Infringed". Both variables are between 0 and 1. The probability of the patent being found "Valid & Infringed" then becomes $1-\beta-\gamma$.

With the variables defined, setting up the expectations equation is straight forward.

$$E(\pi) = (1-\beta-\gamma)V + \gamma(\alpha V) + \beta 0 \tag{2.1}$$

From equation (2.1), we can derive the change in expectations that will occur whenever any court decision is rendered. For instance, when a decision that a patent is "Invalid" is rendered, the patent is worth 0. Therefore, for the patent holder, the change in the expected profit (π) from the suit due to the decision can be expressed as:[12]

$$\Delta E(\pi|IN) = 0 - E(\pi) = -V[(1-\beta-\gamma) + \alpha\gamma] \tag{2.2}$$

Similar equations can be found for the change in expectations conditional on the two other types of decisions:

$$\Delta E(\pi|VI) = V[\beta + \gamma(1-\alpha)] \tag{2.3}$$

$$\Delta E(\pi|NI) = V[\alpha(1-\gamma) - (1-\beta-\gamma)] \tag{2.4}$$

[12]In the equations, "IN" will be used for "Invalid", "VI" for "Valid & Infringed", and "NI" for "Not Infringed".

The change in the expected profits following the decision is the abnormal return that I am capturing in the event study. The model predicts an unambiguously positive change following a "Valid & Infringed" decision and an unambiguously negative change following an "Invalid" decision. The change in expected profits is ambiguous following a "Not Infringed" decision (but will be positive for large values of α). These outcomes are my hypotheses for the cumulative returns from the event study.

Equations (2.2)-(2.4) may also be differentiated with respect to each of the variables to form hypotheses about how they will affect the observed abnormal returns (which is $\Delta E(\cdot)$). The derivatives with respect to the value of the patent to the firm, V, are obvious and take on the same sign as the change in expectations as whole. The derivatives with respect to the probability of invalidity, β, all take on the same value, which is positive:

$$\frac{\delta \Delta E(\pi|VI)}{\delta \beta} = \frac{\delta \Delta E(\pi|IN)}{\delta \beta} = \frac{\delta \Delta E(\pi|NI)}{\delta \beta} = V \tag{2.5}$$

These calculations form the basis for hypotheses for the cross-sectional analysis. Specifically, any factor that decreases the probability of invalidity, β, should decrease the observed abnormal return. After the Federal Circuit was created, Henry and Turner (2006) found that invalidity rates dropped by 28%. Thus, abnormal returns should be less after the Federal Circuit was created (i.e., more negative for "Invalid" decisions, less positive for "Valid & Infringed" decisions). Similarly, the factors that others have found contribute to the value of the patent should be positively correlated with the abnormal returns for patents that were found to be "Valid & Infringed" and negatively correlated with the abnormal returns for patents that were found to be "Invalid".

2.3 The Data

The data set used was originally gathered for use in Henry and Turner (2006). The data set includes all patent cases published in the United States Patent Quarterly that were decided

from 1953-2002. The original data set included 3,327 district court decisions.[13] Each decision was classified as either "Valid & Infringed", "Invalid", or "Not Infringed". For patents that had inconsistent rulings for claims within a patent, we developed an hierarchal way to classify them based on previous work in the field.[14]

To conduct the current study, it is necessary to truncate the data set so that it begins in 1963. The Center for Research in Security Prices (CRSP) database, which provides information on daily stock prices, does not go back further than this, making an event study much more difficult for previous years. The data set was then further reduced by excluding observations for which there was no publicly traded company listed as the patentee in the case.[15] A small number of observations were also excluded because the company was a foreign entity or because the patent made no citations.[16] The remaining list of patent cases left me with 544 usable district court observations (from 382 litigations), of which 235 were "Invalid", 216 "Valid and Infringed", and 93 "Not Infringed." Table A.2 contains some summary statistics.[17]

[13]We only included the first decision by each court of a case; i.e., we didn't include district court decisions on remands, or decisions on a second appeal. Additionally, we only considered decisions that were final, excluding interlocutory rulings on motions or partial decisions. We also limited ourselves to decisions on the validity and infringement of a patent, excluding interference actions, preliminary injunction rulings, unenforceability rulings (due to fraud or inequitable conduct), contempt rulings (cases in which validity had been established in a previous case), and rulings involving collateral estoppel.

[14]Briefly stated, if any claim was found valid and infringed, that is the way we recorded it. If any claim was invalid and others were not infringed, the decision was recorded as "Invalid". "Not Infringed" patents included decisions that were found valid, but not infringed. Oftentimes, courts will only address either the validity question or the infringement question, but not both, making any further subclassification extremely costly in terms of lost data.

[15]As a robustness check, I also conducted the study focusing on the effect of the ruling on the assignee listed on the patent, who may be named as the party in interest in the suit. If the parties are different, I can't conclusively say that the first assignee is not a party in interest (or still the owner of the patent). Some of the plaintiffs may only be licensees of the patent, rather than the true owner. If that is the case, the first assignee would be the best approximation of the true owner of the patent at the time the decision was rendered, and therefore the one that we would expect to lose value if the patent is rendered invalid. In most cases, the first assignee was the same as the patent holder listed in the suit. There is no significant difference in the results.

[16]Since I am using logs in the cross-sectional analysis, the observations with a value of 0 had to be excluded.

[17]All tables appear in the Appendix.

As can be seen in the table, 23% of the "Invalid" decisions, 44% of the "Valid & Infringed" decisions, and 58% of the "Not Infringed" decisions occur during the CAFC-era. This breakdown is not surprising given the more frequent occurrence of the latter two types of decisions in the CAFC-era. Overall, 37% of my observations come after the establishment of the new court. The degree of "Circuit Friendliness" is consistent across all three types of decision.

Patents ruled "Valid & Infringed" tend to have more claims and longer prosecution lengths than patents ruled either "Invalid" or "Not Infringed." They also tend to be about a year older, and are more likely to have resulted from a continuation or a division of another patent application.

Typically, all the patents in a case will receive the same decision. This is seen by looking at the number of "Others Valid & Infringed", "Others Invalid", and "Others Not Infringed" for each type of decision. The real market value of firms is much higher on average for the "Not Infringed" decisions. Although only 43% of decisions in my sample were declared "Invalid", 65% (47 out of 72) of cases that were initiated as a declaratory judgement action resulted in "Invalid" decisions. This is probably a result of the selection of weaker patents into litigation when the alleged infringer initiates the action.

2.4 The Event Study Method

The event study is the generally accepted way of finding abnormal returns to stocks due to new information in the market.[18] The basic regression is:[19]

$$R_{it} = a_i + b_i R_{mt} + e_{it} \tag{2.6}$$

In this equation, i represents a firm, t represents a specific day, R_{it} is the return to the individual stock on that specific day, and R_{mt} is the market return on that specific day. For my study, I use observations taken from a minimum of three and maximum of 255 days

[18] For a more complete description, see Bhagat and Romano (2002*a*).

[19] This is the market model of an event study; other models can also be chosen to get the predicted values of market price.

ending 46 days before the event to estimate this baseline equation for each firm.[20] Once estimates of a_i and b_i are obtained, one may use those estimates and observed values of R_{mt} on the event date to get a predicted value of R_{it} for each firm in the sample. The final step is to compute the difference between the predicted values of R_{it} and the actual value. This difference is the abnormal return on the event date. One may also expand the study to include days around the event date, creating an event window.[21]

The specification of the proper event window is important to the results of any event study. The event study framework is based on the efficient market hypothesis. This hypothesis says that a stock price will change quickly to incorporate all new publicly available information that is available to the market. Therefore, if we see a significant deviation from the predicted price within a certain event window, it is evidence that the event affected the value of the firm. If the window specified around the event is too small, there may not be enough time for the new information from the event to be incorporated into the stock price. Also, if information is leaked to the market outside of the event window, the stock price may adjust fully prior to entering into the window that is studied. This would lead to a false conclusion that the event had no effect on the market value of the firm. If the event window is too large, it may allow other events or new information to be included, biasing results.

In addition, the statistical power of the event study is greater for shorter windows. The statistical power of an event study increases with the number of firms in the sample because a large sample allows any errors caused by unidentifiable confounding events to decrease on average, as long as there are no systematic errors in the data. Therefore, the larger the sample size, the greater the event window that can be studied, while still allowing for mean-

[20]The "days" referred to in the event window are trading days, rather than calendar days. The minimum and maximum number of days used, and the period of time from which they are drawn can be specified differently. The majority of firms in my sample had information for all 255 days in this time period. As a robustness check, I also used observations beginning 46 days after the event and reached similar results. Arguments can be made as to which time period is more appropriate in the litigation context, based on trying to eliminate as much noise from the system as possible.

[21]Typically, the event date is denoted 0, and an event window will be specified as (begin date, end date). For example, (-1,1) denotes the three day window from the day before the event until the day after.

ingful results. Also, larger sample sizes and smaller event windows increase the probability of detecting small abnormal returns.[22]

I have a fairly large sample, which allows me to derive meaningful statistical results even for large event windows. However, it is probable that investors update their expectations about the outcome prior to final decision due to revelations during the course of the trial. The reader should keep this possibility in mind in interpreting my results.

2.5 Event Study Mean Returns

The cumulative results for each type of district court decision are presented in Table A.3. I separate the observations by type of district court decision and run the event study twice. The first time, I include all the observations (denoted "All" in the table). The second set of results presented includes only the cases in which only one patent was ruled upon (denoted "Single" in the table). This second set of results is cleaner based on my model, which isn't equipped to handle disputes involving more than one patent. It is hard to predict the effect a ruling that one patent is "Valid & Infringed" and another is "Invalid" will have on the stock market value of the firm. However, the power of the test is diminished due to the smaller sample size, especially in the longer event window.

I find that "Invalid" decisions reduce the value of a firm by nearly 1% in the three days surrounding the announcement of the decision. This translates into an average loss of about $19 million.[23] In the eleven day event window, there is an even greater drop in firm value. Both findings are statistically significant. My findings are consistent with, although larger than, Marco (2005*a*), which found -.62% and -.84% mean abnormal returns for a two day window and an 11-day window around an "Invalid" decision. The finding of a significant negative return confirms the prediction of the model in (2.2).

[22]MacKinlay (1997)

[23]This was found by multiplying the average drop in value times the average market value. Multiplying the individual drop in value times the individual market value and then averaging results in a positive dollar figure due to some large (in both terms) outliers, and is non-sensical.

For "Valid & Infringed" decisions, only the results for the shorter event window turns out to be statistically significant. Both specifications show an economically significant increase in firm value (about .7%; or $19 million), confriming the prediction of (2.3). The simplest explanation for this increase is that it reflects damage awards won by the patent holder (either in the form of royalties or lost profits). Unfortunately, I don't have information on the amount of damages awarded in each case.[24] However, the increase in value may also be attributable to an increase in investor's perception of the strength of a patent. Despite one valid and infringed ruling, validity may be relitigated in a subsequent suit against a different defendant.[25] Nonetheless, one court ruling is a strong indicator of a "good" patent, which should increase the market valuation of the patent as well. Finally, part of the increase in value is "relief" from the danger of the patent being declared "Invalid" or its scope being limited by a ruling of "Not Infringed." The drop in value for the (-5,5) window is not statistically significant. The point estimates may imply that the decision to appeal is typically made quicker (i.e., within 5 days of the decision) by defendants, which would reduce value back down after a "Valid & Infringed" decision, than by plaintiffs, which would restore some value following an "Invalid" decision.

As anticipated by (2.4), the "Not Infringed" decisions do not result in a statistically significant change in firm value. This result is consistent with my hypothesis that the returns following this type of decision would be ambiguous in sign. However, the drop in firm value should be less following "not infringed" decisions than following "Invalid" decisions, and this is not true for one of the specifications. This could simply be due to the small sample size for "Not Infringed", single case decisions.

[24]Very few court decisions on damages are announced in the USPQ. It may be possible to gather this information by checking *Wall Street Journal* news stories or possibly information contained in the companies' financial statements.

[25]The same defendant would not be able to relitigate this issue after the first trial absent extraordinary circumstances, such as the revelation of new information.

Overall, these results are consistent with other event studies on litigation.[26] The overwhelming majority of previous studies find that there is no increase in value for a plaintiff upon the filing of a suit. Here, in the context of patent litigation, the explanation may be quite obvious. The drop in value from an "Invalid" decision is greater than the increase in value following a "Valid & Infringed" decision. Thus, unless the probability of a "Valid & Infringed" decision is greater than the probability of an "Invalid" decision, the litigation has a negative net expected value for the patent holder, assuming "Not Infringed" decisions have no effect on value.[27]

2.6 Cross-Sectional Analysis

The event study also yields the abnormal returns to each individual firm following each patent decision. These returns can then be used for cross-sectional analysis to find what variables help explain the size of abnormal returns generally. I separated the district court decisions by type and then regressed the following equation using a simple Ordinary Least Squares model, with robust standard errors:[28]

$$AbnormalReturn_i = \alpha + \beta * Expectations_i + \gamma * Characteristics_i + \delta * Controls_i + \varepsilon_i \quad (2.7)$$

Under the heading "Expectations", there are two variables in the regression that should affect the expectations of investors before the decision is rendered. The first is a dummy variable that takes on a value of 1 if the Court of Appeals for the Federal Circuit was the relevant appeals court. Prior to the CAFC, it was much more likely that a patent would be declared invalid.[29] According to the analysis in Section 2, the abnormal returns of all three

[26] For a review of this literature, see Bhagat and Romano (2002*a*) and Bhagat and Romano (2002*b*).

[27] According to Henry and Turner (2006), before the establishment of the Federal Circuit, 55% of cases were "invalid" and only 32% were "valid and infringed". After the Federal Circuit, 27% of cases were "invalid" and 37% were "valid and infringed". This later ratio will result in a slightly positive expected value, but probably not enough to cover costs of the suit.

[28] A concise catalogue of the variables used is presented in Table A.1 in the appendix.

[29] See Fn. 25

types of decisions should be positively correlated with the probability of invalidity. Since the probability of invalidity goes down if this dummy variable has a value of one, (2.5) predicts a negative coefficient for this variable.

The second variable in "Expectations" measures how pro-patentee the circuit in which the litigation takes place had been over the prior five years relative to all other circuits. This variable was constructed using the full data set contained in Henry and Turner (2006). I divided the number of decisions that a patent was "not invalid" (=1-"invalid") by the total number of cases decided over the previous five years for each circuit individually and then across all circuits. I then took the difference between the two values to get my new variable. Thus, as "Friendliness" goes up, the probability of invalidity goes down (relative to the same litigation taking place in a different circuit), which (2.5) predicts should result in a negative coefficient for all three of my dependant variables.

"Characteristics" in the regression equation above contains variables related to the patent that other researchers have found to be important determinants of patent value. These variables are: the number of claims, the length of the prosecution,[30] the number of citations made by the patent, the age of the patent, whether the patent resulted from a continuation or a division of another patent application, and the technology category of the patent (relative to the "Other" category, which was excluded) as defined by Hall, Jaffe and Trajtenberg (2001). I assume a nonlinear relationship with the first four of these variables, and therefore, use the log forms of those variables. Additionally, this allows me to interpret the coefficient estimates as elasticities. According to the analysis in Section 2, patent value is negatively correlated with the dependent variable in the "invalid" regression, and positively correlated with the dependent variables in the "valid and infringed" and "not infringed" regressions. With the exception of age, which will have the opposite signs, the coefficients of these variables should follow the same pattern.

[30]The prosecution period is the time between a patent is applied for and the patent is granted by the Patent Office. Unlike Allison et al. (2004) and Moore (2005), I use the application date for the patent that was granted, rather than the original application date if the patent was a continuation or a division as the beginning date of the prosecution.

Finally, "Controls" contains a list of control variables, including: the number of other patents in the same case found to be "valid and infringed," "invalid," or "not infringed"; the log of the real market value of the firm (using 1982-84 chain weighted dollars); whether the case arose as a declaratory judgment; and whether the decision was published.[31]

The first regression includes all the observations together with dummy variables for the type of decision. Additionally, I ran a separate regression for the subset of cases that involved only one patent because I was concerned that, even with the control variables for other patents decided at the same time, the results would nonetheless be biased. The regression results for the three-day and eleven-day event windows appear in Table A.4. As expected, relative to "Not Infringed" decisions (the omitted dummy variable), "Invalid" decisions cause a greater drop in firm value. However, this drop is only statistically significant in the regressions using the eleven-day event window. Conversely, the results are mixed based on the specification for the "Valid & Infringed" decisions, with only a positive sign for the three-day event window.[32]

This first set of regressions provide weak support for my hypothesis that the Federal Circuit had a profound effect on the way patents are capitalized by the market. Across all specifications, the Federal Circuit dummy's coefficient estimate has a negative value. However, only the single, eleven-day window specification shows statistical significance for this coefficient.[33] The "Circuit Friendliness" variable has little explanatory power under any specification, and takes the wrong sign in three out of four of the regressions. The interpretation of the coefficients on the patent characteristic variables are harder to interpret because my model predicts different signs for the coefficients depending on the decision rendered. Finally, none of the specifications produces a statistically significant constant term.

[31]Occasionally, the United States Patent Quarterly publishes decisions that weren't certified by the judge to be published, and are not allowed to be cited as precedent in subsequent cases.

[32]These outcomes could be anticipated from the results in Table A.3, which show statistically significant results for "Valid & Infringed" decisions for only the shorter event window.

[33]Additionally, interacting the decision dummy variables with the Federal Circuit dummy (not shown) does not reveal any additional information.

Thus, unlike Marco (2005*b*), I can not conclude that certainty (independent of decision type) has any value for the firm.

Because of the varying predictions of the model depending on the decision, I separated the observations by decision type and re-ran the regression in 2.7. The results of these regressions are presented in Table A.5. The dependant variable in each specification is the abnormal return in the (-1,1) event window.

For the "Expectations" variables in the "Invalid" regressions the only statistically significant coefficient estimate is the dummy for the Federal Circuit in the single patent regression. This coefficient estimate also has the sign that the model predicts, indicating that the firm's market value dropped an additional 1.8% in the Federal Circuit era following an "Invalid" decision. Even though not statistically significant, the sign on the Federal Circuit dummy in the full regression and the sign on the measure of venue friendliness in the single patent regression are also as predicted. I believe that the full regression is biased by a large outlier created by a case in which other patents were found to be "Valid & Infringed," and the control variables failed to fully control for this effect.[34] Therefore, the single patent regression is probably the more meaningful specification. In the "Valid & Infringed" regressions, all of the "Expectations" coefficients tested to be statistically significant and all have the predicted sign. The value rose by 1-2% less in the Federal Circuit era. Additionally, a 10% increase in "Friendliness" results in a .5-.7% smaller rise in the market value of the firm. None of the coefficient estimates are significant or have the predicted signs for the "Not Infringed" regressions. Rather than reflecting a flaw in the model, I think that the "Not Infringed" regressions suffer because of the insignificant results found by the event study in general. Because the change in value following such a decision is more amorphous than the other two types of decisions, it also makes it harder to "explain" the observed changes. Focusing on the three specifications that had meaningful results, "Invalid-Single" and both "Valid & Infringed" regressions, it is apparent that the creation of the Federal Circuit made

[34]This case involved Amgen Inc.'s patents related to the drug Epogen, which is used to treat anemia.

patents more valuable to firms (on the magnitude of between 1-2.4% of the firm's market value). The added value comes from the reduction in the probability of the patent being declared "Invalid." After the creation of the Federal Circuit, an "Invalid" decision is more of a shock to the market, resulting in a greater drop in firm value. Additionally, if the patent is found to be "Valid & Infringed," there is less of a relief from the possibility of the patent being declared "Invalid" relative to the same litigation before the new court was established. In other words, the increased value of the patent due to the stronger property rights are already (prior to a decision being made) incorporated into the market value of the firm. This explains why the sign of the coefficient for the dummy variable is negative in either case. The additional value of the stronger property rights is reflected in each patent-holding firm's stock price outside of the litigation context, thereby making each patent more valuable for the firm that holds it.

The same analysis is true for the "Circuit Friendliness" variable. If the patent holder is able to litigate its claims in a more friendly venue, then the patent becomes more valuable for the firm. Focusing on the same three specifications as above, a 10% increase in the friendliness of the court relative to others results in between a .3-.7% increase in the value of the patent to the firm.

As for the "Characteristics" variables, I find little evidence that confirms the work of previous researchers ((Allison et al., 2004) and (Moore, 2005)).[35] In the "Invalid-All" regression, the coefficient estimate of the claims variable indicates that a 10% increase in the number of claims reduces the value of the firm by 6%. This variable does have the predicted sign for the "Valid & Infringed" regressions, but has little statistical significance. The length of the prosecution is never statistically significant. The number of cites made by the patent appears to affect the value of the patent. Although the coefficient estimate is only statistically significant in the "Valid & Infringed-All" regression, the sign is as predicted in every regression.

[35]I do not test whether the number of citations received was a significant factor in determining patent value because of the lack of data available. Additionally, this variable could change at any given time, and estimating the value to solve get around the natural truncation of the variable seems problematic to me. Therefore, I can't compare my findings to Hall (2005).

A 10% increase in the number of cites made results in approximately a 7% increase in the value of the firm. The age of the patent (time from application to the court's decision) is also statistically significant and of the correct sign in the "Valid & Infringed-All" regression. The coefficient implies a 10% increase in the age of the patent results in a 10% increase in the value of the firm. Whether a patent was a continuation of another patent application has the predicted sign in the first four regressions and is nearly statistically significant in the two "Valid & Infringed" regressions. The same is true for the division variable in the "Valid & Infringed-Single" regression. Finally, the technological category of the most valuable patents are different from the two papers cited above. They find computers and mechanical categories to be the most value, but in my regressions, those two categories rank 3rd at best. Contrarily, I find the electrical category to be most valuable in the "Invalid" regressions, and the drugs category to be most valuable in the "Valid & Infringed" regressions.

2.7 Conclusion

I use an event study to find the change in a firm's market value when a court rules on the validity and infringement of one or more of the firm's patents. I find that when a district court declares a patent to be "invalid" the average firm loses 0.85-0.92% of its value over the three days surrounding that decision. This effect is highly economically and statistically significant. According to my model, the reduction in firm value following such a decision can be attributed to a loss in expected damages and the loss of the value of the patent. A decision that a patent is "valid and infringed" only increases firm value by 0.68-0.73%. This gain in value can be derived from the award of damages in the case, or from relief that the patent's value to the firm may be maintained. Finally, a "not infringed" decision causes a statistically insignificant reduction in firm value. The lack of a predictable change in value following such a decision is the result of a loss in expected damages, counterbalanced by the relief from the chance of losing the value of patent. These results clearly show that the patent holder has more to lose in litigation than it stands to gain.

The results of my study confirm the significant effect that the establishment of the Federal Circuit had on patent litigation. Because the Federal Circuit decreased the probability of an "Invalid" district court decision, it is more shocking when one is rendered, causing a larger decrease in firm value. Similarly, because "Valid & Infringed" decisions are more expected, firm value increases less following such a decision. The same is true for firms that have a friendly venue within which to adjudicate their claims. My results show that when property rights become stronger, patents become more valuable to the firms that possess them. Discussing the value of patent without regard to the patent's enforceability is a significant oversight in the previous literature relating to patent value.

I find that the variables related to investors' expectations are at least as important as the patents' characteristics in determining the change in firm value following a court's decision. These expectations, and the value derived from them, should be maintained for the firm even outside of the litigation context, meaning that the results presented here are not contingent the particular patent ever being litigated. Rather, a universal change in the legal landscape, such as the creation of the CAFC, should raise the value of every patent, and therefore every firm that owns a patent, regardless of whether they ever litigate.

The current study is the most comprehensive study of patent litigation to date in terms of the span of data, the number of observations, and the rigor of the cross-sectional analysis. Despite the completeness of this study, further work remains to be done in this area. For instance, incorporating some measure of competitiveness of the industry into the cross-sectional analysis may provide evidence to the debate about what type of market structure is most conducive to patenting activity. Another study could focus on changes in firm value for the alleged infringer. With a matched sample, it may be possible to detect leakages, or deadweight loss, resulting from the litigation. Finally, it may be interesting to study changes in market value associated with the filing of litigation to get a more complete picture of what is happening as a result of the litigation as a whole, rather than just the conclusion.

Chapter 3

Patent Damages and Spatial Competition[1]

[1]Matthew D. Henry and John L. Turner. To be submitted to the *Journal of Industrial Economics*.

3.1 Introduction

The means by which damages are assessed if a patent is found to be infringed will have a substantial effect on how potential litigants will compete in the market. However, the effect of the choice of damage regime on differentiated products competition has been ignored in the literature.[2] Given that protection is fundamentally more important for product patents than other types of patents because of the lack of substitute forms of protection (e.g., trade secrets), and that the question of infringement is essentially one of differentiation, the lack of this consideration leaves a sizeable gap in our understanding of the importance of legal institutions. This paper seeks to fill that gap.

We consider the three primary damage regimes that have been used by United States courts: "lost profits," where damages restore the patentee to a hypothetical monopoly profit, "reasonable royalty," where damages are based on a hypothetical (pre-infringement) bargain between patentee and imitator, and "unjust enrichment," where the imitator must disgorge all profit.[3] Only the first two are still in use today. Courts decide which to apply case by case, and the methods are the subject of much discussion in the legal literature (e.g. Blair and Cotter 1998; Werden, Froeb and Beavers 1999).

Using a model of spatial competition, we analyze the impact of the three damage regimes on bargaining over a license and on subsequent duopoly competition. This setting enriches the analysis of damages for several reasons. Because of location economies, it is both privately and socially optimal for the patentee to license a second firm, so a non-trivial licensing contract obtains in equilibrium.[4] Additionally, a contract implements the joint-profit-maximizing

[2]Only two papers consider the effect of damage regime on product patents (Choi 2006 and Heath et al. 2002), and both consider models of quantity competition, with no deviation in the products' demands.

[3]Unlike other authors, we don't consider "injunctions" as a damage regime, because our model is a one-shot game. In other words, if competition is taking place, there is no injunction. If an injunction is imposed, it just forces the bargaining equilibrium, and therefore, doesn't change our analysis. Heath et al. (2002) discuss damage rules for other countries.

[4]Heath et al. (2002) consider a model of capacity-constrained firms engaging in competition under various damage regimes, which also allows duopoly profits to be greater than monopoly profits. The mechanism is distinct, however.

prices only for particular per-unit royalties. This setting contrasts with the case of Cournot competition with constant marginal costs (e.g. Choi 2006; Anton and Yao 2007), where joint profit is maximized under monopoly, and the case of bilateral monopoly licensing of research tools (e.g. Schankerman and Scotchmer 2001), where only fixed-fee licensing is considered.

We show that the "hypothetical bargain" approach to determining reasonable royalty damages does not pin down unique royalties, leaving the court significant discretion in these decisions. As in the setting of Schankerman and Scotchmer (2001), the court has a continuum of possible fixed fees it can award because of a circularity—the choice of the "reasonable" fixed fee determines the equilibrium fixed fee under the hypothetical bargain. If it is willing to assume parties expect particular threat-point equilibria, we show that the court also has a continuum of possible per-unit royalties it can award. The mechanism driving this latter result, multiple equilibria, is distinct.

The way the court exercises that discretion matters greatly for the extra equilibrium profit earned by the patentee, which we interpret as the incentives to innovate. By choosing the largest possible fixed fee, it maximizes incentives to innovate. Basing "reasonable" fixed fees on observed bargains is quite likely to cause the patentee to earn less profit and to reduce incentives to innovate, however. When patent enforcement is less-than-certain, we find that the patentee and imitator bargain to an equilibrium fixed fee that is strictly lower than the "reasonable" fixed fee that the parties expect the court would impose in damages, whenever the latter is positive.

Hence, we find some justification for the reasoning about the drawbacks of using standard royalties, made by the court in *Panduit Corp. v. Stahlin Bros. Fibre Works, Inc.* (1978):

> "Except for the limited risk that the patent owner, over years of litigation, might meet the heavy burden of proving the four elements required for recovery of lost profits, the infringer would have nothing to lose, and everything to gain if he could count on paying only the normal, routine royalty non-infringers might

> have paid...***(T)he infringer would be in 'heads-I-win, tails-you-lose' position.***" (197 USPQ 726 [6 Cir], emphasis ours.)

If the court instead uses the incentive-maximizing fixed fee and patent enforcement is certain, then the reasonable royalty regime generates the highest incentives to innovate, regardless of product value. The main strength of the reasonable royalty regime is that it yields symmetric prices, maximizing static welfare. When the likelihood of patent enforcement is very high, the firms implement near-collusive prices. When the maximum fixed fee is chosen, nearly all of the imitator's expected profit is transferred to the patentee. Hence, the patentee earns nearly all of the collusive profit.

As the likelihood of patent enforcement falls, the patentee's profit under the reasonable royalty regime falls, because the firms' prices fall. For less-than-perfect enforcement, the lost profits regime generates the highest incentives to innovate for sufficiently valuable products. Its main strength is that it is the only regime that may deter infringement. When it does so, for sufficiently high product value, the patentee earns a monopoly profit while the imitator earns nothing, generating high incentives to innovate. Our results differ sharply from those of Anton and Yao, who show that, for process patents, the lost profits regime generates relatively poor incentives for innovation, and never deters infringement.

The unjust enrichment regime is the weakest of the three, as it never yields the highest incentives to innovate and yields low ex post welfare when bargaining breaks down. Our findings suggest that the Patent Act of 1946 and the 1964 Supreme Court decision in *Aro Manufacturing Co. v. Convertible Top Replacement Co.*,[5] which together ended the use of unjust enrichment damages, are supportable on economic grounds.

Prior to *Aro*, courts usually awarded damages on the basis of the imitator's profit. In *Aro*, the Court found that when Congress amended the statute, in 1946, to say that a patentee is entitled to "damages adequate to compensate for the infringement, but in no event less than a reasonable royalty,"[6] they intended to proscribe unjust enrichment damages. It is

[5]377 US 476.

[6]35 USC Section 284.

clear from the statutory language that the preferred measure of compensation is lost profits. In the landmark decision in *Panduit Corp. v. Stahlin Bros. Fibre Works, Inc.* (1978),[7] the court also announced four factors a patentee must prove to recover lost profits:

(1) demand for the patented product,

(2) absence of acceptable noninfringing substitutes,

(3) his manufacturing and marketing capability to exploit the demand, and

(4) the amount of the profit he would have made.

When the *Panduit* test cannot be satisfied, many courts resort to awarding a reasonable royalty on the basis of a hypothetical (pre-infringement) arm's-length negotiation between the patentee and the imitator. In *Georgia-Pacific Corporation v. U.S. Plywood-Champion Papers Inc.* (1970),[8] the court laid out a fifteen-factor test for determining the royalty rate, which has been widely followed by other courts. Coolley (1993) shows that courts awarded reasonable royalty damages more often than lost profits during 1982-92, but the application of lost profits typically resulted in higher damages.

The effects of damage regimes on infringement decisions and market competition have been examined for research tools (Schankerman and Scotchmer 2001), and for process (Anton and Yao 2007) and product patents (Choi 2006) under quantity competition, but have yet to be examined in the context of differentiated products. In addition to yielding a richer context for bargaining, this framework has significant practical appeal. First, the patent grant is fundamentally, and multi-dimensionally, spatial. The patent issuing country's boundaries determine the covered geographic area, while the patent's claims determine the covered product characteristics.[9] Studying licensing in this context is therefore important to understanding patent licensing generally. Second, the strategic complementarity of prices has yet

[7]197 USPQ 726 [6 Cir].

[8]166 USPQ 235 [S.D.N.Y].

[9]Merges and Nelson (1990, p. 839) state "The economic significance of a patent depends on its scope." The spatial nature of patents has also been analyzed by Klemperer (1990), who studies the welfare tradeoffs between patent scope and length.

to be analyzed by this literature. We show that complementarity is enhanced by both royalties and the likelihood of patent enforcement, so prices may actually be higher under infringement. This may have some implications for techniques used to calculate damages, which typically assume that infringement causes prices to fall. Finally, product patents are highly represented in litigation, and the widespread application of the doctrine of equivalents implies significant differentiation.[10] Perhaps most notably, each of the three pivotal decisions on damage awards (cited above) involves product patents only,[11] and the *Panduit* test is particularly geared toward them.[12]

We adapt a model of the Hotelling (1929) linear city, with fixed firm locations, to a setting of patent infringement and damages. The most natural interpretation of the basic model is pure spatial competition, e.g. the patentee is a company with production facilities in New York, and the potential imitator is located in California. In this case, the transportation costs are interpreted as the cost of shipping the product. Alternatively, the model could be interpreted as reflecting product differentiation, where the transportation costs represent the consumer's loss of utility of not having the "ideal" product. In either case, location economies influence bargaining and equilibrium pricing.

We follow Anton and Yao (2007) and model the lost profits and unjust enrichment damage regimes to mimic how they are carried out in practice. In our model, the court does not assume that the patentee is entitled to the payoff that would be obtained under efficient bargaining. Instead, the court looks to the efficient bargain only for purposes of calculating the "reasonable" royalty rate. Under the lost profits regime, the court bases damages on the patentee's hypothetical payoffs as a monopolist (i.e. absent infringement), not on his

[10]See Merges and Nelson (1990).

[11]In *Aro*, the patent at issue, No. 2,569,724 "Convertible Folding Top With Automatic Seal at Rear Quarter," is a mechanism for convertible automobiles. In *Georgia-Pacific*, the patent at issue, No. 2,286,068 "Plywood Panel," is a plywood product. In *Panduit*, the patent at issue, No. 3,024,301 "Wiring Grille," is a type of duct for wiring of electrical control systems.

[12]It may not even be possible to satisfy (1) when the patent is for a research tool or a process. We know of no case where "lost profits" has been applied for either of those types of patents.

hypothetical payoff under bargaining. Under the unjust enrichment regime, the court bases damages only on the actual profit earned by the imitator.[13]

Schankerman and Scotchmer (2001) study the impact of the lost profits, unjust enrichment, and injunction regimes under certain court enforcement. For their main case, research tools to be used by another party, there is no meaningful distinction between lost profits and lost royalties. All of their analysis is done against the backdrop that the patent will be licensed, and the court is needed only when licensing negotiations break down. They find, as we do, that infringement is not necessarily deterred, and that the patentee might prefer an enforcement regime that leads to infringement, absent a license.

In their main analysis, they also find that there may be a circularity in the assignment of damages when lost royalties is the regime. Because any prospective damages to be awarded by the court influence the threat points in their negotiation, the likely damages (along with the level of bargaining power) determine the size of the license fee. The license fee, in turn, influences the court's setting of lost royalty damages, creating the circularity.

We find the same indeterminacy with respect to the fixed fee component of reasonable royalty damages, and for the same reason. We also find an indeterminacy with respect to the per-unit component, but it is not due to circularity. Regardless of which damage regime is specified, there are multiple per-unit royalty rates under which efficient pricing is an

[13]We are sympathetic to the approach of Schankerman and Scotchmer (2001, 2005) of basing lost profit damages entirely on "equilibrium" profits achieved through bargaining. This approach may be appropriate when court enforcement is certain, as in the Schankerman and Scotchmer (2001) setting, and it is the approach we take with respect to the "hypothetical bargain" in the reasonable royalty regime. However, mimicking their approach would lead us to the unsavory proposition that damages might depend on ex ante beliefs about court enforcement. In section 7 of their 2001 paper, for example, they identify unique damages under the assumption that bargaining leads to efficiency gains. However, this level of damages is based on their finding that infringement is always deterred if bargaining breaks down. This holds only when court enforcement of the patent is certain. If this is relaxed, then infringement is not necessarily deterred, and when it is not, the damage award depends directly on the likelihood of court enforcement. This result, which obtains in the model of the 2005 paper, is awkward, because after a patent is found valid and infringed, the likelihood of enforcement is unity and there is no provision in the law for basing damages on prior beliefs about the outcome of litigation. Importantly, there is no provision in the *Georgia-Pacific* factors for such beliefs.

equilibrium. Only one royalty yields this as a unique equilibrium, however, and we argue that this is most "reasonable" in our context. We develop further results for the reasonable royalty regime using this particular value.

Anton and Yao (2007) restrict attention to process patents, and examine the lost profits, reasonable royalties, and disgorgement (unjust enrichment) regimes in a Cournot duopoly model. They show that, under the lost profits regime, the imitator can infringe without diminishing the patentee's profit, and that this "passive" infringement is an equilibrium for high levels of court enforcement of patents.[14] In contrast, we find that when bargaining breaks down, passive infringement may be an equilibrium, but it is not generally unique.

Anton and Yao also find that the other party is always better off infringing (either passively or actively) than not entering the market. Consequently, the penalty for losing a patent race is lower and the incentive to innovate is blunted. Because passive infringement is not always possible in our setting, we do not find the same effect. Indeed, the lost profits regime is the only one that may deter infringement, and it produces strong incentives to invent in such situations.

Choi (2006) studies product patents in a Cournot duopoly model. He finds that the lost profits regime generates greater profit for the patentee and greater R&D incentives. This result does not hinge on whether infringement is deterred by these regimes. Under spatial competition, by contrast, infringement deterrence is a crucial determinant of which regime provides the best R&D incentives. Choi also finds that if patent enforcement is uncertain, then no "reasonable" royalty rate exists when the patentee makes a take-it-or-leave-it offer in bargaining over a license. This finding emerges because market profit is maximized under monopoly in a Cournot model, and suggests, indirectly, that efficient bargaining should eliminate competition. It does not extend to Coasian bargaining over a license prior to

[14]Basing lost profits on equilibrium licensing (see footnote 13), Schankerman and Scotchmer (2005) show that dissipation of total profits under infringement is a crucial determinant of infringement deterrence.

competition in a differentiated products setting, as we show. Indeed, we find a multiplicity of possible "reasonable" royalty rates, regardless of the strength of patent enforcement.

The only paper we are aware of that studies patent licensing under spatial competition is Poddar and Sinha (2004). They too consider "inside" licensing (i.e. the licensor is a producer) but restrict attention to the case of a process patent and do not study uncertain enforcement or damage regimes. Indeed, their work is done in the spirit of the literature on optimal patent licensing–their main results compare the various ways of selling a license in a non-cooperative framework.[15] Our work, though related, does not take issue with any of the findings in this literature.

3.2 The Model

We begin with a standard model of the Hotelling linear city with fixed firm locations.[16] Consumers have identical reservation value V for the good and are distributed uniformly along a line of unit length. They bear transportation costs t per unit of distance they travel to the seller. The patentee sells at location 0. There are two possible market structures: (1) single-price monopoly, and (2) duopoly including an imitator, who sells at location 1. All parties are risk neutral and their preferences do not display wealth effects.

Before market activity, the patentee and potential imitator bargain over a licensing contract that may specify a per-unit royalty r, paid from the imitator to the patentee, and a fixed payment F. The parties may also fix prices and/or market shares, but any contract must be *self-reinforcing*, i.e., conditional on the specified royalties, neither party has an incentive to deviate from the specified prices or market shares.[17] If they fail to agree, market activity ensues in the shadow of an exogenously specified damage regime that is common knowledge.

[15]This large literature has considered fixed fees, per-unit royalties, auctions, and combinations of fixed fees and royalties, for "outside" licensing of process patents (Kamien and Tauman 1986) and product patents (Katz and Shapiro 1986), as well as for "inside" licensing (Marjit 1990). See Kamien (1992) for a survey.

[16]The assumption of fixed locations implies that the firms have sunk costs, e.g. plant location.

[17]Implicitly, we assume that to enforce a contract that is not self-reinforcing would require costly monitoring, making such contracts sub-optimal.

If the imitator competes, the firms reach a Nash equilibrium in prices. We denote the patentee's price as P_H,[18] and the imitator's price as P_I. Demands are $D_H(P_H, P_I)$ and $D_I(P_H, P_I)$ and revenues are $R_H(P_H, P_I) = P_H D_H(P_H, P_I)$ and $R_I(P_H, P_I) = P_I D_I(P_H, P_I)$, respectively. The imitator produces with the same constant-marginal-cost technology as the patentee, and marginal costs are normalized to zero. If the imitator does not compete, it earns a payoff of 0.

A consumer located at x buys from one of the two sellers if $Max\{V - P_H - tx, V - P_I - t(1-x)\} \geq 0$, and buys from the patentee if $V - P_H - tx \geq V - P_I - t(1-x)$ also holds. Demands are determined by prices through these two conditions. The *pivotal* buyer, who is indifferent between buying from the patentee and the imitator, is

$$\widehat{x}(P_H, P_I) = \frac{1}{2} + \frac{P_I - P_H}{2t} \in [0, 1]$$

Combining these conditions, it is easily seen that the entire market is covered if and only if

$$P_H + P_I \leq 2V - t, \tag{3.1}$$

in which case $D_H(P_H, P_I) = \widehat{x}(P_H, P_I)$ and $D_I(P_I, P_H) = 1 - \widehat{x}(P_H, P_I)$.

For ease of explanation, we restrict attention to the case $V \geq \frac{3}{2}t$. This is sufficient to guarantee that the market is fully covered in equilibrium under duopoly and to rule out uninteresting cases where a negative per-unit royalty may be optimal. It also reduces the incidence of multiple equilibria.[19]

The patent covers a brand-new product. In absence of a licensing contract, if the imitator makes positive sales, the patentee takes it to court, and is entitled to damages if the patent is found valid in court. Following Anton and Yao (2007), we assume that the patent is found valid with exogenous, commonly-known probability $\gamma \in [0, 1]$,[20] abstract from transactions

[18] H is for patent *holder*.

[19] In the standard Hotelling duopoly model with fixed locations, the restriction $V \geq \frac{3}{2}t$ is the minimum sufficient one to rule out multiple equilibria (see, e.g. Mas-Colell, Whinston and Green 1995, p. 398 and exercise 12.C.14, p. 432).

[20] An interesting extension of this model would allow the parties' assessments of this probability to differ, thereby allowing for the special case where infringement is inadvertent.

costs in the litigation stage,[21] and refer to *passive infringement* as a situation where the imitator's infringing market activity does not result in lost profits for the patentee.

We study three damage regimes. Under the *reasonable royalty* regime, the imitator pays the patentee a per-unit royalty for each unit it sells, as well as a fixed fee. The court chooses these measures to mimic a licensing contract under hypothetical arm's-length bargaining. Under the *lost profits* regime, the imitator pays the patentee the difference between its hypothetical monopoly profit and its actual duopoly profit. Under the *unjust enrichment* regime, the imitator pays the patentee all of its market profits.

The timing of the model is as follows. First, the damage regime is exogenously determined. Second, the patentee and imitator bargain over a license for the patent. Third, the imitator decides whether to compete. If the imitator stays out, the patentee operates as a single-price monopolist. If the imitator enters, then the two firms compete in prices and reach a Nash equilibrium. Finally, if bargaining breaks down and the imitator makes sales, then the court decides the patent's validity, and assigns damages.

3.2.1 Bargaining

We denote the payoffs for the patentee and imitator from their market activity (including royalty revenue) under an efficient bargain as $\Pi_H^{B_j}$ and $\Pi_I^{B_j}$, and the expected payoffs from market activity plus damages, when bargaining breaks down, as π_H^j and π_I^j, where $j \in \{RR, LP, UR\}$ depending on the damage regime. These latter payoffs form the *threat points* under bargaining. Following Schankerman and Scotchmer (2001), we abstract from transactions costs of bargaining.

The Coase Theorem implies that the parties will agree to prices that maximize total profit,

$$\Pi_H^{B_j} + \Pi_I^{B_j} = R_H(P_H, P_I) + R_I(P_H, P_I),$$

[21] For detailed models of patent litigation, see Meurer (1989), Choi (1998) or Crampes and Langinier (2001).

and that they will implement that profit with a per-unit royalty that renders the contracted prices to be self-reinforcing. Consider prices first. If the pivotal buyer is not held to reservation utility, then the patentee and imitator can both raise prices by the same amount, maintain market shares, and increase joint profit. Hence, joint profit is maximized only if this buyer earns zero utility, i.e., if (3.1) holds with equality. Factoring in this condition, and doing a bit of algebra, the firms' problem is

$$\begin{aligned} Max_{\{P_H,P_I\}} \quad & (V - \tfrac{1}{2}t) - \tfrac{1}{2t}(P_I - P_H)^2 \\ s.t. \quad & P_H + P_I = 2V - t. \end{aligned} \tag{3.2}$$

Clearly, joint profit is maximized if and only if the efficient bargain results in $P_H = P_I = V - \frac{1}{2}t$.

The firms must also choose a per-unit royalty such that neither wishes to deviate from the efficient prices. A well-chosen positive r can achieve this because it increases the cost of gaining market share, enhancing the strategic complementarity of prices. For the imitator, r is an artificial marginal cost of additional market share. For the patentee, r is an artificial opportunity cost of additional market share. The following result shows that a continuum of per-unit royalties achieve a self-reinforcing, efficient contract.

Lemma 1 *Regardless of the damage regime, the bargain is efficient only if it yields* $P_H = P_I = V - \frac{1}{2}t$. *This is a self-reinforcing equilibrium if and only if the per-unit royalty* $r \in [V - \frac{3}{2}t, V - t] \equiv \mathcal{R}^*$.

For sufficiently low $r < V - \frac{3}{2}t$, both firms have the incentive to cut price below $V - \frac{1}{2}t$ to increase market share. For sufficiently high $r > V - t$, the imitator prefers to reduce royalty payments by charging a higher price than $V - \frac{1}{2}t$ and earning a smaller market share than the patentee.[22]

[22]The firms can implement optimal prices either through price fixing or territorial licensing (quantity fixing). Under price fixing the firms simply agree to $P_H = P_I = V - \frac{1}{2}t$ and $r \in \mathcal{R}^*$. Under territorial licensing, the firms agree to split the consumers into two even territories. As long

Hence, factoring in the per-unit royalty payment of $\frac{1}{2}r$ and the fixed payment F from the imitator to the patentee, we can write the equilibrium payoffs for $r \in \mathcal{R}^*$ and a given j:

$$\begin{aligned} \Pi_H^{B_j} &= (V - \tfrac{1}{2}t)\tfrac{1}{2} + r\tfrac{1}{2} + F \\ \Pi_I^{B_j} &= (V - \tfrac{1}{2}t)\tfrac{1}{2} - r\tfrac{1}{2} - F. \end{aligned} \tag{3.3}$$

The fixed payment F, which affects only the division of wealth, is determined in bargaining. We assume that the patentee and imitator split the *bargaining surplus*, $S_B^j = \Pi_T^{B_j} - (\pi_H^j + \pi_I^j)$, achieved when a contract is implemented in the shadow of regime j, according to exogenous bargaining power. Firm 1 has bargaining power β, while firm 2 has bargaining power $1 - \beta$. Assuming, without loss of generality, that firm 1 is the patentee, efficient bargaining leads to the following payoffs:

$$\begin{aligned} \Pi_H^{B_j} &= \pi_H^j + \beta S_B^j \\ \Pi_I^{B_j} &= \pi_I^j + (1 - \beta) S_B^j. \end{aligned} \tag{3.4}$$

Hence, each party gets its disagreement payoff plus a share of the extra surplus. The equilibrium value of F sets the payoffs in (3.4) equal to those from (3.3). The same total payoff obtains in equilibrium for each damage regime.

3.2.2 Incentives to Innovate

In our model, the importance of the damage regime emerges in the additional profit that it yields to the patentee. We denote this $\Delta_\Pi^j = \Pi_H^{B_j} - \Pi_I^{B_j}$ and interpret it as the firm's *incentives to innovate*.[23] We assume bargaining power is primitive to the firm—namely, firm 1 (which has bargaining power β) gets share β of the bargaining surplus regardless of whether

as $r \in \mathcal{R}^*$, neither firm wishes to intrude on the others' territory and prices so that the $x = \frac{1}{2}$ buyer earns zero utility. This latter conclusion assumes that the firms pick prices conditional on contractually-specified territory, then do not wish to deviate from either the prices or the territory.

[23] For example, in the case of "memoryless" R&D investment technology, an increase in the patentee's payoff that also leads to a wider spread in payoffs yields greater R&D incentives in a patent race setting. For a simple illustration, see section 6 of Anton and Yao (2007). For greater detail, see Reinganum (1989).

it is the patentee or imitator.[24] Hence, its incentives to innovate are just the difference in the threat-point payoffs,

$$\Delta_{\Pi}^{j} = \pi_{H}^{j} - \pi_{I}^{j}.$$

These incentives depend crucially on the likelihood of enforcement γ and on the damage regime j. If $\gamma = 0$, for example, then $\Delta_{\Pi}^{j} = 0$ for all j. If $\gamma > 0$, there are differences across regimes. These are driven primarily by differences in the nature of entry and in *static welfare*, defined as the sum of consumer surplus and joint profit $\pi_{H}^{j} + \pi_{I}^{j}$ under threat-point competition. We now consider the reasonable royalty, lost profits and unjust enrichment damage regimes in turn.

3.3 Reasonable Royalty

The reasonable royalty regime awards per-unit and fixed components of damages. To determine the elements of this pair, which we denote $\{r^*, F^*\}$, we follow existing US court precedent and use a *hypothetical bargain* over a license,[25] where the components are to be

> "...based upon a hypothetical negotiation between the patent owner and the infringer, at the time the infringement began, with both parties to the negotiation assuming that the patent is valid and would be infringed but for the license." (*Northlake v. Glaverbel*, 72 F.Supp. 2d 893 [ND Ill. 1999])

Applied to our setting, the precedent demands that $\{r^*, F^*\}$ be equilibrium outcomes of an arm's-length bargain. Moreover, the threat-point payoffs π_{H}^{RR} and π_{I}^{RR} must reflect the mutual belief that $\gamma = 1$.

[24] That is, if firm 1 were to be the imitator, then the imitator's payoff would be $\Pi_{I}^{B_j} = \pi_{I}^{j} + \beta S_{B}^{j}$, in contrast to $\Pi_{I}^{B_j}$ in (3.4). Note that our main results do not change qualitatively if a firm's bargaining power depends on whether it is the patentee.

[25] Reitzig et al (2006) argue that the royalty calculation imposed by courts often greatly differs from what the agreed-upon royalty rate would have been. This occurs because courts often impose industry-standard royalty rates and fail to consider other factors (i.e., the cost of designing around the patent, the lack of other licensing opportunities for the patentee, the willingness of the imitator to avoid infringement, etc.) that would affect relative threat points in the bargain. Like Schankerman and Scotchmer (2001), we attempt to remain faithful to the what the law prescribes.

It is easiest to determine recursively the components of the reasonable royalty. We first consider threat points under the *actual bargain*, i.e. the bargain that yields the equilibrium payoffs given in (3.4). Threat points in the hypothetical bargain obtain for the special case of $\gamma = 1$. We then use (3.3) to solve for $\{r^*, F^*\}$ and work backwards to compute equilibrium payoffs in the actual bargain.

In the actual bargain, the threat points π_H^{RR} and π_I^{RR} reflect competition in the shadow of both $\{r^*, F^*\}$ and the uncertain level of patent enforcement γ. If bargaining breaks down, the patentee and imitator compete in prices at arm's length, anticipating that, with probability γ, the court will award the patentee a royalty r^* on all units sold by the imitator, as well as a fixed payment F^*. Assuming entry is profitable,[26] this gives rise to the following profit functions, net of expected fixed payments:

$$\begin{aligned} \pi_H^{RR} - \gamma F^* &= Max_{\{P_H\}} \left\{ R_H(P_H, P_I) + \gamma r^* \left[D_I(P_H, P_I) \right] \right\} \\ \pi_I^{RR} + \gamma F^* &= Max_{\{P_I\}} \left\{ R_I(P_H, P_I) - \gamma r^* \left[D_I(P_H, P_I) \right] \right\}. \end{aligned} \tag{3.5}$$

The expected per-unit royalty γr^* enhances the strategic complementarity of prices, while affecting the pricing decisions of the patentee and imitator in exactly the same way. For the imitator, γr^* is an artificial marginal cost of additional market share. For the patentee, γr^* is an artificial opportunity cost of additional market share. In equilibrium, prices are higher than in a standard one-shot Hotelling game but, provided the expected royalty is not too high, market shares are necessarily equal. Hence, total static welfare is maximized. For a sufficiently high expected royalty, there are multiple equilibria and prices may be asymmetric. We have the following result.

Proposition 1 *Suppose bargaining breaks down and competition ensues in the shadow of the reasonable royalty regime, with components* $\{r^*, F^*\}$. *If* $\gamma r^* \leq V - \frac{3}{2}t$, *the equilibrium is unique, with symmetric prices* $P_H^* = P_I^* = t + \gamma r^*$ *and demands* $D_H = D_I = \frac{1}{2}$. *Static welfare is maximized. If* $\gamma r^* \in [V - \frac{3}{2}t, V - t]$, *then the market is fully covered and equilibrium prices*

[26] Because of the way the hypothetical bargain is implemented, entry is always profitable in equilibrium under reasonable royalty. We show this later in this section.

satisfy:

$$i. \quad P_H + P_I = 2V - t$$

$$ii. \quad P_H \geq \tfrac{V}{2}$$

$$iii. \quad P_I \geq \tfrac{V+\gamma r^*}{2}.$$

To see the intuition for the unique-equilibrium case ($\gamma r^* \leq V - \frac{3}{2}t$), consider the symmetric reaction functions:

$$P_H(P_I) = \tfrac{P_I + t + \gamma r^*}{2}$$

$$P_I(P_H) = \tfrac{P_H + t + \gamma r^*}{2}$$

These are plotted in Figure 3.1 for the case $r^* = V - \frac{3}{2}t$. For $\gamma < 1$, they intersect at prices $P_H^* = P_I^* = t + \gamma r^*$ (point A). The pivotal buyer, at $x = \frac{1}{2}$, receives strictly positive net utility. For $\gamma = 1$, they intersect at $P_H^* = P_I^* = V - \frac{t}{2}$ (point B), and the constraint (3.1) holds with equality. Hence, if the actual bargain were to break down, prices would be lower than under bargaining if $\gamma < 1$. Decreases in the likelihood of patent enforcement mitigate the strategic complementarity in the same way that a lower royalty does, decreasing total profit to $t + 2\gamma r^*$ and creating a strictly positive bargaining surplus. Since equilibrium market shares remain symmetric, however, transportation costs are minimized and total static welfare is maximized.

If $\gamma r^* \in (V - \frac{3}{2}t, V - t]$, then there are multiple equilibria. This case is illustrated in Figure 3.2, where we set $r^* = V - t$ and $\gamma = 1$. Point A does not constitute an equilibrium, because the prices violate (3.1). The best response in such situations is either to price on the constraint, in which case the market is covered and the pivotal buyer's net surplus is zero, or, when the other firm's price is uncompetitive (i.e. extremely high), to set price $\underline{P_i}$, for $i \in \{H, I\}$. For the patentee, this is the same as an optimal monopoly price,[27] because marginal changes in P_H do not affect the size of royalty payments when the imitator's price

[27]Monopoly pricing is discussed in detail in section 4.

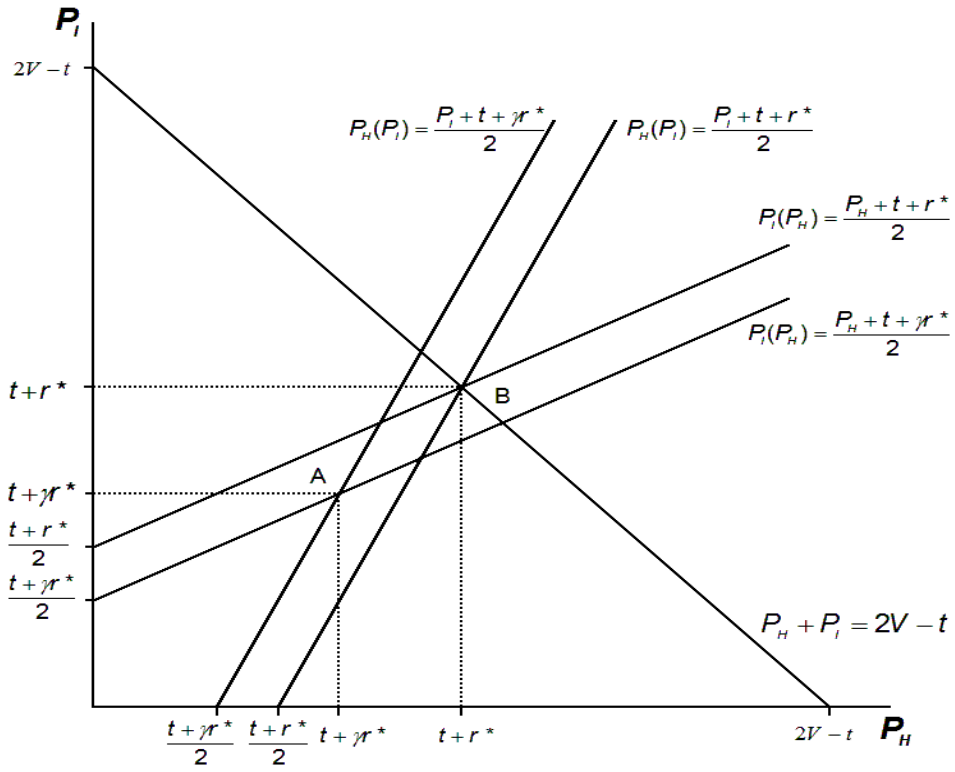

Figure 3.1: Threat Point Competition, Reasonable Royalty, $r^* = V - \frac{3}{2}t$

is uncompetitive. The imitator, however, pays royalties on every unit sold, so $\underline{P_I} = \frac{V+r^*}{2}$ is optimal when the patentee is uncompetitive.[28]

The constraint forms part of *both* reaction functions. The reaction function for the patentee runs from point 0_H to E, then from E to B, then turns vertical at B, while for the imitator, it runs from 0_I to C, then from C to D, then turns horizontal at C. These reaction functions overlap between points C and D, and each point in this interval is an equilibrium. As r increases, $\underline{P_I}$ also shifts up and, for $r > V - t$, the imitator strictly prefers to reduce its market size below $\frac{1}{2}$.

[28]Intuitively, the royalty functions like a marginal cost for the imitator and, for r^* (or any $r \in \mathcal{R}^*$), if the patentee's price is uncompetitive, it is optimal for the imitator to serve less than the entire market.

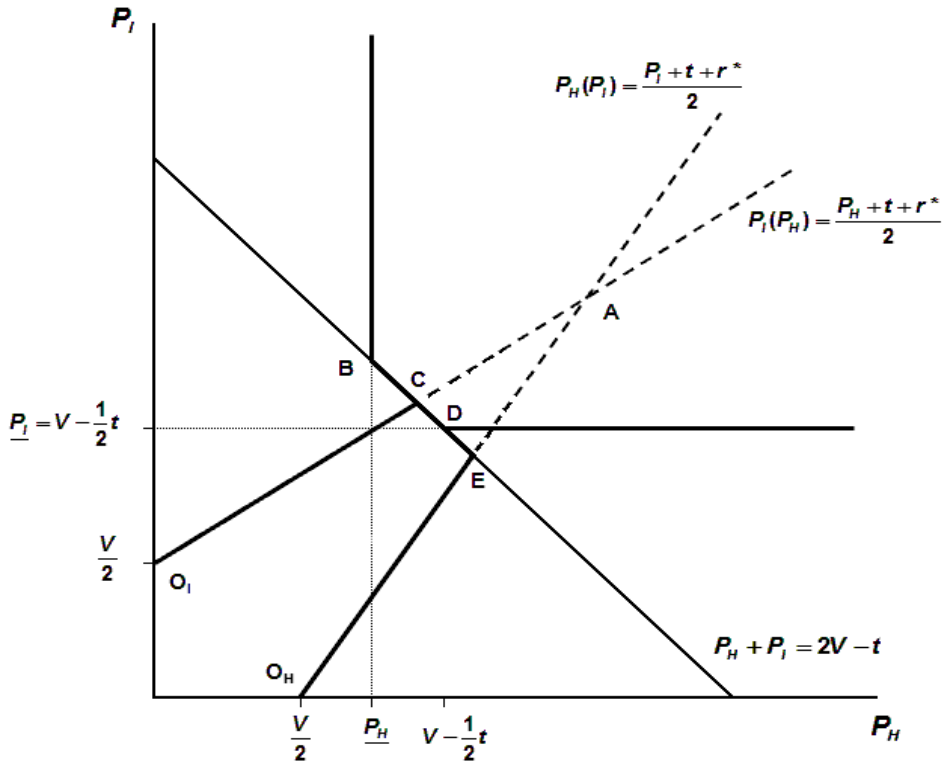

Figure 3.2: Threat Point Competition, Reasonable Royalty, $r^* = V - t$, $\gamma = 1$

3.3.1 The Hypothetical Bargain

By Lemma 1, it is clear that any efficient bargain leads to a per-unit royalty in $\mathcal{R}^*$, so the hypothetical bargain must have $r^* \in \mathcal{R}^*$. Conditioning on this, we solve for the reasonable royalty by setting the patentee's payoff under the efficient bargain, equation (3.3), equal to its threat point payoff plus β times the renegotiation surplus, from equation (3.4).[29] The hypothetical bargain assumes $\gamma = 1$ under threat-point competition. Given an $r^* \in \mathcal{R}^*$, we have, for the patentee,

$$\left(V - \frac{1}{2}t\right)\frac{1}{2} + \frac{r^*}{2} + F^* = P_H D_H(P_H, P_I) + r^* D_I(P_H, P_I) + F^* + \beta\left[\frac{1}{2t}(P_H - P_I)^2\right] \quad (3.6)$$

[29]Using the imitator's payoffs yields the same thing.

, where P_H, P_I, D_H and D_I reflect an equilibrium under (threat-point) competition with per-unit royalty r^*, and the bargaining surplus is obtained using (3.2). It is immediately clear from (3.6) that F^* is not unique, a point of similarity between our setting and that of Schankerman and Scotchmer (2001) that we return to later.

Canceling F^* from both sides of the equals sign, we turn our attention to identifying r^*. From Proposition 1, it is clear that there is only one $r \in \mathcal{R}^*$ for which threat-point equilibrium prices and demands are unique and which satisfies (3.6), $r = r^U = V - \frac{3}{2}t$ (recall Figure 1). Clearly, $r^* = r^U$ is reasonable.

For the other $r \in \mathcal{R}^*$, the prices that the parties expect to obtain in equilibrium under threat-point competition matter for the royalty that they will agree to. If they anticipate the symmetric equilibrium, $P_H = P_I = V - \frac{1}{2}t$, then there is no bargaining surplus and (3.6) is trivially satisfied for all $r \in \mathcal{R}^*$. For asymmetric prices, however, the bargaining surplus is positive. In this case, (3.6) is satisfied for some, but not all, $r \in \mathcal{R}^*$, and the royalties that satisfy the condition depend on β.[30] Since threat-point payoffs are assumed to result from arm's-length competition, where price-fixing does not occur, it is awkward to consider r to be "reasonable" when it satisfies the requirements of the hypothetical bargain for some, but not all, pricing equilibria. It is also awkward for the threat-point pricing equilibrium that is implied by a particular r^* to depend on β, as bargaining power is actually irrelevant under threat-point competition.[31] The following result offers an appealing refinement.

Proposition 2. *The only per-unit royalty that satisfies the requirements of the hypothetical*

[30] Writing demands as a function of P_H and P_I and using the restriction $P_H + P_I = 2V - t$, it can be shown that condition (3.6) is equivalent to $r^* = V - t + \left(\beta - \frac{1}{2}\right)(P_I - P_H)$ and P_H and P_I are equilibrium prices given per-unit royalty r^*. For a given threat-point equilibrium, this condition rules out many per-unit royalties in $\mathcal{R}^*$. For example, if the parties in the hypothetical bargain anticipate asymmetric prices under threat-point competition and $\beta \neq \frac{1}{2}$, then $r^* = V - t$ is not reasonable. On the other hand, if $\beta = \frac{1}{2}$, then $r^* = V - t$ is reasonable for any asymmetric prices, but no other royalty is reasonable.

[31] In essence, the hypothetical bargain does not make much sense if there is bargaining surplus, because the fixed component F^* is part of the threat point payoff and therefore cannot serve as a means of sharing the bargaining surplus.

bargain for all implied threat-point equilibria and β is $r^U = V - \frac{3}{2}t$.

In analyzing the reasonable royalty regime, we henceforth restrict attention to r^U (where the superscript denotes "unique").

It remains to identify F^*. Consider again the hypothetical bargain. If the patentee and imitator were to mutually agree that $\gamma = 1$ if bargaining were to break down, then the threat point payoffs would be, for $r^* = r^U$,

$$\begin{aligned} \pi_H^{RR^*} &= V - t + F^* \\ \pi_I^{RR^*} &= \tfrac{t}{2} - F^*, \end{aligned} \tag{3.7}$$

provided that both payoffs are non-negative. If one of these payoffs were negative, then the firm facing such a payoff would choose to stay out of the market and earn a payoff of 0. However, any F^* that results in a negative payoff in (3.7) cannot satisfy the requirements of the hypothetical bargain.

Proposition 3 *The reasonable fixed component $F^* \in [-(V-t), \frac{t}{2}] \equiv \mathcal{F}^*$*

Because the bargaining surplus is zero, the payoffs in (3.7) are identical to the equilibrium payoffs under the efficient bargain with per-unit royalty r^U and fixed payment F^*, given by equation (3.3). Clearly, the patentee and imitator would never mutually agree to an F^* such that either of those payoffs is negative. Conditional upon this restriction, however, any F^* can be an equilibrium in the hypothetical bargain, precisely because the payoffs above are identical to those in (3.3). The logic of this result is essentially the same as in Schankerman and Scotchmer (2001). The court's choice of F^* determines the fixed component of the license fee, so there is a circularity—multiple values of F^* satisfy the requirement.

3.3.2 Equilibrium Payoffs and Incentives to Innovate

Now consider the actual bargain with reasonable royalty $\{r^U, F^*\}$. In equilibrium, the fixed payment F equates (3.4) and (3.3), yielding

$$F = \gamma F^* + (1-\gamma)(\beta - 1)\left(V - \frac{3}{2}t\right),$$

and incentives to innovate

$$\Delta_{\Pi}^{RR} = \gamma\left(V - \frac{3}{2}t + 2F^*\right).$$

We have the following result.

Proposition 4 *Suppose $r^* = r^U$ and $\gamma < 1$. If $F^* > 0$, then the equilibrium fixed payment $F < F^*$. This payment equals F^* if and only if $F^* = F^R \equiv (\beta - 1)\left(V - \frac{3}{2}t\right) \leq 0$. Incentives to innovate are maximized for $F^* = F^{Max} \equiv \frac{t}{2}$.*

Clearly, if $\gamma = 1$, then $F = F^*$, as the hypothetical bargain requires. Otherwise, the parties reduce the size of the fixed payment in accordance with the weaker bargaining position of the patentee and stronger bargaining position of the imitator.

The only reasonable fixed component for which the actual bargain produces F^* as the equilibrium fixed payment is $F^* = F^R$ (where the superscript "R" denotes "rational"). While rationality is an appealing property for F^*, employing F^R yields peculiar results. First, it implies a negative fixed payment. Second, it yields incentives $\Delta^{RR} = (2\beta - 1)\left(V - \frac{3}{2}t\right)$, which are positive if and only if $\beta > \frac{1}{2}$.

It is clear that incentives to innovate are maximized for the largest value that satisfies the requirements for the hypothetical bargain, $F^* = F^{Max}$. Hence, the reasonable royalty regime with components $\{r^U, F^{Max}\}$ yields incentives

$$\Delta_{\Pi}^{RR} = \gamma\left(V - \frac{1}{2}t\right).$$

As V increases, Δ_{Π}^{RR} increases at rate γ.

3.4 Lost Profits

The lost profits regime assumes that the rightful profit for the patentee is a monopoly profit, and sets damages equal to the difference between monopoly profit and duopoly profit. Consider first the monopoly case. A consumer located at point x on the line will buy from the patentee-monopolist if $P_M \leq V - tx$ (the subscript M denotes "monopolist"). The optimal price depends on the value of the product, relative to transportation costs:

$$P_M = \begin{cases} V - t & \text{if } V > 2t \\ \frac{V}{2} & \text{if } V \leq 2t. \end{cases}$$

For sufficiently high V, the monopolist serves the entire market, and holds the consumer at $x = 1$ to his reservation utility, net of transportation costs. In this case, $\pi_M = V - t$. Otherwise, the monopolist serves only consumers at $x \leq \frac{V}{2t}$, and prices so that marginal revenue for the pivotal buyer equals zero. In this case, $\pi_M = \frac{V^2}{4t}$.

Expected profit functions under competition in the shadow of lost profits are

$$\begin{aligned} \pi_H^{LP} &= Max_{\{P_H\}} \left\{ R_H(P_H, P_I) + \gamma \left[\pi_M - R_H(P_H, P_I) \right] 1(\pi_M > R_H(P_H, P_I)) \right\} \\ \pi_I^{LP} &= Max_{\{P_I\}} \left\{ R_I(P_H, P_I) - \gamma \left[\pi_M - R_H(P_H, P_I) \right] 1(\pi_M > R_H(P_H, P_I)) \right\}, \end{aligned}$$

where $1(\cdot)$ is the indicator function. Passive infringement occurs whenever the imitator makes positive sales but these indicator functions are turned off. This is possible for $V \in [\frac{3}{2}t, 2t)$, as the patentee-monopolist does not cover the entire market. The imitator can charge up to $P_I^* = \frac{3V}{2} - t$ (covering the remainder of the market), and not introduce lost profits. For $\gamma < 3 - \frac{9t}{2V}$, however, this does not hold as an equilibrium.

Proposition 5 *Let $V \geq \frac{9t}{2(3-\gamma)}$. Under the lost profits regime, if the imitator competes, the equilibrium is unique. Prices and demands are not symmetric. The patentee charges a lower price and serves a higher demand than the imitator. Passive infringement, with positive sales by the imitator, is not an equilibrium.*

Unlike the reasonable royalty case, the reaction functions are not symmetric,

$$\begin{aligned} P_H(P_I) &= \tfrac{P_I+t}{2} \\ P_I(P_H) &= \tfrac{(1+\gamma)P_H+t}{2}, \end{aligned}$$

so the equilibrium prices and demands are also asymmetric:

$$\begin{aligned} P_H^* &= \tfrac{3t}{3-\gamma} & D_H(P_H^*, P_I^*) &= \tfrac{3}{6-2\gamma} \\ P_I^* &= \tfrac{(3+\gamma)t}{3-\gamma} & D_I(P_H^*, P_I^*) &= \tfrac{3-2\gamma}{6-2\gamma}. \end{aligned} \tag{3.8}$$

Passive infringement does not obtain because the imitator's optimal reaction to $P_H = P_M$ is to price more aggressively than under passive infringement.[32] The equilibrium in (3.8) is unique for all γ when $V \geq \frac{9}{4}t$, so for sufficiently high values of V, the monopolist covers the entire market and there is a unique, full-coverage equilibrium under duopoly. The patentee charges a lower price than the imitator, and captures more than half of the market. Both prices are increasing in γ, and may exceed P_M.

These results are driven by the strategic complementarity of prices. Just as with reasonable royalty damages, the likelihood of patent enforcement, γ, enhances this complementarity under the lost profits regime, driving prices higher. Effectively, the imitator's only way to minimize the patentee's lost profits is to reduce its market share by raising its price. In response, the patentee raises its price. For sufficiently high γ, the complementarity effect dominates the price-suppressing effects of competition, and prices may exceed $V - t$.[33]

The profits under the equilibrium in (3.8) are:

$$\begin{aligned} \pi_H^{LP^*} &= \tfrac{9t(1-\gamma)}{2(3-\gamma)^2} + \gamma\left(\pi_M\right) \\ \pi_I^{LP^*} &= \tfrac{9t+6\gamma t-2t\gamma^2}{2(3-\gamma)^2} - \gamma\left(\pi_M\right) \end{aligned} \tag{3.9}$$

While the patentee's profit cannot be higher under duopoly than under monopoly, total profits may be higher than under monopoly. The complementarity-enhancing effect of γ is to promote, essentially, more effective price discrimination by the firms.

[32] If the $V \geq \frac{9t}{2(3-\gamma)}$ condition is violated, passive infringement may be an equilibrium, but is not typically unique. We consider this case later in the section.

[33] The patentee's price, which is the lower of the two prices, is higher than P_M whenever $\gamma > \frac{3V-6t}{V-t}$.

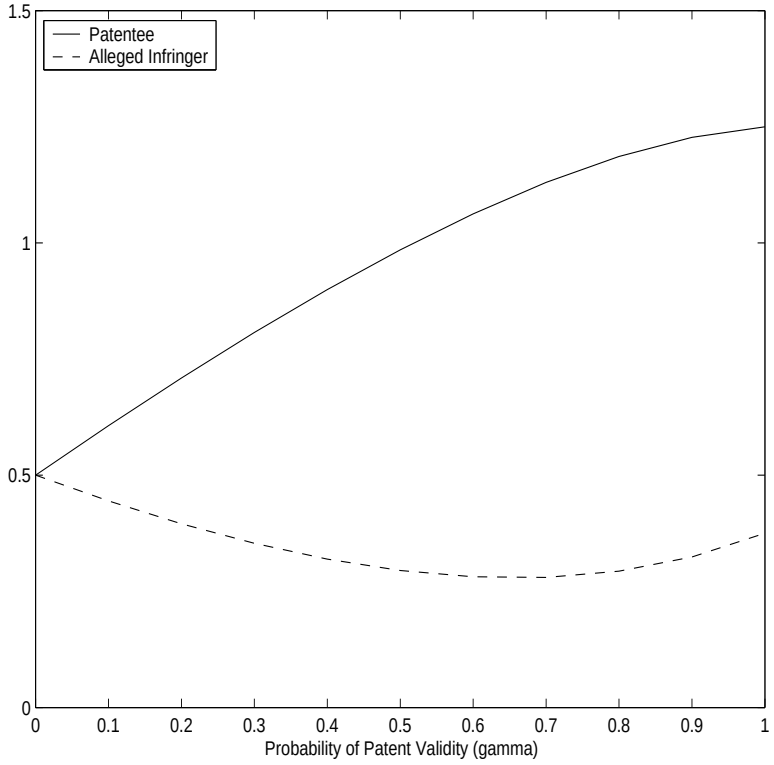

Figure 3.3: Duopoly Profits, Lost Profits Regime, $V = \frac{9}{4}, t = 1$

Increases in γ also increase expected damages, but the imitator's expected profit may nonetheless increase with γ because price-complementarity effects may dominate for high γ. The difference in profits is also not a monotone function of γ and it is possible that the difference in profits is maximized for an interior value of γ. Hence, R&D incentives may be highest for less-than-perfect patent enforcement.

Each point is illustrated in Figure 3.3, for the case $V = \frac{9}{4}, t = 1$. Total profit under duopoly is higher than monopoly profit ($\frac{5}{4}$) for all $\gamma > .46$ (approximately). The imitator's profit is minimized at around $\gamma = .66$. The difference in profits is maximized at around $\gamma = .88$.

When V is very high, relative to t, it may be unprofitable for an imitator to enter.

Corollary 1 *Under the lost profits regime, for any positive γ, the imitator stays out of the market for sufficiently high $V > V^{NE}(\gamma) > 2t$, in which case the patentee earns $\pi_M = V - t$.*

As V increases, lost profit damages increase but revenues do not, so the imitator's expected profit under entry falls and becomes negative once V exceeds V^{NE}, where the latter is defined by $\pi_I^{LP} = 0$ from (3.9).

For products of sufficiently low value ($V < 2t$), passive infringement is possible. As in the model of Anton and Yao (2007), infringement is never deterred in such cases. When the assumption in Proposition 5 does not hold, the cutoff buyer is not willing to buy from either seller at the prices in (3.8), so each seller has the incentive to cut price to cover the market. In this case, there are multiple equilibria, and passive infringement may be among the set. We consider a low-V case to illustrate this, and to compare our results, for product patents, to those for process patents.

In the Cournot model of Anton and Yao (2007), passive infringement is the unique equilibrium for high levels of γ. In our setting, by contrast, passive infringement may be an equilibrium, but is not typically unique. Moreover, when there are multiple equilibria, the others result in positive lost profits. Thus, it appears that passive infringement as a unique equilibrium under the lost profits regime is a phenomenon of process patents.

Consider an example, with $V = \frac{3}{2}$ and $t = 1$. Under monopoly, the patentee sets $P_M = \frac{3}{4}$, and captures $\frac{3}{4}$ of the market, earning a profit of $\frac{9}{16}$. In the standard Hotelling duopoly model with these values, there is a unique equilibrium in prices, $P_H^* = P_I^* = 1$, where (3.1) holds with equality. This corresponds to the case $\gamma = 0$ in our duopoly setting. In this equilibrium, the patentee and the imitator split the market evenly and earn identical profits of $\frac{1}{2}$, so lost profits is $\frac{1}{16}$. Because $\gamma = 0$, the patentee never recovers lost profits.

This is easily seen in Figure 3.4, which plots the firms' reaction functions and constraint (3.1). Point B represents the equilibrium for the $\gamma = 0$ case, while point A represents prices consistent with passive infringement. It is obvious that passive infringement is not an equi-

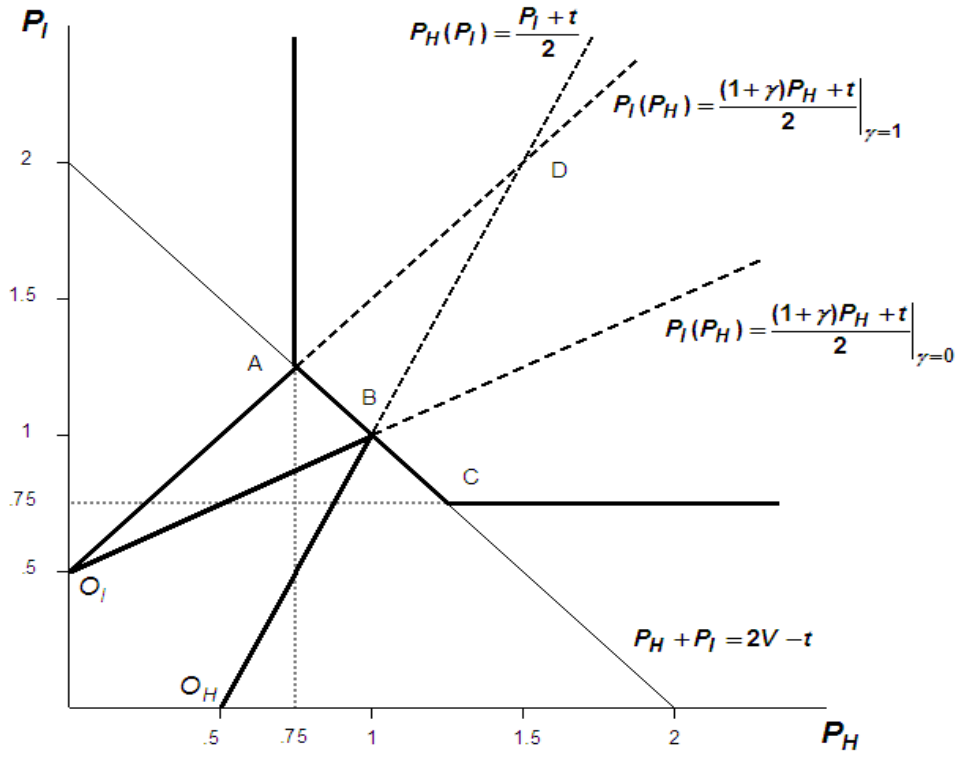

Figure 3.4: Reaction Functions, Lost Profits Regime, $V = \frac{3}{2}, t = 1$.

librium. If the patentee were to price as a monopolist, the imitator gains by lowering price below $\frac{5}{4}$, to the level of its reaction function, and capturing more market share.

Just as with Figure 3.2 earlier, the standard reaction functions $P_H(P_I)$ and $P_I(P_H)$ are correct only if condition (3.1) is satisfied. Once they reach the constraint, each firm's best response is to price so that the market is just covered, so long as their price does not fall below the monopoly price $\frac{3}{4}$. Thus, the reaction functions have three linear pieces. In the figure, the patentee's reaction function runs from point 0_H to B, then from B to A, then from A turns vertical, while the imitator's reaction function runs from 0_I to B, then from B to C, then from C turns horizontal.

As γ rises, the imitator has a stronger incentive to minimize lost profits by raising its price. As a result, its reaction function is steeper. Since the new reaction function crosses the patentee's reaction function at prices (found in (3.8)) that violate (3.1), point D is not an equilibrium. For $\gamma = 1$, the imitator's reaction function runs from point 0_I to A, then from A to C, then from C turns horizontal. In this case, there is a continuum of price combinations, between points A and B on the constraint, that form equilibria.[34] Passive infringement is the only one of these equilibria in which there are no lost profits.

3.4.1 Equilibrium Payoffs and Incentives to Innovate

Restricting attention to $V \geq \frac{9t}{2(3-\gamma)}$, equilibrium payoffs depend on whether the imitator enters and competes. In the former case, the threat points are given by (3.9), and we have:[35]

$$\Delta_{\Pi}^{LP}(\text{Entry}) = \frac{2\gamma^2 t - 15\gamma t}{2(3-\gamma)^2} + 2\gamma(\pi_M).$$

If instead $V > V^{NE}$, then the imitator does not enter, so the patentee earns π_M and the imitator earns 0. Since $V^{NE} > 2t$, we have that $\pi_M = V - t$. Hence,

$$\Delta_{\Pi}^{LP}(\text{No Entry}) = V - t.$$

It is easy to show that, at $V = V^{NE}$, $\Delta_{\Pi}^{LP}(\text{No Entry}) > \Delta_{\Pi}^{LP}(\text{ Entry})$, so the patentee's profit experiences a discrete positive jump at the point where entry is precluded.[36] As V increases further, Δ_{Π}^{LP} increases at rate 1, faster than Δ_{Π}^{RR} increases with V.

[34] Note, for instance, that $P_H^* = P_I^* = 1$ remains an equilibrium.

[35] One can use (3.4) and (3.3) to determine F. It is of no specific interest here, so we omit the tedious calculations.

[36] $V = V^{NE}$ implies that $\pi_I^{LP} = 0$, so $\Delta_{\Pi}^{LP} = \frac{9t(1-\gamma)}{2(3-\gamma)^2} + \gamma(V - t)$. This is smaller than $V - t$ if $V > \frac{27t - 12\gamma t - 2\gamma^2 t}{2(3-\gamma)^2}$. Since the right-hand side is smaller than V^{NE} (see the proof of Corollary 1 in the appendix), the condition holds.

3.5 Unjust Enrichment

Under unjust enrichment, the patentee receives the entire revenue earned by the imitator if its patent is found valid and infringed. Expected profit functions are:

$$\pi_H^{UR} = Max_{\{P_H\}} \{R_H(P_H, P_I) + \gamma R_I(P_H, P_I)\}$$

$$\pi_A^{UR} = Max_{\{P_I\}} \{R_I(P_H, P_I) - \gamma R_I(P_H, P_I).\}$$

Pricing incentives for the patentee and imitator, under this regime, are the mirror images of the lost profits case.

Proposition 6 *Let $V \geq \frac{9t}{2(3-\gamma)}$. Under the unjust enrichment regime, the equilibrium is unique. Prices and demands for the patentee and imitator are reversed from the lost profits equilibrium–the imitator charges a lower price and serves a higher demand than the patentee. Profits are always nonnegative and are never a function of V.*

This follows immediately from the fact that the profit functions, apart from a level shift due to expected lost profit damages $\gamma\pi_M$, are exactly reversed from the lost profits case.[37] Equilibrium prices and demands are:

$$\begin{aligned} P_H^* &= \tfrac{(3+\gamma)t}{3-\gamma} & D_H(P_H^*, P_I^*) &= \tfrac{3-2\gamma}{6-2\gamma} \\ P_I^* &= \tfrac{3t}{3-\gamma} & D_I(P_H^*, P_I^*) &= \tfrac{3}{6-2\gamma}. \end{aligned}$$

This set of findings is quite similar to those in Choi (2006) and Anton and Yao (2007), who find an analogous reversal under quantity competition. Now, the patentee has the greater incentive to raise price because its expected profit increases as the gross profit of the imitator increases. The imitator's expected payoff is proportional to the case where there is no patent (or zero enforcement), so it prices normally. In equilibrium, the imitator garners more than half of the market. Profits are independent of V:

$$\begin{aligned} \pi_H^{UR^*} &= \tfrac{9t+6\gamma t-2t\gamma^2}{2(3-\gamma)^2} \\ \pi_I^{UR^*} &= \tfrac{9t(1-\gamma)}{2(3-\gamma)^2}. \end{aligned} \tag{3.10}$$

[37] Similarly, there are multiple equilibria for $V \in [\frac{3t}{2}, \frac{9t}{2(3-\gamma)}]$.

	Reasonable Royalty $\{r^U, F^{Max}\}$	**Lost Profits** $(V \leq V^{NE})$	**Lost Profits** $(V > V^{NE})$	**Unjust Enrichment**
Threat-Point Demands Symmetric?	Yes	No	No	No
Threat-Point Entry?	Yes	Yes	No	Yes
Incentives to Innovate Δ_{Π}^{j}	$\gamma\left(V - \frac{1}{2}t\right)$	$\frac{2\gamma^2 t - 15\gamma t}{2(3-\gamma)^2} + 2\gamma(\pi_M)$	$V - t$	$\frac{15\gamma t - 2\gamma^2 t}{2(3-\gamma)^2}$

Table 3.1: Summary of Results, $V \geq \frac{9t}{2(3-\gamma)}$

The imitator always earns a non-negative profit, so infringement is never deterred.

3.5.1 Equilibrium Payoffs and Incentives to Innovate

Using the threat points for competition in the shadow of unjust enrichment defined in (3.10), we find:

$$\Delta_{\Pi}^{UR} = \frac{15\gamma t - 2\gamma^2 t}{2(3-\gamma)^2}$$

It is easily seen that $\frac{d\Delta_{\Pi}^{UR}}{dV} = 0$—under the unjust enrichment regime, the reservation value V has no effect on the incentives to innovate. This contrasts with the positive effect of V on Δ_{Π}^{RR} (rate γ) and Δ_{Π}^{LP} (rate 1). Hence, for valuable products, Δ_{Π}^{UR} is small relative to the incentives under the other damage regimes.

3.6 Comparison of Regimes

In equilibrium, there is no difference in static welfare under the various regimes, as the prices set under efficient bargaining are the same. The key differences pertain to characteris-

tics of threat-point competition. Most importantly, because a firm with bargaining power β earns the same share of the bargaining surplus in equilibrium regardless of whether it is the patentee or imitator, the difference in threat-point payoffs measures exactly the incentives to innovate and patent. Additionally, these payoffs reflect what would happen if bargaining were to break down or never take place (if, say, transactions costs are high), something that often occurs in practice.

Results for the unique equilibrium case of $V \geq \frac{9t}{2(3-\gamma)}$ are summarized in Table 3.6. The reasonable royalty regime is the only one that yields symmetric demands under threat-point competition, while the lost profits regime is the only one that may deter infringement. Each of these characteristics improves incentives to innovate.

With symmetric demands, the maximum level of surplus is generated under threat-point competition. When γ is high under the reasonable royalty regime, equilibrium threat-point prices are near the collusive level, so the firms' profits are nearly equal to the maximum joint profit. With the fixed fee set at F^{Max}, nearly all of the imitator's profit is transferred to the patentee. Hence, the difference in the threat-point payoffs, which equal incentives to innovate, are high. As γ approaches 1, the patentee receives the entire collusive profit, so incentives are *maximized.* Generally, then, the reasonable royalty regime with $\{r^U, F^{Max}\}$ generates high incentives when γ is high, and low incentives when γ is low.

On the other hand, the lost profits regime is the only regime that may deter infringement. For $V > V^{NE}$, the imitator's expected payoff from competing in the shadow of the lost profits regime is negative, so it chooses to stay out of the market. When this happens, the patentee earns the monopoly payoff, $V - t$, while the imitator earns nothing. Incentives to innovate equal the patentee's payoff. For $\gamma = 1$, this is always smaller than the incentives under reasonable royalty $\{r^U, F^{Max}\}$. For any $\gamma < 1$, however, the lost profits regime generates the highest incentives to innovate for sufficiently high V.

Even if the lost profits regime does not preclude infringement (e.g., if γ is low), the incentives to innovate still grow quickest with V under this regime. For $V \geq 2t$, we have

$\pi_M = V - t$, so Δ_Π^{LP} increases with V at rate 2γ. In contrast, Δ_Π^{RR} increases with V at rate γ, and Δ_Π^{UR} does not change with γ. Hence, Δ_Π^{LP} is highest for sufficiently large V.[38]

Unjust enrichment does not generate symmetric demands or deter entry, so it is a poor mechanism for generating incentives to innovate. Since Δ^{UR} does not increase with V, it generates particularly poor incentives for innovating valuable products. The following summarizes our results.

Proposition 7. *Let $V \geq \frac{9t}{2(3-\gamma)}$ and suppose the reasonable royalty regime uses components $\{r^U, F^{Max}\}$. For $\gamma \in (0,1)$, we have the following. The unjust enrichment regime fails to generate the highest incentives to innovate. If the lost profits regime does not preclude entry, then it generates the highest incentives to innovate for*

$$V > \frac{3t}{2} + \frac{15t - 2\gamma t}{2(3-\gamma)^2}. \tag{3.11}$$

If the lost profits regime does preclude entry, then it generates the highest incentives to innovate for

$$V > \frac{(2-\gamma)t}{2(1-\gamma)}. \tag{3.12}$$

If either case holds, we have $\Delta_\Pi^{LP} > \Delta_\Pi^{RR} > \Delta_\Pi^{UR}$. If $\gamma = 1$, the the reasonable royalty regime generates the highest incentives to innovate for any V.

Figure 3.5 shows which regime provides the highest incentives to innovate for all γ and $\frac{V}{t}$. The gray area covers combinations where $V < \frac{9t}{2(3-\gamma)}$, i.e. where equilibria are not unique under the lost profits or unjust enrichment regimes. Just above this region the reasonable royalty regime is best, while higher still the lost profits regime is best. The curve separating the top two regions is not smooth. For low $\gamma < \widehat{\gamma}$, the lost profits regime may generate higher incentives to innovate even if it does not preclude infringement, and the cutoff follows (3.11). For higher γ, the reasonable royalty regime yields incentives high enough so that the lost

[38] If $V < 2t$, then Δ_Π^{LP} grows slower with V, but still faster than Δ_Π^{RR} and Δ_Π^{UR}. Recalling that $\pi_M = \frac{V^2}{4t}$ in that case, we have $\frac{d\Delta_\Pi^{LP}}{dV} = 2\gamma\left(\frac{V}{2t}\right) = \gamma\left(\frac{V}{t}\right)$, which exceeds γ when $V > \frac{3t}{2}$.

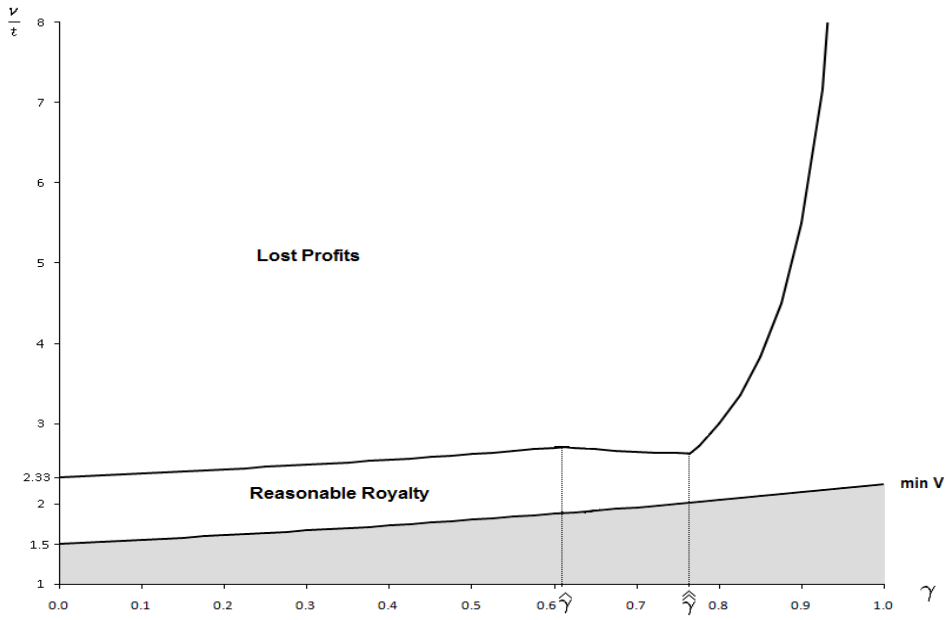

Figure 3.5: Highest Incentives to Innovate, $V \geq \frac{9t}{2(3-\gamma)}$

profits regime dominates only if it precludes infringement, and the cutoff follows (3.12). The middle (jag-tooth) section of the curve, for $\gamma \in [\widehat{\gamma}, \widehat{\widehat{\gamma}}]$ is precisely the cutoff $\frac{V^{NE}}{t}$.[39]

If $F^* < F^{Max}$, the incentives under the reasonable royalty regime decrease, shifting the top curve down. The rankings $\Delta_{\Pi}^{LP} > \Delta_{\Pi}^{RR} > \Delta_{\Pi}^{UR}$ from Proposition 7 continue to hold for (lower) sufficiently high values of V. While starting at a lower level, incentives under the reasonable royalty regime still increase with V at rate γ.

[39]Note that, in cases where the reasonable royalty regime generates the highest incentives to innovate, the unjust enrichment regime may generate higher incentives than the lost profits regime. The clearest case is when the lost profits regime fails to deter entry, but γ is high. Because of the location economies in this model, there are efficiency gains from duopoly relative to monopoly. Under the lost profits regime, the imitator gets to keep some of these gains, even for $\gamma = 1$. Under unjust enrichment, however, the imitator expects to surrender virtually all of them when γ is high. Since total profit is identical under the lost profits (with entry) and unjust enrichment regimes, it follows that the patentee is better off under the latter for high γ.

Clearly, our results yield a strong efficiency argument against the use of the unjust enrichment regime. It fails to provide strong R&D incentives and fails to yield market efficiency if bargaining breaks down. There is a third, subtle, reason why it is inappropriate. In the equilibrium, the patentee has a stronger incentive to raise his price because doing so increases the damages he expects to receive. In general (though no patent cases could be found that discussed this issue), courts require plaintiffs in civil suits to mitigate damages.[40] The behavior under the unjust enrichment regime is perverse, in light of this.

3.7 Conclusion

Focusing on product patents in a differentiated, duopoly setting, we find that the lost profits regime results in the biggest difference in profits for extremely valuable patents, as it is the only regime that may deter infringement. Contrary to recent work on process patents, we do not typically find unique equilibria characterized by passive infringement. Since bargaining does not yield a unique per-unit royalty, we also find that the reasonable royalty regime's use of the hypothetical bargain has a fundamental flaw. Nonetheless, this regime does promote market efficiency when bargaining breaks down. The unjust enrichment regime provides poor incentives to innovate for valuable products and does not yield market efficiency, making it the weakest of the three.

The reasonable royalty regime seems to be the easiest regime for US courts to implement, but lost profit damages are not uncommon. In a study of published damage awards over 1982-92, Coolley (1993) finds that a reasonable royalty rate was set in 65 cases, lost profits were awarded in 40 cases, and a combination of the two remedies was used in 19 cases. The application of lost profit damages yielded higher payoffs, on average, consistent with the general perception of patentees.

In practice, setting a damage award for lost profits is as much of an art as it is a science, but it clearly relies on economic benchmarks. Focusing on quantity competition, Werden,

[40]For instance, if a buyer breaches a contract to purchase tomatoes, the seller must try to sell them to others before they rot.

Froeb and Beavers (1999) argue that many courts award damages incorrectly, either by ignoring "price erosion," or by allowing for price erosion but ignoring "quantity accretion." When products are differentiated, prices do not necessarily fall with competition. Indeed, we find that prices may be higher than the monopoly price under the lost profits or unjust enrichment regimes. Thus, our results may also help to inform the use of simulation models (see Werden, Froeb and Langenfeld 2000), or related empirical examination of the current court system. We look forward to further progress.

Chapter 4

Conclusion

As we have seen, academic research in the field of patent law has left open many questions. Chapter 2 adds to the understanding of how firms value patents and demonstrates the importance of the legal institutions in allowing firms to derive value from their patents. Chapter 3 shows the difference that the choice of damage regime has on market competition, and derives the conditions under which the various regimes should be selected to maximize the incentives to innovate. I will conclude by fleshing out a number of other studies that should be done to continue to advance the field.

Recall, one of the main premises of Jaffe and Lerner (2004) is that the existence of numerous imprudently granted patents in the marketplace stunt innovative activity. They provide evidence for imprudently granted patents through numerous anecdotes of patents that were "obviously" bad patents. I contend in Chapter 1 that it is likely that "obviously" bad patents are easy to invalidate and that this may be done at low cost. Therefore, they should have no (or very little) effect on the business decisions (such as investing the research and development) of firms. But this theory needs to be tested empirically.

Litigation costs can be obtained following the methods of Bessen and Meurer (2007) or through data collected in the AIPLA Report of Economic Survey. AIPLA's report comes out every other year, and contains detailed information from which costs/case could be estimated (although, the report may also contain exact information). The "ease" of the case can be proxied by various metrics, such as the number of pages of the decision, the number of subsequent cites, or the number of headnotes given to the opinion by Westlaw or Lexis. Additionally, summary judgement decisions can be another explanatory variable. According

to Prof. Paul Janicke's website (www.patstats.org), over 50% of adjudicated cases in 2005 were decided by summary judgment, up from about 33% in 1979. This would indicate that there may be more ridiculous cases being brought, but that doesn't necessarily increase costs. It may also be useful to examine the appeal and affirmation rates of decisions decided by summary judgement versus decisions after a full trial. Not only would this inquiry test whether our patent system is broken, but would also shed light on Lemley's (2001) "rational ignorance" theory.

Critics of the status quo argue that important innovation is being hampered by the current patent system. Thus, it would also be important to test whether important innovation is still occurring within the U.S. One simple way to do this would be to compare the world-wide share of "important" (defined as those which have been patented in the U.S., Japan, and Europe) inventions that originated in the United States versus the shares originating elsewhere.[1] Secondly, using a suitable sample of firm level data, the productivity of R&D can be studied by using a probit or logit regression of important inventions on firm and industry specific data, such as R&D spending, previous patenting experience, firm size, etc. Importantly, the changes that have occurred over time should be considered. Again, the comparison of research productivity could be compared across patent systems to see how the U.S. system fares compared to others. It may also be worthwhile to see if the important inventions occur in crowded patent classes or in new fields, to serve as an additional check on Lerner (1995).

Another test of the "crowding-out" theory would be to gather information on the patenting activity of all of the companies in a certain industry (perhaps, defined by 4-digit SIC code), and see how this activity changes over time, controlling for factors such as R&D spending. Graphically, with number of patents (or rate of patent applications) on the y-axis and time on the x-axis, a linear curve would imply that previous patenting would have no

[1] Jaffe and Lerner (2004) only state that there has been a 51% increase over an 11 year period.

effect on future patenting. A concave curve would support the crowding-out theory, while a convex curve would support the spillover model of technological innovation.

Much has been made in the literature about the need for an opposition system in the United States, and Congress is currently considering a law which would create one here. However, my literature review has not turned up any empirical examination of the functioning of foreign opposition systems in terms of cost savings or the facilitation of inventive activity. This is a surprising void. One way to assess the opposition system would be to look at subsequent litigation rates and success rates. It would be particularly appealing if patents that had been opposed in a foreign system had U.S. counterparts that were subsequently litigated in the U.S. It is unclear how many observations of this type exist. The simplest test of the functionality of the opposition would be comparing a matched sample of U.S. and foreign companies in terms of R&D spending. If opposition systems facilitate more invention (by decreasing potential litigation costs), foreign companies would be much more willing to invest in R&D than their U.S. counterparts.

Finally, from a practical standpoint, it would be interesting to find out whether patents that are written in a certain way fare better in litigation. For instance, patents with more claims may be more likely to be invalid, but may also be more likely to be infringed. Additionally, citing more prior art should increase the likelihood of validity. Patents with longer prosecutions should also be more likely to be held valid, assuming that the delay was due to a more thorough examination (conversely, it may have just taken longer to convince an examiner to grant a patent). Similarly, the patents resulting from a continuing or divisional application may be held valid more often. Particularly important, especially in characterizing the changes made by the Federal Circuit, is how any of these trends may have changed over time. The most practical way of testing these hypotheses would be to use a probit or logit regression with the right-hand side variable being a positive or negative outcome on either the validity or infringement inquiry in a court, and the independent variables being the patent's characteristics.

Bibliography

Allison, John and Mark Lemley. 2000. "How Federal Circuit Judges Vote in Patent Validity Cases." *Florida State University Law Review* 27:745–66.

Allison, John R., Mark A. Lemley, Kimberly A. Moore and R. Derek Trunkey. 2004. "Valuable Patents." *Georgetown Law Journal* 92:435–479.

Anton, James J. and Dennis A. Yao. forthcoming 2007. "Finding 'Lost' Profits: An Equilibrium Analysis of Patent Infringement Damages." *Journal of Law, Economics and Organization* 27.

Austin, David H. 1993. "An Event-Study Approach to Measuring Innovative Output: The Case of Biotechnology." *American Economic Review* 83:253–58.

Ayres, Ian and Paul Klemperer. 1999. "Limiting Patentee's Market Power Without Reducing Innovation Incentives: The Perverse Benefits of Uncertainty and Non-Injunctive Remedies." *Michigan Law Review* 97:985–1033.

Benjamin, Stuart Minor and Arti K. Rai. 2007. "Who's Afraid of the APA? What the Patent System Can Learn from Administrative Law." *The Georgetown Law Journal* 95:269–336.

Bessen, James and Michael J. Meurer. 2007. *Do Patents Work? The empirical evidence that today's patents fail as property and discourage innovation, and how they might be fixed.*

Bhagat, Sanjai, James A. Brickley and Jeffrey L. Coles. 1994. "The Wealth Effects of Interfirm Lawsuits." *Journal of Financial Economics* 35:221–247.

Bhagat, Sanjai, John Bizjak and Jeffrey L. Coles. 1998. "The Shareholder Wealth Implications of Corporate Lawsuits." *Financial Management* 27:5–27.

Bhagat, Sanjai and Roberta Romano. 2002*a*. "Event Studies and the Law: Part I: Technique and Corporate Litigation." *American Law and Economics Review* 4:141–168.

Bhagat, Sanjai and Roberta Romano. 2002*b*. "Event Studies and the Law: Part II: Empirical Studies of Corporate Law." *American Law and Economics Review* 4:380–423.

Bittlingmayer, George. 1988. "Property Rights, Progress, and the Aircraft Patent Agreement." *Journal of Law and Economics* 31:227–248.

Bizjak, John M. and Jeffrey L. Coles. 1995. "The Effect of Private Antitrust Litigation on the Stock-Market Valuation of the Firm." *American Economic Review* 85:436–461.

Blair, R.D. and T.F. Cotter. 1998. "An Economic Analysis of Damages Rules in Intellectual Property Law." *William and Mary Law Review* 38:1585–1694.

Burge, David A. 1999. *Patent and Trademark Tactics and Practice, 3rd ed.* John Wiley & Sons, Inc.

Choi, Jay Pil. 1998. "Patent Litigation as an Information-Transmission Mechanism." *American Economic Review* 88:1249–1263.

Choi, Jay Pil. February 2006. "How Reasonable is the 'Reasonable' Royalty Rate? Damage Rules and Probabilistic Intellectual Property Rights." *Michigan State Working Paper* .

Cohen, Wesley M., Richard R. Nelson and John Walsh. 2004. "Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)." *NBER Working Paper 7552* .

Coolley, Ronald B. 1993. "Overview and Statistical Study of the Law on Patent Damages." *Journal of the Patent and Trademark Office Society* 75:515–537.

Crampes, Claude and Corinne Langinier. 2002. "Litigation and Settlement in Patent Infringement Cases." *RAND Journal of Economics* 33:258–274.

Dreyfuss, Rochelle Cooper. 1989. "The Federal Circuit: A Case Study in Specialized Courts." *New York University Law Review* 64:1–.

Dreyfuss, Rochelle Cooper. 2004. "The Federal Circuit: A Continuing Experiment in Specialization." *Case Western Reserve Law Review* 54:769–801.

Duffy, John F. 2004. "Rethinking the Prospect Theory of Patents." *University of Chicago Law Review* 71:439–509.

Engelmann, Kathleen and Bradford Cornell. 1988. "Measuring the Cost of Corporate Litigation: Five Case Studies." *Journal of Legal Studies* 17:377–399.

Federico, P.J. 1993. "Commentary on the New Patent Act." *Journal of the Patent and Trademark Office Society* 75:161–231.

Forman, Howard I. 1967. "Retrospections and Introspections Concerning Patents and Government Patent Policy." *Journal of the Patent Office Society* 49:678–690.

Ghosh, Shubba and Jay Kesan. 2004. "What Do Patents Purchase? In Search of Optimal Ignorance in the Patent Office." *Houston Law Review* 40:1219–1264.

Hall, Bronwyn H. 2005. "Exploring the Patent Explosion." *Journal of Technology Transfer* 30:35–48.

Hall, Bronwyn H., Adam Jaffe and Manuel Trajtenberg. 2001. "The NBER Patent Citations Data File: Lessons, Insights and Methodological Tools." NBER Working Paper 8498.

Hall, Bronwyn H., Adam Jaffe and Manuel Trajtenberg. 2005. "Market Value and Patent Citations." *RAND Journal of Economics* 36:16–38.

Hall, Bronwyn H. and Rosemarie H. Ziedonis. 2001. "The Determinants of Patenting in the U.S. Semiconductor Industry, 1980-1994." *The RAND Journal of Economics* 32:101–128.

Heath, C., J. Henkel and M. Reitzig. 2002. "Who Really Profits from Patent Infringements? Innovation Incentives and Disincentives from Patent Indemnification Rules." *Copenharen Business School Working Paper, 2002-18* .

Henry, Matthew D. and John L. Turner. 2006. "The Court of Appeals for the Federal Circuit's Impact on Patent Litigation." *Journal of Legal Studies* 35:85–117.

Hotelling, Harold. 1929. "Stability in Competition." *Economic Journal* 39:41–57.

Jaffe, Adam B. and Josh Lerner. 2004. *Innovation and Its Discontents*. Princeton University Press.

Kamien, Morton I. 1992. Patent Licensing. In *Handbook of Game Theory 1*, ed. R.J. Aumann and S. Hart.

Kamien, Morton I. and Yair Tauman. 1986. "Fees Versus Royalties and the Private Value of a Patent." *Quarterly Journal of Economics* 101:471–491.

Katz, Michael L. and C. Shapiro. 1986. "How to License Intangible Property." *Quarterly Journal of Economics* 101:567–589.

Kitch, Edmund W. 1977. "The Nature and Function of the Patent System." *Journal of Law and Economics* 20:265–290.

Klemperer, Paul. 1990*a*. "How broad should the scope of patent protection be?" *RAND Journal of Economics* 21:113–130.

Klemperer, Paul. 1990*b*. "Optimal Patent Length and Breadth." *RAND Journal of Economics* 21:106–112.

Kortum, Samuel and Josh Lerner. 1998. "Stronger Protection or Technological Revolution: What Is Behind the Recent Surge in Patenting?" *Carnegie-Rochester Series on Public Policy* 48:247–304.

Landes, William M. and Richard A. Posner. 2004. "The Political Economy of Intellectual Property Law." *AEI-Brookings Joint Center for Regulatory Studies* .

Lanjouw, Jean O. and Mark Schankerman. 2001. "Characteristics of Patent Litigation: A Window on Competition." *RAND Journal of Economics* 32:129–151.

Lemley, Mark A. 2001. "Rational Ignorance at the Patent Office." *Northwestern University Law Review* 95:1495–1532.

Lemley, Mark A. 2005. "Property, Intellectual Property, and Free Riding." *Texas Law Review* 83:1031–1075.

Lerner, Josh. 1995. "Patenting in the Shadow of Competitors." *Journal of Law and Economics* 38:463–495.

Levin, Richard C. 1986. "A New Look at the Patent System." *The American Economic Review (Papers and Proceedings)* 76:199–202.

Levin, Richard C., Alvin Klevorick, Richard R. Nelson and Sidney Winter. 1987. "Appropriating the Returns from Industrial Research and Development." *Brookings Papers on Economic Activity* 1987:783–831.

Lunney, Jr., Glynn S. 2004. "Patent Law, the Federal Circuit, and the Supreme Court: A Quiet Revolution." *Supreme Court Economic Review* 11:1–79.

Machlup, Fritz and Edith Penrose. 1950. "The Patent Controversy in the Nineteenth Century." *The Journal of Economic History* 10:1–29.

MacKinlay, Craig. 1997. "Event Studies in Economics and Finance." *Journal of Economic Literature* 35:13–39.

Marco, Alan C. 2005*a*. "Learning by Suing: Structural Estimates of Court Errors in Patent Litigation." *Working Paper* . Working Paper No. 68, Vasser College Economics Working Paper Series.

Marco, Alan C. 2005*b*. "The Value of Certainty in Intellectual Property Rights: Stock Market Reactions to Patent Litigation." *Working Paper* .

Marjit, Sugata. 1990. "On a Non-Cooperative Theory of Technology Transfer." *Economics Letters* 33:293–298.

Mas-Colell, Andreu, Michael D. Whinston and Jerry R. Green. 1995. *Microeconomic Theory*. Oxford University Press.

Meador, Daniel J. 1992. "Origin of the Federal Circuit: A Personal Account." *American University Law Review* 41:581–.

Merges, Robert P. 1988. "Commercial Success and Patent Standards: Economic Perspectives on Innovation." *California Law Review* 76:803–876.

Merges, Robert P. and Richard R. Nelson. 1990. "On the Complex Economics of Patent Scope." *Columbia Law Review* 90:839–916.

Meurer, Mike. 1989. "The Settlement of Patent Litigation." *RAND Journal of Economics* 20:77–89.

Moore, Kimberly A. 2005. "Worthless Patents." *Berkeley Technology Law Journal* 20:1521–1552.

Munson, Daniel C. 1994. "The Equitable Profits and Reasonable Royalty Remedies–An Economic Connection." *Journal of the Patent and Trademark Society* 76:887–902.

Nordhaus, William D. 1969. *Invention, Growth, and Welfare.* The M.I.T. Press.

Plant, Arnold. 1934. "The Economic Theory Concerning Patents for Inventions." *Economica* 1:30–51.

Poddar, Sougata and Uday Bhanu Sinha. 2004. "On Patent Licensing in Spatial Competition." *Economic Record* 80:208–218.

Posner, Richard A. 1988. "The Insignificance of Macroeconomics in Patent Antitrust Law: A Comment on Millstein." *Cardozo Law Review* 9:1203–1207.

Prager, Frank D. 1961. "Historic Background and Foundation of American Patent Law." *The American Journal of Legal History* 5:309–325.

Prager, Frank D. 1962. "Trends and Developments in American Patent Law from Jefferson to Clifford (1790-1870), Part II." *The American Journal of Legal History* 6:45–62.

Reinganum, Jennifer F. 1989. The Timing of Innovation: Research, Development and Diffusion. In *Handbook of Industrial Organization*, ed. R. Willig and R. Schmalensee. North-Holland.

Reitzig, Markus, Joachim Henkel and Christopher Heath. 2006. "On Sharks, Trolls, and Other Patent Animals: "Being Infringed" as a Normatively Induced Innovation Exploitation Strategy." *SSRN Working Paper 885914* .

Romer, Paul M. 1990. "Endogenous Technological Change." *Journal of Political Economy* 98:S71–102.

Say, Jean Baptiste. 1803. *Traite d'economie politique.* 1st ed. Paris.

Schankerman, Mark and Suzanne Scotchmer. 2001. "Damages and Injunctions in Protecting Intellectual Property." *RAND Journal of Economics* 32:199–220.

Schankerman, Mark and Suzanne Scotchmer. 2005. "Still Looking for Lost Profits: The Case of Horizontal Competition." *U. California-Berkeley Working Paper* .

Scherer, F.M. 2006. "The Political Economy of Patent Policy Reform in the United States." Harvard Working Paper.

Scotchmer, Suzanne. 1991. "Standing on the Shoulder of Giants: Cummulative Research and the Patent Law." *The Journal of Economic Perspectives* 5:29–41.

Seidenberg, Steve. 2007. "Patent Owners Take a Double Hit." *ABA Journal eReport* 6. **URL:** *www.abanet.org/journal/ereport/my4patent.html*

Thomas, John R. 2001. "Collusion and Collective Action in the Patent System: A Proposal for Patent Bounties." *University of Illinois Law Review* 2001:305–.

Turner, John L., Scott Atkinson and Alan Marco. 2007. "The Economics of a Centralized Judiciary: Uniformity, Forum Shopping and the Federal Circuit." *Working Paper* .

von Hayek, Friedrich A. 1949. *Individualism and Economic Order*. Routledge and Kegan Paul.

Werden, Gregory J., Luke M. Froeb and James Langenfeld. 2000. "Lost Profits from Patent Infringement: The Simulation Approach." *International Journal of the Economics of Business* 7:213–227.

Werden, Gregory J., Luke M. Froeb and Lucian Wayne Beavers. 1999. "Economic Analysis of Lost Profits from Patent Infringement With and Without Noninfringing Substitutes." *AIPLA Quarterly Journal* 27:305–333.

Appendix A

Tables from Chapter 2

The following table provides a concise description of the variables used in the cross-sectional analysis.

Table A.1: List of Variables Used

Variable	Units	Description
Expectations		
Federal Circuit	1/0	"1" if the CAFC was the relevant appeals court
Circuit Friendliness		deviation of the rate of patents found to be "Not Invalid" (=1-Invalid) in the circuit of the trial compared to the mean across all circuits over the previous 5 years
Patent Characteristics		
Ln(Claims)		log of the number of claims made by the patent
Ln(Prosecution Length)		log of the number of days between the application and the issuance of the patent (this is the duration of the prosecution of the patent)
Ln(Cites Made)		log of the number of references to US patents
Ln(Age)		log of the number of days between the application and the rendering of the court's decision (this is the life of the patent prior to the decision; patents typically expire 20 years after application)
Continuation	1/0	"1" if the application was a continuation
Division	1/0	"1" if the application was a division
Chemical	1/0	"1" if product code in NBER "chemical" category
Computer	1/0	"1" if product code in NBER "computer" category
Drug	1/0	"1" if product code in NBER "drugs" category
Electical	1/0	"1" if product code in NBER "electrical" category
Mechanical	1/0	"1" if product code in NBER "mechanical" category
Controls		
Others "'Valid & Infringed"	count	number of other patents declared "Valid & Infringed" in the same judgment
Others "Invalid"	count	number of other patents declared "Invalid" in the same judgment
Others "Not Infringed"	count	number of other patents declared "Not Infringed" in the same judgment
Ln(Market Value)		log of the real market value of the firm on the event date in 1982-84 dollars (in millions)
Declaratory Judgment	1/0	"1" if the case was filed by declaratory judgement
Published	1/0	"1" if the decision was certified for publication

Table A.2: Descriptive Statistics

Category	**Invalid**			**Valid & Infringed**			**Not Infringed**		
Variable	N	Mean	Std. Dev.	N	Mean	Std. Dev.	N	Mean	Std. Dev.
Expectations									
Federal Circuit	235	0.23	(0.42)	216	0.44	(0.50)	93	0.58	(0.50)
Circuit Friendliness	235	-0.02	(0.14)	216	-0.01	(0.13)	93	-0.01	(0.10)
Patent Characteristics									
Claims	235	11.77	(8.82)	216	14.36	(12.87)	93	11.88	(8.42)
Prosecution Length	235	1023.87	(581.62)	216	1119.06	(929.47)	93	906.62	(530.33)
Cites Made	235	7.29	(5.85)	216	9.26	(9.68)	93	9.87	(10.17)
Age	235	4019.09	(2027.71)	216	4432.55	(1949.01)	93	3831.29	(1824.02)
Continuation	235	0.18	(0.38)	216	0.30	(0.46)	93	0.25	(0.43)
Division	235	0.07	(0.26)	216	0.13	(0.33)	93	0.06	(0.25)
Chemical	235	0.16	(0.37)	216	0.25	(0.44)	93	0.11	(0.31)
Computer	235	0.04	(0.20)	216	0.06	(0.24)	93	0.22	(0.41)
Drugs	235	0.09	(0.28)	216	0.12	(0.33)	93	0.13	(0.34)
Electrical	235	0.17	(0.38)	216	0.10	(0.30)	93	0.08	(0.27)
Mechanical	235	0.19	(0.39)	216	0.17	(0.38)	93	0.22	(0.41)
Other	235	0.35	(0.48)	216	0.30	(0.46)	93	0.25	(0.43)
Controls									
Others "Valid & Infringed"	235	0.20	(0.84)	216	1.20	(1.41)	93	0.22	(0.88)
Others "Invalid"	235	0.78	(1.48)	216	0.21	(0.53)	93	0.16	(0.50)
Others "Not Infringed"	235	0.06	(0.24)	216	0.13	(0.33)	93	1.71	(3.64)
Real Market Value	235	2260.13	(5213.50)	216	2664.97	(5338.12)	93	3970.47	(7029.83)
Declaratory Judgement	235	0.20	(0.40)	216	0.08	(0.27)	93	0.09	(0.28)
Published	235	0.50	(0.50)	216	0.43	(0.50)	93	0.47	(0.50)

Table A.3: District Court Mean Cumulative Abnormal Returns

	Invalid Abnormal Return *(Patell Z stat)*		**Valid & Infringed** Abnormal Return *(Patell Z stat)*		**Not Infringed** Abnormal Return *(Patell Z stat)*	
Window	All (N=235)	Single (N=126)	All (N=216)	Single (N=83)	All (N=93)	Single (N=45)
(-1,+1)	-0.85%**	-0.92%*	0.73%**	0.68%*	-0.76%	-1.13%
	(-3.46)	*(-2.28)*	*(2.73)*	*(1.79)*	*(-0.59)*	*(-0.62)*
(-5,+5)	-1.67%**	-2.37%*	-0.23%	0.4%	0.24%	0.00%
	(-2.77)	*(-2.23)*	*(-1.26)*	*(0.41)*	*(0.30)*	*(0.20)*

* - indicates significance at the 5% level
** - indicates significance at the 1% level

Table A.4: District Court OLS Results, Decision Dummies

	All		Single	
	Car(-1,1)	Car(-5,5)	Car(-1,1)	Car(-5,5)
	(t-stat)	*(t-stat)*	*(t-stat)*	*(t-stat)*
Decision Dummy				
"Invalid"	-0.0103	-0.0370*	-0.0074	-0.0497*
	(-0.86)	*(-2.42)*	*(-0.38)*	*(-2.12)*
"Valid & Infringed"	0.0117	-0.0136	0.0057	-0.0213
	(1.04)	*(-0.95)*	*(0.30)*	*(-0.93)*
Expectations				
Federal Circuit	-0.0060	-0.0105	-0.0135	-0.0354*
	(-1.07)	*(-1.13)*	*(-1.50)*	*(-2.18)*
Circuit Friendliness	0.0253	0.0253	-0.0188	0.0042
	(1.38)	*(0.97)*	*(-0.62)*	*(0.08)*
Patent Characteristics				
Ln(Claims)	0.0002	-0.0027	-0.0013	-0.0068
	(0.08)	*(-0.64)*	*(-0.31)*	*(-0.96)*
Ln(Prosecution Length)	-0.0044	-0.0044	-0.0019	-0.0181
	(-0.92)	*(-0.67)*	*(-0.21)*	*(-1.36)*
Ln(Cites Made)	0.0036	0.0028	0.0008	0.0091
	(1.14)	*(0.67)*	*(0.15)*	*(1.14)*
Ln(Age)	-0.0003	-0.0006	0.0065	0.0121
	(-0.06)	*(-0.07)*	*(0.76)*	*(0.87)*
Continuation	0.0025	0.0123	0.0027	0.0144
	(0.40)	*(1.25)*	*(0.26)*	*(0.83)*
Division	0.0151$	0.0058	0.0292$	-0.0058
	(1.92)	*(0.52)*	*(1.73)*	*(-0.18)*
Chemical	-0.0057	0.0036	-0.0063	0.0079
	(-1.08)	*(0.43)*	*(-0.82)*	*(0.59)*
Computer	-0.0278*	0.0049	0.0080	0.0730$
	(-2.11)	*(0.27)*	*(0.26)*	*(1.72)*
Drugs	0.0011	-0.0205	-0.0093	-0.0224
	(0.14)	*(-1.32)*	*(-0.77)*	*(-0.78)*
Electrical	-0.0240**	-0.0254$	-0.0224	0.0244
	(-2.91)	*(-1.94)*	*(-1.53)*	*(1.00)*
Mechanical	-0.0056	-0.0066	-0.0192	-0.0092
	(-0.64)	*(-0.59)*	*(-1.38)*	*(-0.53)*
Controls				
Others "Valid & Infringed"	0.0000	-0.0004	-	-
	(0.01)	*(-0.16)*		
Others "Invalid"	0.0150**	0.0151**	-	-
	(4.56)	*(4.09)*		
Others "Not Infringed"	0.0026	-0.0030	-	-
	(1.60)	*(-1.40)*		
Ln(Market Value)	0.0022$	0.0022	0.0026	0.0078$
	(1.67)	*(0.94)*	*(1.13)*	*(1.83)*
Declaratory Judgment	0.0027	0.0154	-0.0145	-0.0057
	(0.23)	*(1.09)*	*(-0.81)*	*(-0.27)*
Published	-0.0043	0.0017	-0.0196*	-0.0211
	(-0.86)	*(0.23)*	*(-2.15)*	*(-1.55)*
α	0.0116	0.0342	-0.0347	0.0166
	(0.26)	*(0.55)*	*(-0.55)*	*(0.17)*
N	544	544	254	254
R^2	0.1417	0.0885	0.0888	0.1175

$ - indicates significance at the 10% level
* - indicates significance at the 5% level
** - indicates significance at the 1% level

Table A.5: District Court OLS Results, Three Day Event Window

	Invalid		Valid & Infringed		Not Infringed	
	All	Single	All	Single	All	Single
	(t-stat)	*(t-stat)*	*(t-stat)*	*(t-stat)*	*(t-stat)*	*(t-stat)*
Expectations						
Federal Circuit	-0.0071	-0.0188*	-0.0108$	-0.0239*	0.0033	0.0375
	(-0.91)	*(-2.37)*	*(-1.68)*	*(-2.00)*	*(0.10)*	*(0.54)*
Circuit Friendliness	0.0294	-0.0253	-0.0482*	-0.0747*	0.1587	0.1712
	(1.12)	*(-0.81)*	*(-2.41)*	*(-2.20)*	*(1.50)*	*(1.18)*
Patent Characteristics						
Ln(Claims)	0.0065$	0.0065	0.0005	0.0011	-0.0166	-0.0308
	(1.81)	*(1.52)*	*(0.16)*	*(0.26)*	*(-0.98)*	*(-1.27)*
Ln(Prosecution Length)	-0.0001	0.0073	0.0003	0.0001	-0.0350	-0.0416
	(-0.01)	*(0.59)*	*(0.06)*	*(0.02)*	*(-1.42)*	*(-0.74)*
Ln(Cites Made)	-0.0062	-0.0074	0.0073*	0.0070	0.0213	0.0395$
	(-1.17)	*(-0.98)*	*(2.41)*	*(1.18)*	*(1.36)*	*(1.71)*
Ln(Age)	-0.0058	-0.0046	-0.0104*	-0.0003	0.0494$	0.0954*
	(-0.82)	*(-0.39)*	*(-2.18)*	*(-0.04)*	*(1.87)*	*(2.13)*
Continuation	-0.0058	-0.0056	0.0089	0.0177	-0.0417	-0.0465
	(-0.62)	*(-0.35)*	*(1.33)*	*(1.47)*	*(-1.27)*	*(-1.26)*
Division	0.0195	-0.0008	0.0000	0.0312	0.0634	0.1435**
	(1.63)	*(-0.04)*	*(0.00)*	*(1.62)*	*(1.48)*	*(2.62)*
Chemical	-0.0076	-0.0007	-0.0020	-0.0084	0.0470	0.0450
	(-0.94)	*(-0.07)*	*(-0.36)*	*(-0.74)*	*(1.20)*	*(0.70)*
Computer	-0.0121	-0.0100	-0.0367**	-0.0354*	0.0097	0.0671
	(-0.83)	*(-0.31)*	*(-5.56)*	*(-2.52)*	*(0.21)*	*(1.14)*
Drugs	-0.0219$	-0.0191	0.0138	0.0175	0.0287	0.0249
	(-1.70)	*(-1.34)*	*(1.53)*	*(0.94)*	*(0.78)*	*(0.48)*
Electrical	-0.0298*	-0.0321	-0.0051	-0.0387	-0.0232	0.0411
	(-2.54)	*(-1.62)*	*(-0.52)*	*(-1.44)*	*(-0.57)*	*(0.98)*
Mechanical	0.0049	-0.0086	-0.0019	-0.0165	-0.0248	-0.0096
	(0.58)	*(-1.08)*	*(-0.23)*	*(-1.38)*	*(-0.83)*	*(-0.16)*
Controls						
Others "Valid & Infringed"	0.0014	-	0.0013	-	0.0043	-
	(0.46)		*(0.60)*		*(0.37)*	
Others "Invalid"	0.0146**	-	-0.0086	-	-0.0214	-
	(4.93)		*(-1.20)*		*(-1.25)*	
Others "Not Infringed"	0.0071	-	0.0153*	-	-0.0012	-
	(0.42)		*(2.16)*		*(-0.31)*	
Ln(Market Value)	0.0040*	0.0029	0.0005	-0.0012	0.0043	0.0003
	(2.16)	*(1.38)*	*(0.40)*	*(-0.49)*	*(0.84)*	*(0.03)*
Declaratory Judgement	0.0111	-0.0038	-0.0070	0.0074	-0.0899	-0.1577
	(1.56)	*(-0.40)*	*(-0.86)*	*(0.58)*	*(-1.03)*	*(-1.59)*
Published	0.0119$	0.0051	-0.0136**	-0.0206*	-0.0488	-0.1021*
	(1.86)	*(0.61)*	*(-2.69)*	*(-2.35)*	*(-1.55)*	*(-2.50)*
α	0.0017	-0.0291	0.0819*	0.0167	-0.1666	-0.4863
	(0.03)	*(-0.45)*	*(2.25)*	*(0.25)*	*(-0.88)*	*(-1.25)*
N	235	126	216	83	93	45
R^2	0.3548	0.1737	0.2527	0.3477	0.2317	0.4691

$ - indicates significance at the 10% level
* - indicates significance at the 5% level
** - indicates significance at the 1% level

Appendix B

Proofs of Propositions in Chapter 3

Proof of Lemma 1. It is clear from (3.2) that total profit is maximized only if $P_H = P_I = V - \frac{1}{2}t$. We now identify royalties such that this is a self-reinforcing equilibrium.

Consider first the case where (3.1) holds strictly. The profit functions are

$$\begin{aligned} \pi_H^{RR} &= \tfrac{P_H}{2} + \tfrac{P_H P_I - {P_H}^2}{2t} + r\left(\tfrac{1}{2} + \tfrac{P_H - P_I}{2t}\right) + F \\ \pi_I^{RR} &= \tfrac{P_I}{2} + \tfrac{P_H P_I - {P_I}^2}{2t} - r\left(\tfrac{1}{2} + \tfrac{P_H - P_I}{2t}\right) - F, \end{aligned} \tag{B.1}$$

and yield the following first order conditions:

$$\begin{aligned} P_H(P_I) &= \tfrac{P_I + t + r}{2} \\ P_I(P_H) &= \tfrac{P_H + t + r}{2}. \end{aligned} \tag{B.2}$$

Solving these reaction functions yields the equilibrium:

$$\begin{aligned} P_H^* = t + r \quad D_H(P_H, P_I) = \tfrac{1}{2} \quad \pi_H^* = \tfrac{1}{2}t + r \\ P_I^* = t + r \quad D_I(P_H, P_I) = \tfrac{1}{2} \quad \pi_I^* = \tfrac{1}{2}t. \end{aligned} \tag{B.3}$$

Conditional on the prices above, (3.1) is a strict inequality if and only if $r < V - \frac{3}{2}t$. In such cases, prices are strictly lower than the efficient level.

As r approaches $V - \frac{3}{2}t$ from below, (3.1) approaches equality and prices approach the profit-maximizing levels. This is not the only royalty that yields these prices as an equilibrium, however. Consider $r = V - \frac{3}{2}t + \epsilon$, with ϵ small. The prices in (B.3) violate (3.1), so they do not form an equilibrium. However, $P_H = P_I = V - \frac{1}{2}t$ is an equilibrium. To see this, note (from the reaction functions) that if it were possible for either firm to respond to the other's price of $V - \frac{1}{2}t$ by setting its own price higher, without violating (3.1), then

it would do so. However, pricing higher does violate this constraint, and would create local monopolies with less-than-full market coverage. We proceed to identify all per-unit royalties such that neither firm, as local monopolist, would raise its price.

For the patentee, since the market would not be fully covered, marginal changes in its price would not affect royalty revenue, so we have $MR_H = \frac{V-2P_H}{t}$, which is clearly negative at $P_H = V - \frac{1}{2}t$. Thus, the patentee (as a local monopolist) would not raise its price. For the imitator, marginal changes in its price do affect royalty payments, and we have $MR_I = \frac{V-2P_I+r}{t}$. This is non-positive at $P_I = V - \frac{1}{2}t$ as long as $r \leq V - t$. Thus, $P_H = P_I = V - \frac{1}{2}t$ is an equilibrium for $r \in [V - \frac{3}{2}t, V - t]$. For $r > V - t$, the imitator prefers to serve a smaller market to reduce royalty payments. Therefore, the bargain is efficient only if it yields a royalty $r \in [V - \frac{3}{2}t, V - t] \equiv \mathcal{R}^*$. ***QED***

Proof of Proposition 1. If bargaining breaks down and the firms compete in the shadow of the reasonable royalty regime, the firms have the following expected profit functions:

$$\begin{aligned} \pi_H^{RR} &= \tfrac{P_H}{2} + \tfrac{P_H P_I - {P_H}^2}{2t} + \gamma r^* \left(\tfrac{1}{2} + \tfrac{P_H - P_I}{2t}\right) + \gamma F^* \\ \pi_I^{RR} &= \tfrac{P_I}{2} + \tfrac{P_H P_I - {P_I}^2}{2t} - \gamma r^* \left(\tfrac{1}{2} + \tfrac{P_H - P_I}{2t}\right) - \gamma F^*, \end{aligned} \tag{B.4}$$

where we restrict attention to $r^* \in \mathcal{R}^*$. Conditional on (3.1) holding, taking first-order conditions and solving this system yields:

$$\begin{aligned} P_H^* &= t + \gamma r^* \quad D_H(P_H, P_I) = \tfrac{1}{2} \\ P_I^* &= t + \gamma r^* \quad D_I(P_H, P_I) = \tfrac{1}{2} \end{aligned} \tag{B.5}$$

This equilibrium therefore holds whenever $\gamma r^* \leq V - \frac{3}{2}t$. Because the market is split evenly, static welfare is maximized.

Now consider $\gamma r^* \in \left(V - \frac{3}{2}t, V - t\right]$. Similar to the proof of Lemma 1, prices following the solution to the first-order conditions are not equilibria because (3.1) is violated. We now analyze best responses (Figure 2 is an extremely helpful guide). When (3.1) holds, the optimal responses are according to the reaction functions in (B.2), with γr^* substituted for

r—for this proof, call this condition (B.2*). When (3.1) does not hold, there are two possible best responses: (A) set price $\underline{P_i}$, which is such that the (local monopolist) $MR_i = 0$; and (B) lower price so that (3.1) holds with equality–the market is fully covered and the pivotal buyer gets zero net surplus.

It is clear that, in response to an uncompetitive (i.e. extremely high) price by the other firm, either firm will choose option (A). If the other firm's price is competitive, but still high enough that responding according to (B.2*) would violate (3.1), then, following the analysis of marginal revenues in the Proof of Lemma 1, the optimal response is (B), to set the highest price such that the constraint holds. This consists of pricing along the constraint itself. Hence, each firm's reaction function includes a section of that constraint. This section runs between where the function in (B.2*) crosses the constraint and where the other firm's price becomes uncompetitive. Above this uncompetitive price, the reaction function is constant at $\underline{P_i}$.

For $\gamma r^* \in \left(V - \frac{3}{2}t, V - t\right]$, the reaction functions do indeed share a section of the constraint. Therefore, all of the equilibria in this range lie on the constraint, $P_H + P_I = 2V - t$, satisfying i. Condition ii follows directly from $MR_H = \frac{V-2P_H}{t} \leq 0$, while iii follows directly from $MR_I = \frac{V-2P_I+\gamma r^*}{t} \leq 0$. ***QED***

Proof of Proposition 2. The hypothetical bargain imposes $\gamma = 1$ if bargaining were to break down. From the Proof of Proposition 1, it is clear that there are multiple equilibria if $\gamma r^* > V - \frac{3}{2}t$. Hence, if bargaining in the hypothetical bargain were to break down, then for $r^* > V - \frac{3}{2}t$, there are multiple equilibria. Hence, r^U is the only per-unit royalty in $\mathcal{R}^*$ such that the threat-point equilibrium is unique. ***QED***

Proof of Proposition 3. This follows immediately from the discussion in the text. ***QED***

Proof of Proposition 4. From the text, we have $F = \gamma F^* + (1-\gamma)(\beta-1)(V - \frac{3}{2}t)$. Let $F^* \geq 0$ and $\gamma < 1$. Subtracting F from F^* yields

$$\begin{aligned} F^* - F &= F^* - \gamma F^* - (1-\gamma)(\beta-1)(V - \tfrac{3}{2}t) \\ &= (1-\gamma)\left[F^* + (1-\beta)(V - \tfrac{3}{2}t)\right] \end{aligned}$$

Clearly, this is positive if $F^* > 0$ and $\gamma < 1$.

Setting the previous equation equal to zero reveals

$$F^* = (\beta-1)(V - \frac{3}{2}t),$$

which is clearly non-positive because $\beta \leq 1$. ***QED***

Proof of Proposition 5. Under the lost profits regime, if (3.1) holds, then first order conditions yield the following reaction functions:

$$\begin{aligned} P_H(P_I) &= \tfrac{P_I + t}{2} \\ P_I(P_H) &= \tfrac{(1+\gamma)P_H + t}{2}. \end{aligned}$$

Solving these two equations yields the following equilibrium:

$$\begin{aligned} P_H^* = \tfrac{3t}{3-\gamma} \qquad & D_H(P_H^*, P_I^*) = \tfrac{3}{6-2\gamma} \\ P_I^* = \tfrac{(3+\gamma)t}{3-\gamma} \qquad & D_I(P_H^*, P_I^*) = \tfrac{3-2\gamma}{6-2\gamma}. \end{aligned}$$

Given the assumption $V \geq \frac{9t}{2(3-\gamma)}$, these prices satisfy (3.1).

Thus, this equilibrium is unique by the arguments in the Proof of Proposition 1 if lost profits are indeed nonnegative in equilibrium. For $V < 2t$, it must be true that

$$\frac{V^2}{4t} \geq \frac{9t}{2(3-\gamma)^2}.$$

Rearranging terms, we have $VV \geq \left(\frac{4t}{3-\gamma}\right)\left(\frac{9t}{2(3-\gamma)}\right)$, which holds whenever $V \geq \frac{9t}{2(3-\gamma)}$. Since $\frac{V^2}{4t} \geq V - t$ for all V, the condition holds for $V \geq 2t$.

Passive infringement is possible only if the patentee-monopolist covers less than the full market, and charges price $\frac{V}{2}$. To passively infringe, the imitator can charge a price no lower

than $\frac{3V}{2} - t$. The partial derivative of profit with respect to own price,

$$\frac{\partial \pi_I^{LP}}{\partial P_I} = \frac{P_H - 2P_I + t + \gamma P_H}{2t},$$

evaluated at $P_H = P_M = \frac{V}{2}$, is negative if $\frac{1}{2} + \frac{V(1+\gamma)}{4t} - \frac{3V-2t}{2t} < 0$, or $V > \frac{6t}{5-\gamma}$. Given the assumption that $V \geq \frac{9t}{2(3-\gamma)}$, this holds, so passive infringement is not an equilibrium. ***QED***

Proof of Corollary 1. We first show that if $V < 2t$, then infringement is never deterred, that is,

$$\frac{9t + 6\gamma t - 2\gamma^2 t}{2(3-\gamma)^2} - \gamma\left(\frac{V^2}{4t}\right) < 0$$

is impossible. We prove it by contradiction, so assume the above holds. Then it must be the case that $\frac{9+6\gamma-2\gamma^2}{2\gamma(3-\gamma)^2} < (\frac{V}{2t})^2$. Since $V < 2t$, this implies that $\frac{9+6\gamma-2\gamma^2}{2\gamma(3-\gamma)^2} < 1$. A bit of algebra shows that this is equivalent to $12\gamma - 10\gamma^2 + 2\gamma^3 > 9$, which does not hold for any $\gamma \in [0, 1]$. Hence, the imitator will stay out of the market only if $\pi_M = V - t$.

Thus, infringement is deterred if and only if $\frac{9t+6\gamma t-2\gamma^2 t}{2(3-\gamma)^2} < \gamma\,(V - t)$. This condition is equivalent to $V > \frac{9t+24\gamma t-14\gamma^2 t+2\gamma^3 t}{2\gamma(3-\gamma)^2} \equiv V^{NE}(\gamma)$. Clearly, $V^{NE}(\gamma)$ is finite for any $\gamma > 0$. ***QED***

Proof of Proposition 6. This follows immediately from the fact that, except for the constant term $\gamma\pi_M$, the profit functions for the patentee and imitator are reversed from the lost profits case. Hence, the equilibrium prices and market shares are reversed. ***QED***

Proof of Proposition 7. Assume $F^* = F^{Max} = \frac{t}{2}$ and $V \geq \frac{9t}{2(3-\gamma)}$. By the proofs of Propositions 5 and 6, the second assumption guarantees a unique equilibrium for the lost profits and unjust enrichment regimes. The assumption $r^* = r^U = V - \frac{3}{2}t$ guarantees that the reasonable royalty regime has a unique equilibrium. Consider first the incentives to innovate under the unjust enrichment regime compared to the other two regimes (the incentives under these assumptions are summarized in Table 1). The incentives to innovate will be greater

under the reasonable royalty regime if $\gamma(V - \frac{1}{2}t) > \frac{15\gamma t - 2\gamma^2 t}{2(3-\gamma)^2}$. This implies

$$V > \frac{24t - 8\gamma t + \gamma^2 t}{2(3-\gamma)^2},$$

which holds for any γ if $V \geq \frac{9t}{2(3-\gamma)}$. Therefore, $\Delta_{\Pi}^{RR} > \Delta_{\Pi}^{UR}$. Thus, the unjust enrichment regime fails to generate the best incentives to innovate.

Now consider the incentives to innovate under lost profits compared to reasonable royalties. Assume first that infringement is not deterred under lost profits. Then $\Delta_{\Pi}^{LP} > \Delta_{\Pi}^{RR}$ implies

$$\begin{aligned} \frac{2\gamma^2 t - 15\gamma t}{2(3-\gamma)^2} + 2\gamma(\pi_M) &> \gamma V - \frac{\gamma t}{2} \\ \Rightarrow \quad 4(\pi_M) - 2V + \frac{-6t - 4\gamma t + \gamma^2 t}{(3-\gamma)^2} &> 0 \end{aligned}$$

Note that $\frac{-6t - 4\gamma t + \gamma^2 t}{(3-\gamma)^2} < 0$ for all γ. Then, it is necessary that $4(\pi_M) - 2V$ be positive in order that $\Delta_{\Pi}^{LP} > \Delta_{\Pi}^{RR}$. This can not be true if $V \leq 2t$, because $\pi_M = \frac{V^2}{4t}$ in that case. Hence, consider $V > 2t$ and $\pi_M = V - t$. Continuing from above, and substituting in this condition, we get $\Delta_{\Pi}^{LP} > \Delta_{\Pi}^{RR}$ if

$$V > \frac{3t}{2} + \frac{15t - 2\gamma t}{2(3-\gamma)^2}.$$

Assume now that entry is deterred under the lost profits regime. In this case, $\Delta_{\Pi}^{LP} > \Delta_{\Pi}^{RR}$ if:

$$V > \frac{(2-\gamma)t}{2(1-\gamma)}.$$

Therefore, if either case holds, we have $\Delta_{\Pi}^{LP} > \Delta_{\Pi}^{RR} > \Delta_{\Pi}^{UR}$. Notice that as $\gamma \to 1$, the right-hand side of the conditional above (for when entry is precluded) approaches ∞. Thus, the only time when there will not exist a value of V such that this conditional is met is when $\gamma = 1$. In this case, the reasonable royalty regime generates the highest incentives to innovate for any V. ***QED***