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CERTAIN PATENTS

Alan C. Marco and Saurabh Vishnubhakat^{*}

16 YALE J.L. & TECH. 103 (2013)

ABSTRACT

This Article presents the first in a series of studies of stock market reactions to the legal outcomes of patent cases. From a sample of patents litigated during a 20-year period, we estimate market reactions to patent litigation decisions and to patent grants. These estimates reveal that the resolution of legal uncertainty over patent validity and patent infringement is, on average, worth as much to a firm as is the initial grant of the patent right. Each is worth about 1.0–1.5% excess returns on investment. There are significant differences between such market reactions before and after the establishment in 1982 of the United States Court of Appeals for the Federal Circuit. There are also significant differences among the reactions of patent holders to resolved uncertainty depending on their litigation posture as plaintiffs or defendants. Interestingly, there is no similar effect for appellate decisions relative to trial decisions. The normative implications of these findings proceed, not from the magnitude of the quantitative results—which are statistically meaningful but modest—but rather from our illustration that uncertainty in the value of patent rights is quantifiable and so can be correlated with patentee and litigant behavior in developing patent policy.

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I. INTRODUCTION

This Article presents the first in a series of quantitative studies of stock market reactions as a proxy for the resolution of uncertainty in granted U.S. patents. Reactions in the stock market both to court decisions and to patent grants can provide estimates of the magnitude of changes in beliefs about patent validity. It is from litigating patents that market actors “learn” from the court about the validity of those patents, and update their beliefs accordingly.

The analysis presented here employs an event-study approach. Litigation events are well identified, with little, if any, information leakage about what the actual decision will be. Moreover, litigation events can be directly associated with changes in the uncertainty as to a patent’s validity. If a patent is ruled valid, nothing about the decision affects the value of the underlying technology; the change in value may reasonably be attributed to changes in beliefs about the uncertainty regarding the property right.

The results are illuminating. The market response to patent litigation tends to be on par with the market response to the patent grant itself. That is, the resolution of uncertainty about validity or infringement is worth as much on average as is the initial patent right, indicating the presence of significant legal uncertainty. Indeed, this result follows from option pricing theory. The fundamental value of a patent right is the right to exclude others from using the technology. Because enforcement is

imperfect and costly,¹ the right to exclude is more precisely a right to sue with some probability of success.²

Thus, the patent *qua* property right is an option to bring a lawsuit against an alleged infringer. As with financial options, the option to sue need not be exercised in order for it to have value, and the exercise of an option may well be worth more than the initial option value.³ Interestingly, there is no significant difference in this regard between appeals court and district court decisions. Moreover, there are significant differences in market reactions based on whether the patent was adjudicated before or after the establishment in 1982 of the United States Court of Appeals for the Federal Circuit (CAFC), and whether the patent was owned by the plaintiff or the defendant in the suit.

Part II contextualizes the present study within the rich legal and economic literature on uncertainty in the patent system and its implications for open and closed innovation models, strategic decisions regarding market entry, and the determinants, outcomes, and policy levers of patent litigation. Part III lays out the econometric specification of the current study, and Part IV describes the patent data, litigation data, and the event study results, as well as estimations based on several models which explain the magnitudes of the market reactions and which compare the effects of infringement suits where the patent holder brings the suit to defensive suits where the patent holder is the defendant. Part V concludes.

¹ John M. Golden, *Principles for Patent Remedies*, 88 TEX. L. REV. 505, 544–45 (2010). See generally FREDERIC M. SCHERER, *THE ECONOMIC EFFECTS OF COMPULSORY PATENT LICENSING* 84 (1977) (framing the goal of sound patent policy as providing “enough protection to sustain a desired flow of innovations, but not superfluous protection in view of alternate incentives for innovation and the social burdens monopoly power imposes”). For a discussion of the consequences of imperfect patent enforcement, compare Ian Ayres & Paul Klemperer, *Limiting Patentees’ Market Power Without Reducing Innovation Incentives: The Perverse Benefits of Uncertainty and Non-Injunctive Remedies*, 97 MICH. L. REV. 985, 1019–20 (1999) (articulating the benefits of imperfect enforcement), with F. Scott Kieff, *Property Rights and Property Rules for Commercializing Inventions*, 85 MINN. L. REV. 697, 733 (2001) (articulating the costs of imperfect enforcement).

² See generally Alan C. Marco, *The Option Value of Patent Litigation: Theory and Evidence*, 14 REV. FIN. ECON. 323 (2005); Carl Shapiro, *Antitrust Limits to Patent Settlements*, 34 RAND J. ECON. 391, 395 (discussing patents as a form of “partial property rights”); Ayres & Klemperer, *supra* note 1, at 993–94 (explaining how the probabilistic nature of patent enforcement can constrain patentee market power).

³ See generally Fischer Black & Myron Scholes, *The Pricing of Options and Corporate Liabilities*, 81 J. POL. ECON. 637, 637–40 (1973) (explaining the basics of option pricing and its relationship to the value of the underlying right).

II. THE CHARACTER OF UNCERTAINTY IN THE PATENT SYSTEM

It is a truism that, since patents are property rights, the legal environment in which they reside can significantly affect the economic value of patent protection.⁴ Because title to property is only as good as the ability to enforce it,⁵ either formally or informally,⁶ uncertainty over whether title can be enforced undermines the market value of the property right. Legal uncertainty can be especially pervasive in emerging technology areas or, relatedly, in emerging and growing areas of patenting activity such as business methods and software patents.⁷

Where uncertainty is prevalent, its effects on the behavior of firms, and on their ability to appropriate value from their patents, can be dramatic.⁸ And because a principal purpose of the patent system is to

⁴ See generally Jean O. Lanjouw, *Economic Consequences of a Changing Litigation Environment: The Case of Patents* (Nat'l Bureau of Econ. Research Working Paper No. 4835, 1994), <http://www.nber.org/papers/w4835>; Mark A. Lemley & Carl Shapiro, *Probabilistic Patents*, 19 J. ECON. PERSP. 75 (2005).

⁵ Cases highlighting the importance of enforceable property rights abound in the history of U.S. frontier settlement. Seven-year-old Abraham Lincoln's father left the Kentucky territory in 1816, for example, due to legal irregularities in land title. Indeed, almost half of Kentucky's early settlers fell prey to problems such as "shingling," the overlap of land tracts that resulted because Virginia—of which Kentucky was then the western part—did not provide public land surveys. RONALD C. WHITE, JR., A. LINCOLN: A BIOGRAPHY 20–21 (2009).

⁶ See generally ROBERT C. ELLICKSON, *ORDER WITHOUT LAW: HOW NEIGHBORS SETTLE DISPUTES* (1991) (comparing formal and informal dispute resolution).

⁷ See, e.g., Stuart J.H. Graham & Saurabh Vishnubhakat, *Of Smart Phone Wars and Software Patents*, 27 J. ECON. PERSP. 67, 70–73 (2013) (discussing the uncertain legal treatment of emerging innovations through the lens of historical patent disputes surrounding the cotton gin, the eye-pointed needle sewing machine, the airplane, and LASER technology).

⁸ ASHISH ARORA, ANDREA FOSFURI & ALFONSO GAMBARDELLA, *MARKETS FOR TECHNOLOGY: THE ECONOMICS OF INNOVATION AND CORPORATE STRATEGY* 110–111 (2004) (discussing the transaction costs of competitive hold-up, bargaining, and imperfect contracting that result in technology environments "marked by Knightian uncertainty"). For a discussion of Knightian uncertainty—uncertainty which cannot be measured, as distinct from risk, which can—see generally FRANK H. KNIGHT, *RISK, UNCERTAINTY, AND PROFIT* (1921). The value of property rights, particularly intangible property rights, is also affected by other institutional and technological factors and the availability of alternative means of appropriating value. See ARORA ET AL., *supra*, at 265 (discussing the effects of uncertainty from an institutional perspective); Wesley M. Cohen, Richard R. Nelson & John P. Walsh, *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)* 9–11 (Nat'l Bureau of Econ. Research Working Paper No. 7552, 2000), <http://www.nber.org/papers/w7552> (discussing the relative effectiveness of different appropriability mechanisms such as lead time, marketing, and trade secrecy).

provide incentives for research, innovation, and knowledge diffusion by creating rewards, an inability to appropriate those rewards unduly diminishes the very incentives for which the system was designed.

To be sure, the policy implications of reduced appropriability alone are not always straightforward. Professor Siebrasse has noted, for example, that even where patents constitute a relatively small incentive, it does not follow that patent protection is unnecessary, unless non-patent incentives are also inadequate.⁹ Patents in a given technology may be a weak incentive because they are easily evaded,¹⁰ and if non-patent incentives are also weak, then the appropriate policy response may be to strengthen patents, not to abolish them.¹¹

A. Decision Points in the Innovation Cycle

Due to the vagaries of appropriating value from innovation, intellectual property managers regularly face decisions about whether to patent innovations or not, and about how to manage market transactions in the patents they do acquire, whether through prosecution or purchase.¹² Different legal or institutional environments can affect the incentives for firms to carry out a range of activities, whether they are conducting their own research and development versus licensing outside technology into their operations,¹³ entering a particular market,¹⁴ or litigating their patent rights.¹⁵

⁹ Norman Siebrasse, *The Structure of the Law of Patentable Subject Matter*, 23 INTELL. PROP. J. 169, 183 (2011).

¹⁰ *Id.* See also Stuart J.H. Graham et al., *High Technology Entrepreneurs and the Patent System: Results of the 2008 Berkeley Patent Survey*, 24 BERKELEY TECH. L.J. 1255, 1285 (2009); Richard C. Levin et al., *Appropriating the Returns to Industrial Research and Development*, in 18 BROOKINGS PAPERS ON ECON. ACTIVITY 783 (1987).

¹¹ Siebrasse, *supra* note 9, at 16-17.

¹² Bronwyn H. Hall & Rosemarie H. Ziedonis, *The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995*, 32 RAND J. ECON. 101 (2001) (finding significant improvements to the internal patent management processes of semiconductor firms as well as greater participation of in-house patent attorneys in decisions to license and litigate); Joshua Lerner, *Patenting in the Shadow of Competitors*, 38 J.L. & ECON. 463 (1995) (empirically studying the effect of differential litigation costs on the patenting behavior of new biotechnology firms).

¹³ See, e.g., Jennifer F. Reinganum, *The Timing of Innovation: Research, Development, and Diffusion*, in 1 HANDBOOK OF INDUSTRIAL ORGANIZATION 850 (Richard Schmalensee & Robert D. Willig eds., 1989).

¹⁴ See, e.g., Anna B. Laakmann, *Collapsing the Distinction Between Experimentation and Treatment in the Regulation of New Drugs*, 62 ALA. L. REV. 305, 341-42 (2011) (arguing, in the context of FDA regulation, that the decision to enter a market populated by patents is, at heart, a trading away of otherwise proprietary information for competitive benefits in

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The first of these decisions, whether to develop innovations in-house or license them from others, reflects the choice between so-called “closed” and “open” models of innovation, respectively.¹⁶ Indeed, prior scholarship has explicitly regarded these alternatives as economic substitutes,¹⁷ as in the case of R&D innovation race models, where the losing firms replace their in-house research and development with licenses from the winning competitor.¹⁸

Licensing, for its part, often provides additional information and know-how pertaining to the invention that cannot be gleaned from the patent disclosure.¹⁹ Yet this information-sharing dynamic carries its own challenges. For example, Professor Fromer argues that cross-licensing such as in the chemical-process industry and informal tacit knowledge-sharing and employee mobility such as in the high-technology industry “typically involve sharing of information only among the in-crowd of established players.”²⁰ The result, Fromer concludes, is that such forms of information-sharing “do not serve an essential purpose of disclosure—giving informational opportunities to potential inventors on the periphery or outside of the establishment—which would minimize barriers to entry, a founding premise of the American patent system.”²¹

The second of these decisions, whether to enter a particular market versus enter an alternate market or stay out of the market altogether, reflects the would-be entrant’s response, in view of patents as market entry barriers

return). See generally Jay Pil Choi, *Patent Litigation as an Informational-Transmission Mechanism*, 88 AM. ECON. REV. 1249 (1998) (framing the dynamics of market entry as an externality of patent validity information revealed in litigation).

¹⁵ See, e.g., Michael J. Meurer, *The Settlement of Patent Litigation*, 20 RAND J. ECON. 77 (1989) (modeling the patent litigation settlement calculus on the basis of public versus private information regarding patent validity, bluffing by the patent holder, and legal-cost allocation rules such as the British “loser pays” regime).

¹⁶ See generally FTC, *THE EVOLVING IP MARKETPLACE: ALIGNING PATENT NOTICE AND REMEDIES WITH COMPETITION* 32-48 (2011), <http://www.ftc.gov/os/2011/03/110307patentreport.pdf>.

¹⁷ E.g., Joshua S. Gans & Scott Stern, *Incumbency and R&D Incentives: Licensing the Gale of Creative Destruction*, 9 J. ECON. & MGMT. STRATEGY 485, 485 (2000). Gans and Stern argue that firms see licensing and in-house research as “strategic substitutes.”

¹⁸ Ashish Arora et al., *Does In-House R&D Increase Bargaining Power?: Evidence from the Pharmaceutical Industry 2* (CMU Heinz College Working Paper No. 15, 2004), <http://www.heinz.cmu.edu/research/171full.pdf>. See also Nancy T. Gallini & Ralph A.

Winter, *Licensing in the Theory of Innovation*, 16 RAND J. ECON. 237 (1985); Michael L. Katz & Carl Shapiro, *R and D Rivalry with Licensing or Imitation*, 77 AM. ECON. REV. 402 (1987); Carl Shapiro, *Patent Licensing and R & D Rivalry*, 75 AM. ECON. REV. 25 (1985).

¹⁹ Jeanne C. Fromer, *Patent Disclosure*, 94 IOWA L. REV. 539, 556 (2009).

²⁰ *Id.* at 556.

²¹ *Id.* at 557.

of varying strength, to information about various aspects of such barrier patents, particularly validity.²² Where such information is lacking, firms may, in turn, act out of rational fear borne from the cost of defending nuisance lawsuits, or from the threat of insolvency due to an anti-competitive lawsuit, or from a patentee's predatory reputation for litigating weak lawsuits to conclusion.²³ Thus, as Professor Choi argues, patent validity information that is revealed through litigation influences the relative payoffs of patentees and imitators to enter or delay entry.²⁴

For potential entrants, the consequences of this market entry dynamic between relinquishing valuable information and receiving adequate competitive benefit can be profound. In the pharmaceutical industry, for example, even well-established firms have suffered from patent invalidation and subsequent market entry by rivals as a result of their own market entry decisions vis-à-vis patent acquisition, by disclosing too much or filing too early.²⁵ Proposals for reform in the pharmaceutical industry of market entry-delaying practices such as reverse settlements further highlight the information-signaling connection between the market entry decision and patent validity.²⁶

The third of these decisions, whether to litigate one's own patents, reflects considerations similar to those informing market entry at the risk of infringing the patents of others, particularly with respect to risk aversion in the outcome of litigation.²⁷ Professor Chien recently framed the patent

²² Christopher R. Leslie, *The Anticompetitive Effects of Unenforced Invalid Patents*, 91 MINN. L. REV. 101, 116-17 (2006) (arguing that firms may reasonably be loath to risk potentially infringing activity "even if they believe the dominant firm's patent is invalid because the costs of being wrong are too high").

²³ See Michael J. Meurer, *Controlling Opportunistic and Anticompetitive Intellectual Property Litigation*, 44 B.C. L. REV. 509, 515 (2003).

²⁴ Choi, *supra* note 14. Professor Choi has found, moreover, that these entry dynamics turn on the degree of patent protection available, and that stronger patent rights are not always desirable for patentees in this regard.

²⁵ See, e.g., Christopher M. Holman, *Unpredictability in Patent Law and Its Effect on Pharmaceutical Innovation*, 76 MO. L. REV. 645, 651-62 (2011) (discussing the invalidation of Eli Lilly's patents on its pancreatic cancer drug Gemzar® and its attention deficit hyperactivity disorder drug Strattera®, and the consequent generic entry into those markets by Sun Pharmaceuticals Industries, Ltd., and Actavis Elizabeth LLC, respectively).

²⁶ See, e.g., Gregory Dolin, *Reverse Settlements As Patent Invalidity Signals*, 24 HARV. J.L. & TECH. 281 (2011) (proposing automatic reexamination in the USPTO for any patent involved in a reverse settlement, reasoning that such an agreement's pro- or anti-competitive effect—vis-à-vis market entry, for example—turns on the strength of the underlying patent and the likely conclusion of the litigation).

²⁷ See generally Damon C. Andrews, *Why Patentees Litigate*, 12 COLUM. SCI. & TECH. L. REV. 219 (2011) (arguing that the cost and risk of patent litigation have diminished the value of traditional remedies such as damages and injunctions, leaving patentees to plan

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litigation decision as a correlate of distinct sets of explanatory variables: on one hand, the intrinsic qualities of a patent; on the other, the after-acquired qualities of a patent, including the qualities of the entity or entities who own the patent over time.²⁸

In this framework, intrinsic qualities result from the examination process that generates the patent, and characterize the patent from the start: e.g., the number of claims in the patent,²⁹ the number of backward citations to prior art,³⁰ and the number of jurisdictions in which protection is concurrently sought.³¹ Notably, these intrinsic qualities are also correlated with patent value,³² which can itself be a driver of litigation.³³ Acquired qualities attend the patent post-issuance and reflect its transactional history:

deliberately around a likely up-front settlement). *See also* Jay P. Kesan & Andres A. Gallo, *Why “Bad” Patents Survive in the Market and How Should We Change?—The Private and Social Costs of Patents*, 55 EMORY L.J. 61, 68-69 (2006) (presenting a game-theoretic model to compare quantitatively the litigation costs and risks as between plaintiff and defendant—and finding that even demonstrably invalid patents can survive in the market as a result).

²⁸ Colleen V. Chien, *Predicting Patent Litigation*, 90 TEX. L. REV. 283 (2011). Of these sets of variables, Professor Chien’s analysis focuses on the acquired qualities of patents.

²⁹ A higher number of claims is correlated with a greater incidence of litigation. *See* Jean O. Lanjouw & Mark Schankerman, *Characteristics of Patent Litigation: A Window on Competition*, 32 RAND J. ECON. 129, 140-41 (2001).

³⁰ A higher number of backward citations to prior art is correlated with a greater incidence of litigation. *See, e.g.*, John R. Allison et al., *Valuable Patents*, 92 GEO. L.J. 435, n.59 (2004). As to this relationship, Professor Allison and his co-authors highlight the larger dataset used in their population study and their inclusion of all prior art references, not merely U.S. patents: these aspects, they say, may be what distinguish their results from the orthogonal findings of Professors Lanjouw & Schankerman, *supra* note 29, at 140-41 (finding no significant relationship between backward citation and likelihood of litigation). *See also* John R. Allison & Emerson H. Tiller, *The Business Method Patent Myth*, 18 BERKELEY TECH. L.J. 987 (2003) (similarly arguing that a higher incidence of litigation is correlated with greater backward citation).

³¹ A higher number of such jurisdictions is correlated with a greater incidence of litigation. Katrin Cremers, *Determinants of Patent Litigation in Germany* 13 (Ctr. for European Econ. Research (ZEW), Discussion Paper No. 04-72, 2004), <ftp://ftp.zew.de/pub/zew-docs/dp/dp0472.pdf>. Dr. Kremers refers to this measure as the “family size” of the patent, where each patent in a family covers substantially the same invention in a different territorial jurisdiction. *See also* Jon Putnam, *The Value of International Patent Rights*, PhD thesis, Yale University (1996) (introducing the general use of patent family size as a correlate of value).

³² *See* Dietmar Harhoff, Frederic M. Scherer & Katrin Vopel, *Citations, Family Size, Opposition and the Value of Patent Rights*, 32 RES. POL’Y 1343 (2003).

³³ *See generally* Allison et al., *supra* note 30, at 439–43 (defending the use of litigation probability as a proxy for patent value).

e.g., changes in patent ownership,³⁴ the amount of post-issuance investment in the patent,³⁵ the collateralization or not of the patent,³⁶ and the number of subsequent forward citations to the patent.³⁷

In subsequent literature, the strength of these findings and the significance of these explanatory variables has also been the subject of critique as to source data and methodology.³⁸ And the decision to litigate has more generally been the subject of increasing scholarly inquiry, from patent litigation by universities,³⁹ to patent litigation in response to macroeconomic trends,⁴⁰ to the odds of patent litigation victory among firms of varying resources and thus varying degrees of freedom in deciding to litigate.⁴¹

In the face of these legal and institutional influences, firms may organize transactions through arm's-length negotiations where property rights are well-defined.⁴² In uncertain legal environments, however, the

³⁴ Changes in ownership are correlated with a greater incidence of litigation. Chien, *supra* note 28, at 301–04, 316–17, 320–21 (measuring ownership change along three metrics: the number of recorded assignments of the patent, the number of true transfers of the patent, and the change in size, if any, of the patent owner from a small entity to a large entity, or vice-versa).

³⁵ A higher amount of post-issuance investment is correlated with a greater incidence of litigation. *Id.* at 304–06, 316–17, 320–21 (measuring post-issuance investment along two metrics: (i) the payment of statutory maintenance fees 3.5, 7.5, and 11.5 years from issuance that are required to keep a patent in force, and (ii) the *ex parte* reexamination, if any, of a patent).

³⁶ Collateralization of the patent is correlated with a greater incidence of litigation. *Id.*

³⁷ A higher number of forward citations is correlated with a greater incidence of litigation. *Id.* (using the accepted metric of “adjusted forward citations,” which excludes citations having one or more inventors in common with the cited patent, thereby minimizing bias from inventors citing their own past patents). For a discussion of self-citation in patents, see Bronwyn H. Hall, Adam B. Jaffe & Manuel Tratjenberg, *The NBER Patent Citations Data File: Lessons, Insights and Methodological Tools* 21–23 (Nat'l Bureau of Econ. Research Working Paper No. 8498, at 21–23, 2001), <http://www.nber.org/papers/w8498>.

³⁸ Jay P. Kesan, David L. Schwartz & Ted Sichelman, *Paving the Path to Accurately Predicting Legal Outcomes: A Comment on Professor Chien's Predicting Patent Litigation*, 90 TEX. L. REV. 97 (2012).

³⁹ See, e.g., Jacob H. Rooksby, *University Initiation of Patent Infringement Litigation*, 10 J. MARSHALL REV. INTELL. PROP. L. 623 (2011).

⁴⁰ See, e.g., Iman Lordgooei, *Bear Market Litigation: Showing the Relationship Between Patent Litigation and a Down Economy*, 27 U. PA. J. INT'L ECON. L. 1077 (2006).

⁴¹ See, e.g., Paul M. Janicke & LiLan Ren, *Who Wins Patent Infringement Cases?*, 34 AIPLA Q.J. 1 (2006).

⁴² See, e.g., Pol Antràs, Mihir A. Desai & C. Fritz Foley, *Multinational Firms, FDI Flows, and Imperfect Capital Markets*, 124 Q.J. ECON. 1171 (2012) (finding that stronger protections of the property rights of investors—such as patents—are correlated with more arm's-length transactions among multinational firms).

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likely result is more integrated transactions, ranging from cross-licensing⁴³ to strategic alliances⁴⁴ to outright consolidation.⁴⁵ To the extent that uncertainty affects or drives these decisions, therefore, uncertainty and its management are of great strategic importance to firms.

B. Managing Uncertainty

Moreover, to the extent that policy makers have some control over the amount of legal uncertainty, or legal quality as that term has been framed by Professor Merges,⁴⁶ it is an important policy instrument.⁴⁷ Simulation estimates have found, for example, that changes in patent law or in the legal environment writ large can significantly change the value of

⁴³ See, e.g., Peter C. Grindley & David J. Teece, *Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics*, 39 CAL. MGMT. REV. 8, 8-10 (1997) (finding that firms engage in cross-licensing both as an *ex ante* deterrent to market hold-up problems such as royalty stacking and as an *ex post* settlement option to litigation, particularly mutual infringement litigation).

⁴⁴ See, e.g., Clarisa Long, *Patents and Cumulative Innovation*, 2 WASH. U. J.L. & POL'Y 229, 236 (2000) (arguing that the need to manage uncertainty leads to much research and development, creating "an environment in which strategic alliances and brokerage functions dominate").

⁴⁵ See, e.g., Alan C. Marco & Gordon C. Rausser, *The Role of Patent Rights in Mergers: Consolidation in Plant Biotechnology*, 90 AM. J. AGRIC. ECON. 133, 136 (2008) (predicting the increasingly frequent resolution of patent litigation by merger between the parties, possibly because "uncertainty in patent rights causes a breakdown in arm's-length contracting that provides incentives for consolidation").

⁴⁶ Robert P. Merges, *As Many As Six Impossible Patents Before Breakfast: Property Rights for Business Concepts and Patent System Reform*, 14 BERKELEY TECH. L.J. 577 (1999). Professor Merges discusses patent quality in terms of measurable, acceptable error rates in the issuance of patents. Notably, he discusses quality in the context of business methods, then an emerging—and commensurately uncertain—domain of patenting activity in the wake of *State Street Bank & Trust Co., Inc. v. Signature Financial Group, Inc.*, 149 F.3d 1368 (Fed. Cir. 1998) (overruling cases holding "methods of doing business" were not patentable).

⁴⁷ See, e.g., David Orozco, *Administrative Patent Levers*, 117 PENN. ST. L. REV. 1 (2012) (discussing administrative levers in the quality of business methods as "rules that represent a coordinated policy at the PTO to target a particular technology class" and the reaction of policymakers to the implementation of such rules); Peter S. Menell, *Governance of Intellectual Resources and Disintegration of Intellectual Property in the Digital Age*, 26 BERKELEY TECH. L.J. 1523, 1544 (2011) (discussing patent quality as a determinacy problem in evaluating inventions for patent protection, in contrast to the doctrine of unitary patent protection).

patent protection,⁴⁸ not just for litigated patents but for all patents even if none are ever litigated.⁴⁹

Legal uncertainty thus understood makes its way into the patent system through both the United States Patent and Trademark Office (USPTO) and through relevant judicial institutions, particularly the CAFC. Established in 1982, the CAFC provided—among other things—a single forum to hear the appeals of patent cases from all federal district courts.⁵⁰ Because of the importance of enforcement on the value of intellectual property,⁵¹ many researchers in the U.S. have pointed to the very establishment of the CAFC in 1982 as a watershed event in the rights of patent holders.⁵²

Indeed, conventional wisdom has it that the CAFC significantly strengthened the rights of patent holders—that the court is, and has been, more pro-patent than have the district courts.⁵³ The expected result of this kind of substantive inclination would be stronger belief that a court will find a given patent to be valid or find a given product or process to be infringing, though empirical findings on these question are mixed.⁵⁴ Nevertheless, to

⁴⁸ Jean O. Lanjouw, *Patent Protection in the Shadow of Infringement: Simulation Estimations of Patent Value*, 65 REV. ECON. STUD. 671 (1998); Lanjouw, *supra* note 4.

⁴⁹ For example, Professor Lanjouw estimates that if the underlying probability of success for a plaintiff fell from 75% to 50%, and legal fees doubled, then the average patent value would be halved in her simulation, even if no cases were litigated. *Id.* at 29-32 (discussing estimation and simulation results).

⁵⁰ Federal Courts Improvement Act, Pub. L. No. 97-164, 96 Stat. 25 (1982).

⁵¹ See *supra* notes 2-7 and accompanying text.

⁵² E.g., Jonathan M. Barnett, *Intellectual Property as a Law of Organization*, 84 S. CAL. L. REV. 785, 832-33 (2011); Patrick E. King, Ryan M. Roberts & Andrew V. Moshirnia, *The Confluence of European Activism and American Minimalism: “Patentable Subject Matter” After Bilski*, 27 SANTA CLARA COMPUTER & HIGH TECH. L.J. 247, 271-72 (2011). But see Paul R. Gugliuzza, *Rethinking Federal Circuit Jurisdiction*, 100 GEO. L.J. 1437, 1456-57 (applying to the CAFC Professor Lawrence Baum’s general argument that specialized courts arise in no small part from “interest-group desire to influence the substance of judicial policy, and not the ‘neutral virtues’ of efficiency, accuracy, and uniformity that permeate the political debate”) (citing LAWRENCE BAUM, *SPECIALIZING THE COURTS* 207-209 (2011)).

⁵³ See, e.g., Samuel Kortum & Joshua Lerner, *What is Behind the Recent Surge in Patenting?*, 28 RES. POL’Y 1 (1999); Lanjouw, *supra* note 4; Lanjouw & Shankerman, *supra* note 29; Lerner, *supra* note 12.

⁵⁴ See, e.g., Matthew D. Henry & John L. Turner, *The Court of Appeals for the Federal Circuit’s Impact on Patent Litigation*, 35 J. LEGAL STUD. 85 (2006) (discussing the pro-patent reputation of the CAFC while investigating empirically the scope and extent of the CAFC’s impact). Professors Henry and Turner find that—as compared to its predecessor courts, the U.S. Court of Customs and Patent Appeals (CCPA) and the U.S. Court of Claims—the CAFC has affirmed district court decisions of patent invalidity with less

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the extent that changes in the institutions governing patent rights can increase or decrease the uncertainty over the scope and validity of patents, the literature has shown that such uncertainty affects the incentives of firms to license or conduct research and development,⁵⁵ to enter markets,⁵⁶ and to litigate their patents.⁵⁷

Even where firms do not abstain altogether from patenting, uncertainty may still affect the incentives to patent in certain areas.⁵⁸ Firms facing high litigation costs may be particularly likely to target less crowded technology areas in order to avoid disputes.⁵⁹ These effects may be large,⁶⁰ and may consequently be an important driver of behavior within the patent system.⁶¹

Policymakers, for their part, have recognized the potential of legal uncertainty as a regulatory lever.⁶² Because it is expensive for an examination authority to authenticate every patent that it issues,⁶³ it may be

frequency, but has affirmed district court decisions of non-infringement with roughly equal frequency.

⁵⁵ See *supra* notes 16-21 and accompanying text.

⁵⁶ See *supra* notes 22-26 and accompanying text.

⁵⁷ See *supra* notes 27-37 and accompanying text.

⁵⁸ See generally Stuart J.H. Graham et al., *High Technology Entrepreneurs and the Patent System: Results of the 2008 Berkeley Patent Survey*, 24 BERKELEY TECH. L.J. 1255 (finding that motivations both for seeking and for not seeking patents is highly specific to industry, technology, and context).

⁵⁹ Lerner, *supra* note 12, at 465.

⁶⁰ *Id.* Professor Lerner notes, for example, that established firms in certain industries engage in broad cross-licensing to reduce the likelihood of expensive patent litigation. Such behavior would dampen the observed effect upon the patenting behavior of firms, and, indeed, Professor Lerner focuses his analysis on new biotechnology startup firms among whom such cross-licensing arrangements are less common. *Id.* at 473-75.

⁶¹ See, e.g., Stuart J.H. Graham & Ted Sichelman, *Why Do Start-Ups Patent?*, 23 BERKELEY TECH. L.J. 1063, 1085-86 (discussing the impact upon patenting activity of the high costs of patenting and patent litigation).

⁶² See, e.g., *American Innovation at Risk: The Case for Patent Reform: Hearing Before the Subcomm. on Courts, the Internet, and Intellectual Prop. of the H. Comm. on the Judiciary*, 110th Cong. 20-22 (2007) (statement of Suzanne Michel, Chief Intellectual Property Counsel and Deputy Assistant Director for Policy Coordination, FTC), <http://judiciary.house.gov/hearings/printers/110th/33315.pdf> (discussing major categories of effects that uncertainties in patent quality can have on competition, innovation, and market efficiency).

⁶³ See, e.g., Joseph Farrell & Robert P. Merges, *Incentives to Challenge and Defend Patents: Why Litigation Won't Reliably Fix Patent Office Errors and Why Administrative Patent Review Might Help*, 19 BERKELEY TECH. L.J. 943, 946 (2004) (arguing that perfect patent examination would be unduly expensive—and unnecessary, in view of methods available to invalidate improperly issued patents *ex post*). Understandably, conventional wisdom has it that such expense is an undesirable, but inevitable, trait of cumbersome federal bureaucracy. *But see* David Fagundes & Jonathan S. Masur, *Costly Intellectual*

acceptable, to some extent, that individual firms enforce their own patents and that not every patent be investigated in depth.⁶⁴ Some scholars have even suggested allowing uncertainty as to the validity and scope of patents, so that expenditure on each granted patent would be reduced, and only those patents in dispute would be investigated in court at further cost.⁶⁵ Under such a framework, the socially optimal amount of uncertainty would, indeed, be nonzero.

Therefore, as much in responding to private actors within the patent system as in tailoring evidence-based patent policy, it is important to understand quantitatively the impact of uncertainty on the value of patent rights.

III. EMPIRICAL MODEL, DATA & METHODOLOGY

A. Generally

To arrive at such an understanding, patent litigation proves to be an especially useful area of law in which to examine market responses, for three reasons. First, the question of validity may reasonably be framed as a binary decision.⁶⁶ The issue of infringement is not as straightforward, but a court's decision still generally fits into a binary classification. Second,

Property, 65 VAND. L. REV. 677 (applying costly screen theory to patent examination). Professors Fagundes and Masur argue that the cost of examination deters applicants where the exclusive right at issue is worth less than the cost of obtaining it. The result, they conclude, is that “the costly examination process is not a deadweight loss at all, but an efficient way to exclude the very kind of patents most likely to generate anticommons concerns.” *Id.* at 680.

⁶⁴ FTC, TO PROMOTE INNOVATION: THE PROPER BALANCE OF COMPETITION AND PATENT LAW AND POLICY, http://www.wipo.int/wipolex/en/text.jsp?file_id=177488 (framing the management of patent quality as a balance of “how best to invest limited resources”).

⁶⁵ See, e.g., Mark A. Lemley, *Rational Ignorance at the Patent Office*, 95 NW. L. REV. 1495, 1497 (arguing that “the PTO doesn’t do a very detailed job of examining patents, but we probably don’t want it to”).

⁶⁶ Strictly speaking, the unit of adjudication is the claim rather than the patent, and a court may find a patent valid in part and invalid in part. Yet it is now common for patent litigations to be decided on the basis of “representative claims”—whether by stipulation or by court order. Patricia E. Campbell, *Representative Patent Claims: Their Use in Appeals to the Board and in Infringement Litigation*, 23 SANTA CLARA COMPUTER & HIGH TECH. L.J. 55, 69-70. Empirical scholarship on patent litigation, too, largely speaks of valid and invalid patents. See, e.g., Ayres & Klemperer, *supra* note 1, at 3 (comparing the likelihoods that valid patents versus invalid patents will be enforced); Lemley & Shapiro, *supra* note 4 (framing uncertainty in the patent property right upon the risk that a patent will be found valid or invalid); David O. Taylor, *Clear but Unconvincing: The Federal Circuit’s Invalidity Standard*, 21 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 293 (discussing the social disutility of finding truly valid patents invalid, and vice-versa).

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there is little or no information leakage prior to the announcement of the decision. Third, all *new* information that the decision provides about the patent pertains to changes in beliefs about the property right as opposed to the underlying technology.

For patent i born at time 0, we assume that the value at time t can be approximated by

$$v_{it} = p_{it}V \cdot p_{it}I \cdot z_{it}$$

where V is the value of the patent, pV is the probability of winning on validity, pI is the probability of winning on infringement, and z is some underlying private value of the technology were it to be perfectly enforceable.

If the patent is litigated at time τ , the change in patent value is given by

$$(1) \quad \Delta v_{i\tau} = \Delta p_{i\tau}V \cdot p_{i\tau}I \cdot z_{i\tau} + \Delta p_{i\tau}I \cdot p_{i\tau}V \cdot z_{i\tau} + \Delta p_{i\tau}V \cdot \Delta p_{i\tau}I \cdot z_{i\tau}$$

where Δ represents the change in the variable as a result of the court's decision. It may be that $\Delta p_{i\tau}V = 0$ or $\Delta p_{i\tau}I = 0$ if there is no decision on validity or infringement, respectively. Importantly, we assume that actual technological value z does not change as the result of the court's decision. Put another way, the court makes decisions only about the property right, and not about the technology.

From these considerations, the econometric specification is

$$(2) \quad \Delta v_{i\tau} = \beta_0 + X_{i\tau}V\beta_1 + X_{i\tau}I\beta_2 + X_{i\tau}VI\beta_3 + \epsilon_{i\tau}$$

where $X_{i\tau}V$ is a vector of variables that affect the market response to validity or invalidity decisions, $X_{i\tau}I$ is a vector of variables that affect the market response to infringement or non-infringement decisions, and $X_{i\tau}VI$ is a vector of interaction terms between $X_{i\tau}V$ and $X_{i\tau}I$. In a simple specification, we define $X_{i\tau}V = D_{i\tau}V D_{i\tau}NV$ and $X_{i\tau}I = D_{i\tau}I D_{i\tau}NI$ where $D_{i\tau}V$, $D_{i\tau}NV$, $D_{i\tau}I$, and $D_{i\tau}NI$ are indicator variables for decisions of validity, non-validity, infringement, and non-infringement, respectively. We keep all the indicator variables in the equation because $D_{i\tau}V + D_{i\tau}NV$ may be equal to zero if there is no decision on validity at date τ ; likewise with infringement. $X_{i\tau}VI$ then becomes

$$Xi\tau VI = Di\tau V \cdot Di\tau I, Di\tau V \cdot Di\tau NI, Di\tau NV \cdot Di\tau I, Di\tau NV \cdot Di\tau NI.$$

Note that the third term in Equation (1), $\Delta pi\tau V \cdot \Delta pi\tau I \cdot zi\tau$, has only a second order effect. If this effect is negligible, the estimation equation reduces to

$$(3) \quad \Delta vi\tau = \beta_0 + Xi\tau V\beta_1 + Xi\tau I\beta_2 + \epsilon i\tau$$

It is clear from Equation (1) that the change in the value of the patent will be a function of both the marginal change in the expected probability of winning on validity and infringement and the private value of the underlying technology. For present purposes, we aim only to characterize the distributions of stock market reactions to litigation decisions and to patent grants in order to characterize the value of resolution of legal uncertainty relative to the initial property right.⁶⁷

B. Multiple Patents-in-Suit

Beyond this marginal change function, there remains the econometric issue of multiple patents-in-suit. We are, strictly speaking, able to observe changes only in the value of a firm, not in the value of a patent. Thus, where there are multiple patents-in-suit, we observe only the aggregate market reaction. Table 2 shows that, of 295 adjudications, 209 involved a single patent. The remaining 76 adjudications account for decisions on 266 patents. If there are N patents-in-suit that are adjudicated simultaneously,

$$(4) \quad \Delta fi\tau = \Delta vi\tau 1 + \Delta vi\tau 2 + \dots + \Delta vi\tau N$$

where $\Delta vi\tau n$ represents the change in the value of patent n of firm i at time τ . So, while we observe $\Delta fi\tau$, what we seek is the expectation of $\Delta vi\tau n$ given $\Delta fi\tau$, or $E\Delta vi\tau \Delta fi\tau$. In cases where $N=1$, there is no difficulty in the estimation. Whereas removing cases where $N>1$ would leave unexploited the informational value of decisions upon multiple patents-in-suit—and perhaps bias the results as well—we instead apply the

⁶⁷ A more econometrically complete analysis—in which we estimate a structural model to disentangle the marginal change in the expected probability of winning on validity and infringement from the private value of the underlying technology—is the subject of a subsequent article in progress.

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Expectation-Maximization (EM) Algorithm to make use of the data when there are “missing” Δvitrn values.⁶⁸ The intuition is that we estimate Equation (2) to predict values of Δvitrn for multiple patents-in-suit. These predicted values are used in a new iteration of the estimation, and the process is repeated until the parameter estimates converge.

C. Patents & Litigations

Our data begin with a database compiled by researchers at the National Bureau of Economic Research (NBER) and Case Western Reserve University (CWRU).⁶⁹ The sample consists of over 417,000 patents owned by publicly traded U.S. manufacturing firms. The patents are assigned CUSIP identifiers⁷⁰ using the 1989 ownership structure of the patent holder.

Litigation data were hand-collected from the United States Patents Quarterly (USPQ) for the 1977–1997 period.⁷¹ The USPQ publishes annual indices containing patents on which adjudications were made in that year. USPQ contains only “published” adjudications, which is a subset of all adjudications. However, the advantage of the USPQ is that it contains clear information on the disposition of the case with regard to validity and infringement. The USPQ data were merged with the NBER/CWRU data to obtain a list of litigated patents owned by publicly traded firms.

The merged data contain 701 case citations involving 670 patents. We entered the disposition data for each adjudication containing decisions relevant to validity or infringement.⁷² Adjudications involving preliminary motions about discovery, jurisdiction, etc. were discarded, as were USPTO interference proceedings and examination proceedings. When a USPQ

⁶⁸ See *infra* Section IV.C. For a good overview of the EM Algorithm with applications to economics, see Paul A. Ruud, *Extensions of Estimation Methods Using the EM Algorithm*, 49 J. ECONOMETRICS 305 (1991). For an extensive treatment of the subject, see GEOFFREY J. MCLACHLAN & THIRYAMBAKAM KRISHNAN, *THE EM ALGORITHM AND EXTENSIONS* (1997).

⁶⁹ Bronwyn H. Hall et al., *Market Value and Patent Citations: A First Look*, (Nat’l Bureau Econ. Res. Working Paper No. 7741, 2000), <http://www.nber.org/papers/w7741>. Sincere thanks to Bronwyn Hall for permitting access to the data.

⁷⁰ The CUSIP system assigns nine-character identification codes to North American securities for transactional purposes. The system is so named for the Committee on Uniform Securities Identification Procedures that established it. See U.S. SEC. & EXCH. COMM’N, CUSIP NUMBER (2013), <http://www.sec.gov/answers/cusip.htm>.

⁷¹ See John R. Allison & Mark A. Lemley, *Empirical Evidence on the Validity of Litigated Patents*, 26 AIPLA Q.J. 185 (1998); see also Henry & Turner, *supra* note 54, at **Error! Bookmark not defined.**

⁷² The opinions themselves were obtained electronically from Lexis, to whom we are grateful for access to the USPQ file.

citation expressly referred to a related earlier decision, we incorporated that case into the dataset.

In sum, the final adjudication dataset consists of 390 decisions involving 413 patents owned by 158 publicly traded firms. The unit of observation is a patent-decision. For example, a single case may involve four patents. When a decision is made, we record four patent-decisions. In total, we have 610 patent-decisions. About half the cases involve only one patent-decision. The implied litigation rates are given in Table 1, where case filing data were calculated using information from the LitAlert patent litigation database.⁷³

To facilitate analysis of adjudications by our event-study methodology, we also obtained data on daily stock returns from the Center for Research in Security Prices.⁷⁴ Of the 390 adjudications, ownership and returns data were available for 295. These 295 adjudications represent 325 patents and 475 patent-decisions. Of those 325 patents, returns data were available for 287 patent application dates and 309 issuance dates; for 283 patents, we have returns data for both dates.

Table 2 shows the breakdown of the 475 decisions into various subsamples. The first important subsample is whether the case was decided in a lower court or an appellate court. In our sample, 277 individual decisions were at the district court level. Note that our sample is subject to both right-hand and left-hand truncation. That is, for a 1977 appellate decision, we would not have in our sample the original lower court decision; for a 1997 lower court decision, we would not have in our sample the subsequent appeal. In any case, one might expect appellate decisions to be weighted differently by the market than district court decisions.

The next subsample shows that 125 cases occurred prior to 1982, when the CAFC was established. This distinction is important for two reasons. First, the CAFC is a centralized appellate court for patent cases. So, all appeals heard after 1982 were heard in the same court. Second, the centralization may have led to a harmonization among circuits in terms of precedent. Either of these may cause stock market reactions to differ pre- and post-CAFC.

In most cases, the plaintiff is the patent holder. Only 48 decisions involve a defendant patent holder. Market reactions between these two subsamples are likely to differ because of different selection effects. Plaintiff patent holders engage in the typical patent infringement case. A

⁷³ It is likely that filing data and adjudication data in LitAlert are under-reported.

⁷⁴ The CRSP is based at the University of Chicago and provides historical stock market data. See generally CENTER FOR RESEARCH IN SECURITY PRICES, <http://www.crsp.chicagobooth.edu/> (last visited Jan. 24, 2013).

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patent holder becomes a defendant in one of two instances: either it has been preemptively sued for a declaratory judgment that the patent is invalid, or it has been sued for patent infringement, and it counter-sues for infringement of its own patent rights. In either case, defendant patent holders may have different incentives to settle than plaintiff patent holders.⁷⁵ These different selection effects may lead to different market responses.

The last two rows of Table 2 show the breakdown by type of adjudication. Out of 475 patent decisions, 326 decisions involved validity, and 298 decisions involved infringement. Importantly, not every adjudication involves both infringement and validity. In many trials the issue of validity is determined separately from that of infringement. Frequently the trial is bifurcated, or even trifurcated: validity is determined first, followed by infringement, and finally damages. Settlement may occur at any phase of the trial. Our sample may show such a case first as an adjudication of validity, and subsequently an adjudication of infringement: one trial, two adjudications—unless settlement occurs.

Moreover, in some trials, validity may not be questioned as a defense, so that the court rules only on infringement. Accordingly, our regression analysis codes four dummy variables to represent various types of rulings: validity (*V*), invalidity (*NV*), infringement (*I*), and non-infringement (*NI*).⁷⁶ Since any given adjudication can rule a patent valid, invalid, or can refrain from ruling on validity (and similarly for infringement), we include all four dummy variables and a constant in the estimation equation.

Also important is the relative frequency of validity rulings (326) relative to infringement rulings (298). Whereas the majority of patent suits are initiated by the patent holder, there are more validity rulings than infringement rulings. Certainly challenging the validity of a patent is a common defense, and a patent holder may expect to face a decision on validity when bringing an infringement suit. Among validity rulings, the win rate for the patent holder is 59%; among infringement rulings, 64%. And the correlation coefficient between positive validity rulings and positive infringement rulings is 0.63. If we define the following variables in terms of positive rulings—

⁷⁵ See George L. Priest & Benjamin Klein, *The Selection of Disputes for Litigation*, 13 J. LEGAL STUD. 1 (1984); Joel Waldfogel, *The Selection Hypothesis and the Relationship Between Trial and Plaintiff Victory*, 103 J. POL. ECON. 229 (1995).

⁷⁶ Technically, since validity is presumed, the court will rule that the patent is either invalid or not invalid. We refer to valid and invalid patents for parsimony.

$$gV = V - NV$$

$$gI = I - NI$$

—we find that the correlation between gV and gI is 0.50.⁷⁷

D. Event Studies

As an estimate of the value to a patent holder of news about a patent, we rely on the event study methodology. In particular, we investigate two pieces of news: (1) news about the patent grant (at the time of application and the time of issuance); and, (2) news about a court's decision about the validity or infringement of a patent. Event studies measure the change in the value of the firm using cumulative abnormal returns, or excess returns. The methodology is the accepted way to tie stock market valuations to particular events,⁷⁸ but there are two caveats that should be mentioned.

First, if information about the event leaks into the market prior to the event date, then the excess returns will measure only a portion of the total reaction. This problem is likely to be more important for patent grants than for patent adjudications. The announcement effect of a patent application or patent grant cannot be readily interpreted as representing the full value of the patent because announcement effects only reflect changes in value with respect to news about the patent. It is more likely that news about noteworthy patents may be known ahead of time. However, news about a court's decision is likely to be unknown prior to the decision.

Second, excess returns are notoriously noisy, since multiple factors can influence a stock price on any given day. So long as those other factors are not systematically correlated with news about patents, then they will add noise but will not bias the results.

Previous work on patent litigation and value has not explicitly made use of the information contained in market responses to patent litigation decisions, or on the outcomes of court decisions. Some renewal models use

⁷⁷ The correlation coefficients are based on individual patent decisions. Thus, they do not account for earlier decisions by the same court on that patent.

⁷⁸ But see Glynn S. Lunney, Jr., *On the Continuing Misuse of Event Studies: The Example of Bessen and Meurer*, 16 J. Intell. Prop. L. 35 (2008) (questioning the use of the stock market event study as a valid model for estimating losses to a firm and, by extension, for establishing the “true” cost of patent litigation). The present study, however, does not engage in the cost-benefit extrapolations that Professor Lunney criticizes—particularly as to the Equivalence Assumption—but is instead limited to those market beliefs themselves which market capitalization represents.

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the incidence of litigation as well as renewal rates to estimate the parameters of the model.⁷⁹ But these papers do not look at legal outcomes. Professors Allison and Lemley investigate patent cases published in the U.S. Patents Quarterly.⁸⁰ The authors do investigate the dispositions of these cases, but their focus is on the legal character of the cases more than the economic implications.⁸¹

We use cumulative abnormal returns as measured by event studies to measure the stock market reactions to patent decisions. Event studies are appropriate for several reasons. First, changes in value are precisely what event studies are designed to measure. Second, while event studies have been used by researchers to investigate the effects of other types of litigation,⁸² no study has concentrated on patent litigation.⁸³ Market reactions provide information that has not been previously incorporated into the analysis of patent value. Third, litigation events are well identified: court records for published decisions identify the date of the decision. Last, litigation events can be directly associated with changes over beliefs about the legal patent right. If a patent is ruled to be valid, nothing about the decision affects the value of the underlying technology, so the change in value reflects changes in beliefs about the uncertainty over property rights.

In order to estimate Equation (2), we need to calculate a measure for the market reaction to the litigation event. The market model is the model most frequently used in event studies.⁸⁴ The estimation equation is

$$R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it}$$

where

R_{it} = proportionate return on the stock of firm i from time $t-1$ to time t

R_{mt} = proportionate return on the overall market from time $t-1$ to

⁷⁹ E.g., Lanjouw, *supra* note 48, at 12.

⁸⁰ Allison & Lemley, *supra* note 71, at 19.

⁸¹ For instance, the incidence of certain legal defenses to infringement. *See id.*

⁸² Sanjai Bhagat et al., *The Costs of Inefficient Bargaining and Financial Distress*, 35 J. FIN. ECON. 221 (1994).

⁸³ Event studies have been used to examine market reactions to patent issuance. *See* David H. Austin, *An Event-Study Approach to Measuring Innovative Output: The Case of Biotechnology*, 83 AM. ECON. REV. 253 (1993).

⁸⁴ *See* JOHN Y. CAMPBELL ET AL., *THE ECONOMETRICS OF FINANCIAL MARKETS* 155-57 (1997) (describing the characteristics, usage, and benefits of the market model relative to other statistical and economic models in event-study analysis).

time t

Abnormal returns are calculated by estimating the parameters of the market model in some pre-event equilibrium. Essentially, the abnormal return is the forecast error. The cumulative abnormal returns are given by

$$CAR_{it} = -\tau_1 \tau_2 u_{it}$$

That is, cumulative abnormal returns are the summation of abnormal returns over the event window $-\tau_1$ to τ_2 , where the event occurs on day 0. For the analysis below the pre-event equilibrium is $-300, -20$, measured in trading days. For the adjudication events, the abnormal returns are calculated for symmetric event windows of 1, 3, 5, 7, 9, and 11 trading days around the event date, and an asymmetric window of two days: day 0 and day +1. For patent grants, we drop the one-day window. The Equal Weighted Market Return is used for R_m , as defined by CRSP.

E. Expectation-Maximization Algorithm

The EM Algorithm allows estimation of the change in the value of a particular patent given that we know the change in the value of the firm, and the dispositions of the patent in question and of other simultaneously adjudicated patents. That is, the EM Algorithm allows estimation of values for Δv , conditional on Δf , for the special case where Δv 's are missing. Because multiple patents may be adjudicated simultaneously, the excess returns for the firm's stock price must be apportioned across the Δv 's. To do so, we require $E\Delta v_{itn} \Delta f_{it}, X_{itn}$ where X_{itn} is a vector of characteristics of the disposition of the case. Let

$$\Delta v_{itn} = X_{itn} \beta + \epsilon_{itn}$$

where

$$\epsilon_{itn} \sim N(0, \sigma^2)$$

so that the error term is normal and the ϵ_{itn} terms are independently and identically distributed. The assumption of independence is convenient but not innocuous. We can imagine that patents that are litigated together may not be independent, but instead be part of a larger system. The validity of any component may rise and fall by the validity of the system. The

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potential dependence of component patents warrants further investigation; for simplicity, however, we assume independence in this paper.

Since we assume that $\Delta f_{i\tau} = N\Delta v_{i\tau}n$, we can write the following:

$$\Delta f_{i\tau} \sim N(NX_{i\tau}n, N\sigma^2)$$

$$\text{Var}\Delta v_{i\tau}n = \sigma^2$$

$$\text{Var}\Delta f_{i\tau} = N\sigma^2$$

$$\text{Cov}\Delta v_{i\tau}n, \Delta f_{i\tau} = \sigma^2$$

Generally if two random variables A and B are correlated, the expectation of A given B can be written as:

$$EAB = EA + \text{Cov}A, B \text{Var}B - EB$$

Applying this formula to the case at hand yields:

$$E\Delta v_{i\tau}n\Delta f_{i\tau} = E\Delta v_{i\tau}n + \text{Cov}\Delta v_{i\tau}n, \Delta f_{i\tau} \text{Var}\Delta f_{i\tau} - E\Delta f_{i\tau}$$

$$E\Delta v_{i\tau}n\Delta f_{i\tau} = E\Delta v_{i\tau}n + 1N\Delta f_{i\tau} - E\Delta f_{i\tau}$$

Using predicted values this can be approximated by

$$(5) \quad E\Delta v_{i\tau}n\Delta f_{i\tau} = \Delta v_{i\tau}n + 1N\Delta f_{i\tau} - N\Delta v_{i\tau}n$$

Implementing the EM Algorithm involves using a predicted value of the vector Δv to obtain a parameter estimate, which is used to get a better prediction for Δv :

$$\Delta v_0 \rightarrow \beta_0 \rightarrow \Delta v_1$$

In this case Δv_0 is the starting value. In our application, Δv_0 consists of only single-patent cases from which we obtain a parameter vector β_0 (this is the maximization step because the EM Algorithm is a maximum likelihood technique). We use β_0 to predict Δv_1 . This prediction does not incorporate any information from Δf . In particular, for multi-patent cases, the sum of $N\Delta v_{i\tau}n$ is likely to be a poor predictor of $f_{i\tau}$. Instead a new value

$\Delta vitn1$

can be given by

$$\Delta vitn1 = E\Delta vitn \Delta fit = \Delta vitn1 + 1N\Delta fit - N\Delta vitn$$

(this is the expectation step). $\Delta v1$ is regressed on the explanatory variables to determine $\beta1$ and the process is iterated until the sequence $\beta0, \beta1, \dots$ converges to a fixed point, βEM .

The framework described here addresses several important attributes of patent litigation examined in this study: the assertion of one patent or many in the dispute; the litigation outcomes of interest as to validity and infringement; the relevant time window of observation surrounding judicial decisions; the baseline behavior of the stock market from which changes may be attributed to a judicial decision; and the potential for interactions among these attributes. Examination of these attributes produces a range of informative results about the responses of the stock market to patent litigation.

IV. DISCUSSION

A. *Excess Returns*

Tables 3 and 4 summarize the results of the event studies. The first column lists the event window used to calculate the excess returns: 2 to 11 days. Additionally, we calculate a bootstrap sample. For a single bootstrap replication, a sample of patents (with replacement) is drawn from our sample. For each patent a single event window is randomly chosen. The distribution given in each table represents the distribution of 500 bootstrap replications. To be sure, the random event window is arbitrary, but it is less arbitrary than choosing a single event window for all application and issuance dates.⁸⁵

It is evident from Table 3 that the application date produces a significant positive reaction from the market, in contrast to both the issuance date and the sum of the returns at the application and issuance dates. This may seem strange in light of U.S. patent laws: applications are not immediately published upon filing, whereas patents are upon issuance.

⁸⁵ It is unlikely that a single event window would represent all firms equally well. In the absence of a prior as to which window would work better for different types of firms or patents, we rely on the more robust bootstrapping estimator of the mean.

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However, leakage is important in this context because, particularly in the case of important patents, more information may leak near the application date than near the issuance date: accordingly, Professor Austin in his patent-issuance event study analysis found, for example, that the patent issuance date is a more appropriate point of reference than the application filing date.⁸⁶

For all windows greater than two days, the 90% confidence interval shows positive excess returns around the patent application date. For nine- and 11-day windows, the sum of the application and issuance date returns is also significantly positive. The 11-day returns show a response of 1.4% to 2% for the application date, and 1.2% to 3.3% for the sum of application and issuance returns. The bootstrap estimates show a smaller confidence interval of 0.14% to 1.0% at the date of application. Finally, bootstrap estimates show a dollar value (calculated from excess returns and market capitalization) of \$28.1 million at the mean, and a 90% confidence interval of \$0.7 million to \$55.4 million.

To put this in context, we compare these reactions to the estimates made by Professor Austin of excess returns from patent issuance: he finds that excess returns range from a mean of about \$500,000 for the full sample, to a mean of \$33 million for those patents mentioned in *The Wall Street Journal*.⁸⁷ If litigated patents do, indeed, comprise a sample of the most valuable patents,⁸⁸ then the comparison to “Wall Street Journal patents” is certainly apt.

Table 4 and Figures 1 and 2 present excess returns at application date by the patent’s later infringement or validity status,⁸⁹ as determined by the court. Do patents that are later found to be valid or infringed show higher excess returns at the time of birth? The short answer is no. In fact, the histograms in Figures 1 and 2 show that excess returns at the date of application are likely to be slightly higher for invalidated or not infringed patents than for valid or infringed patents, although the difference is not statistically significant. Patents that are later found valid have mean excess returns of 0.46% compared to 0.59% for patents that are later found invalid. Similarly, infringed patents have mean excess returns at the date of application of 0.53% compared to 0.99% for non-infringed patents. Only the non-infringed result is significantly different from zero at the 10% level. The lower returns for subsequently valid and infringed patents are not

⁸⁶ Austin, *supra* note 83, at 254.

⁸⁷ *Id.* at 255-56.

⁸⁸ See *supra* notes 32-33 and accompanying text.

⁸⁹ For the current tables and figures, and those that follow, the bootstrap estimates of the distribution are presented.

surprising and are almost certainly due to a selection effect. There may be some uncertainty over the strength of the original property right for patents that are later litigated. If a patent holder has private information about a patent's validity,⁹⁰ it will be more likely to pursue litigation if the market's perception of the patent is particularly low relative to the patent holder's. Thus, the low returns to later validated patents may be a signal of the market's perception of value, rather than the patent holder's.

Table 4 and Figure 3 present the excess returns by type of disposition at the time of adjudication. The results of the response at adjudication is meaningless in the aggregate because they contain information for both good news and bad news events, as well as "mixed" events (e.g., a valid but not infringed patent). We expect the market returns to be somewhat noisy despite the precision of the event date. First, firms differ in size, so reactions to good or bad news about patents will vary not only according to revision in beliefs, but also according to the firm's market capitalization. Large firms will have smaller responses, *ceteris paribus*. Additionally, there will be individual heterogeneity at the patent level because of the heterogeneity in the underlying technological value. We control for this heterogeneity by using the log of the dollar returns as the dependent variable, and by using a random-effects model.

It is evident that the mean reaction to infringement is positive and the mean reaction to non-infringement is negative. Validity leads to a positive response, but invalidity leads to an even higher positive response. In fact, of the four types of dispositions, only invalidity is significantly different from zero (at the 10% level). The market reactions to adjudications are confounded by two factors. First, multiple-patent decisions misstate the market reaction to any individual patent that is a part of the decision. If two patents are adjudicated simultaneously, and the decision is that one patent is valid and infringed, and one patent is not valid, then the market reaction will be a combination of the response to each patent.⁹¹ Secondly, the decision on an individual patent may be a mix of good news and bad news, e.g., valid and not infringed or invalid and infringed.⁹²

⁹⁰ Meurer, *supra* note 15.

⁹¹ Cases in the sample contain as many as 12 patents.

⁹² Oddly enough, the latter decision is not unheard of. Six observations in our data are valid and not infringed. District courts began the practice in recognition that their decision on validity might be overturned on appeal. This is the consequence of anticipated appeals on the part of district courts. If an invalidity decision is overturned by the Court of Appeals for the Federal Circuit, then it can expedite proceedings to decide both issues at the time of the original trial, rather than have a separate trial on remand. In that instance, the court

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Because of the confounding influences affecting market reactions to adjudication, it is appropriate to turn to regression analysis to disentangle the effects of multiple patents and mixed decisions.

B. Regression Results

Table 5 presents the results of estimating a variation of Equation (3)

$$(6) \quad CAR_{it} = \beta_0 + V_{it}\beta_1 + NV_{it}\beta_2 + I_{it}\beta_3 + NI_{it}\beta_4 + \epsilon_{it}$$

where *CAR* indicates the cumulative abnormal return at the time of adjudication from the event studies. All estimations use the EM Algorithm,⁹³ and all standard errors are bootstrapped with 1000 replications. Since the bias in the estimates relative to the bootstrap replications tended to be large (usually greater than 0.25 of the standard error), bias-corrected coefficients are reported and significance levels are determined from the bias-corrected confidence intervals rather than from the bootstrapped standard errors.⁹⁴

The first model uses the two-day excess returns as the independent variable. The second model uses another application of the bootstrap, similar to that used in examining the means of the excess returns in section 4.1. Each replication consists of a sample of 475 observations drawn from the sample (with replacement). The event window is then chosen randomly for each observation from the set {1, 2, 3, 5, 7, 9, 11} as above. The rationale is the same as with the means: there is no justification for choosing any particular event window since the appropriate window is likely to differ on the basis of the individual patent, company, and decision. Thus, we choose a random window for each observation. The bootstrapping procedure yields consistent estimates. The third model in Table 5 estimates a random-effects version of Equation (7):

$$(7) \quad CAR_{it} = \beta_0 + V_{it}\beta_1 + NV_{it}\beta_2 + I_{it}\beta_3 + NI_{it}\beta_4 + u_i + \epsilon_{it}$$

would save time to rule on both matters simultaneously. *See, e.g., Datascope Corp. v. SMEC, Inc.*, 224 U.S.P.Q. 694 (D.N.J. 1984).

⁹³ *See supra* Section IV.C.

⁹⁴ *See generally* BRADLEY EFRON & ROBERT TIBSHIRANI, AN INTRODUCTION TO THE BOOTSTRAP (1993); Andrew H. Briggs et al., *Pulling Cost-Effectiveness Analysis Up by Its Bootstraps: A Non-Parametric Approach to Confidence Interval Estimation*, 6 HEALTH ECON. 327 (1997).

where u_i is a patent-specific disturbance term and ε_{it} is the standard disturbance term. In addition to the ordinary parameter estimates, the random-effects model estimates parameters σ_u and ρ , the proportion of the overall variance associated with σ_u as opposed to σ_ε . Lastly, the fourth model estimates a random-effects model with the log of the dollar value of the excess returns as the dependent variable. The remaining regressions all use the bootstrapped random-effects model with the EM Algorithm.

Model 1 (using the two-day window) shows a significant value for *NV* (not valid) decisions only. The estimated market reaction is -1.25% . Model 2 yields no significant results. However the random-effects model estimates the parameters with much more precision. Again, from Equation (1), the market response will depend on the value of z (the underlying technological value). The heterogeneity embedded in z is approximated by the random-effects model.

The coefficients show a 1.6% excess return due to validity, -1.4% return from invalidity, a -1.8% response to a non-infringement ruling, and a 0.8% response in the constant term; reaction to infringement is not measured precisely. Note that the constant term reflects a positive market reaction to the conclusion of a case. This is not unexpected since the resolution of uncertainty tends to be favored by the market. Additionally, providing certainty about validity, invalidity or infringement is worth about 1.5% to the firm. That is, more certain property rights are worth as much to the firm as the estimates of patent value at the time the patent is born (around 1%).

The estimate of ρ is quite high, indicating that much of the unobserved heterogeneity is patent specific (as opposed to observation specific), which is consistent with the idea that the random-effects model captures the heterogeneity embedded in z_i . The log dollars equation confirms only the negative coefficient on invalidity. It is interesting that the dollars equation does not more accurately measure the coefficients, since some of the noise in excess returns arises from differences in firm size. However, it is standard in the event study literature to use excess returns rather than dollar values, and in this instance it does not appear to harm the precision of the estimates (as long as the random-effects model is used).

Table 6 compares the simple random-effects model (model 3 of Table 5) to an estimation that includes the interaction terms according to Equation (2). The interaction terms are mostly insignificant, and most of the coefficients on the primary disposition variables also become insignificant (including the constant term). The exceptions are the validity coefficient of 3.4% (significant at the 99% level) and the valid and not

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infringed interaction term of -4.9% (significant at the 95% level). These coefficients are much larger than without the interaction terms. Several of the other coefficients are large in magnitude but imprecisely measured, probably due to the presence of multicollinearity among the regressors. For the remaining regressions, we rely on the non-interacted model for the sake of simplifying the interpretation. That restriction does affect the results on the subsample regressions below.

In Table 2, we described several different subsamples that might affect the size of market reactions to patent adjudications and the resolution of uncertainty in patents. The next section investigates those subsamples in more detail.

C. Subsamples

Table 2 listed three ways to divide the sample:

1. appeals versus district court decisions,
2. pre- versus post-1982 decisions, and
3. plaintiff patent holders versus defendant patent holders.

For each pair of complementary subsamples, we use a Chow test to determine whether the coefficients of each subsample are different from one another (using the random-effects model on excess returns in Table 5). Based on non-bias-corrected coefficients, none of the subsamples have a significant effect; the largest Chi-squared statistic (five degrees of freedom) is 8.1, with a p-value of only 0.15.

Two of the three Chow tests using the bias-corrected coefficients were significant. Comparing the pre- and post-1982 decisions led to a statistic of 16.7 (p-value < 0.01). Reactions to plaintiff patent holders were significantly different from defendant patent holders, with a statistic of 13.0 (p-value < 0.05). It is very interesting that the appellate decisions did not lead to larger market responses than lower court decisions, on average (chi-squared statistic of 3.2, p-value = 0.67). One would think that the higher courts would have final say on validity and infringement (since very few patent cases go to the Supreme Court), and that markets would respect this greater power. While this may be true, the effect is not large enough to show in the data. However, the pre- and post-CAFC era does seem to make a difference, whether at the appellate level or the district level.

Tables 7 and 8 compare the results of estimating Equation (6) for the pre- and post-CAFC era, and for plaintiff and defendant patent holders, respectively. Interestingly, the post-CAFC era is characterized by smaller

excess returns in response to validity and larger (negative) responses to invalidity. Pre-CAFC reactions to infringement decisions were much larger than post-CAFC responses (and both infringement and non-infringement led to negative responses). Taken together, a valid and infringed patent had a negligible market reaction prior to the establishment of CAFC, and the loss on infringement was a significant negative. This indicates that only very strong patents (patents that were believed to be likely to win) were being litigated because the response to the upside was small, and the response to the downside was large.

There is an intriguing result as to plaintiff and defendant patent holders. Market reactions tend to be larger with validity decisions for plaintiffs and for infringement decisions with defendants. On the surface this may seem strange, since plaintiff cases are usually straight infringement cases, and defendant cases usually deal with validity (declaratory judgments for invalidity). However, this result has to do with selection, expectations, and uncertainty. Since plaintiff cases are brought with regard to infringement, it may be that the markets well predict the infringement outcome relative to the validity outcome. Similarly, since defendant cases are usually brought with respect to validity, the markets may well predict the validity outcome in comparison to the infringement outcome. Additionally, the constant term is significant (1.8%) for defendant cases. Because defendant cases are, in a sense, involuntary on the part of the defendant, their existence signals greater risk to the company than a lawsuit deemed necessary for the protection of the firm's property. Thus, the conclusion of such a case is likely to be more valuable to defendant patent holders.

Separating the subsamples leads to one surprising result: that appellate courts do not generate more significant market responses than lower courts. Additionally, the comparison of pre- and post-1982 and plaintiff and defendant patent holders highlights the impacts of selection on the returns to litigation.

To be sure, findings that comport with *a priori* expectations, no less than those that reveal potentially unexpected relationships between the uncertainty in patent rights being litigated and the selection effects that arise from the value of the rights and informational asymmetries among the litigating parties, rely in this study upon simplifying assumptions, particularly about interactions among different observed effects. Such assumptions invites further study beyond the proof of principle presented in this article. To that end, the next study in this series will employ more econometrically detailed specifications to explore fully the assumptions used thus far, as well as invest in expanding the dataset to include more current litigations. Moreover, though the responsiveness of stock markets

to legal uncertainty is not new, such greater detail of analysis will also shed light on ways in which the markets have begun in recent years to account in more sophisticated ways for patent rights.

V. CONCLUSION

By investigating the size of the market reactions, and how they differ systematically among cases, we are able to make some inferences about the value of certainty in patent rights. This paper is the first to estimate market reactions to patent litigation events, and to compare them to market reactions at patent birth. The primary result is that the resolution of uncertainty is as valuable to the firm as the initial patent grant (which is subject to uncertainty). If the sample is at all representative, then this result is an indication that there may be a significant amount of legal uncertainty created by the patent system. For some models, merely the conclusion of a case is worth a 1% return, similar in magnitude to the original patent grant.

Additionally, we find that firms can expect validity rulings whether the patent is owned by the plaintiff or defendant. This result is important because patent validity is one source of asymmetry of stakes, which is very important in the literature on selection effects in litigation.⁹⁵ If a patent-holder expects to face a decision on validity, then the opportunity cost of an invalid patent (that affects negotiations with all potential licensees) becomes a significant litigation cost (near -1.5% return in our estimates). On the other hand, a win on validity has a similarly asymmetric upside. However, since returns to validity decisions are similar to returns on infringement decisions, it may be that a ruling on infringement can lead to similar asymmetry.

One important caveat bears mention about the results: they are conditional on litigation, and because selection effects are well-known, this sample is not random. As litigated patents represent a significant population of valuable patents, however, the results are nevertheless important. If valuable patents are subject to uncertainty about validity and infringement, then resolving that uncertainty is important to patent holders, and leaving such uncertainty unresolved reduces patent value as well as rewards to innovation.⁹⁶ Perhaps this is warranted: it may be that the patenting authorities wish to accommodate some uncertainty in the

⁹⁵ See, e.g., Alan C. Marco, *The Selection Effects (and Lack Thereof) in Patent Litigation: Evidence from Trials*, 4 B.E. J. ECON. ANALYSIS & POL'Y: TOPICS ECON. ANALYSIS & POL'Y 1 (2004); Priest & Klein, *supra* note 75; Waldfogel, *supra* note 75.

⁹⁶ Mark A. Lemley & Carl Shapiro, *supra* note 4, at 75.

system,⁹⁷ but where uncertainty in the patent system is unintentional, a consequent reduction in patent value is likely to be sub-optimal.

Legal uncertainty, therefore, remains a potentially powerful policy lever in the patent system.⁹⁸ The growing literature on patent litigation observes that uncertainty tends inherently to be high in emerging technology areas and in emerging patenting areas, such as software.⁹⁹ Indeed, it may be precisely those areas where policymakers should allow uncertainty to persist—or, conversely, allow rewards to be low—in order that, as cases are litigated, and the pertinent legal environment is clarified, both uncertainty and reward may reach a sustainable equilibrium. In this regard, it is not the scale of our quantitative findings that carries greatest weight, but rather our showing that uncertainty in the value of patent rights is quantifiable and thus amenable to economically meaningful analysis and policy development.

⁹⁷ Iain Cockburn et al., *Are All Patent Examiners Equal? The Impact of Examiner Characteristics on Patent Statistics and Litigation Outcomes* (Nat'l Bureau Econ. Res. Working Paper No. 8980, 2002), <http://www.nber.org/papers/w8980>.

⁹⁸ Marco, *supra* note 2, at 346–48.

⁹⁹ See, e.g., Jason Schultz & Jennifer M. Urban, *Protecting Open Innovation: The Defensive Patent License As a New Approach to Patent Threats, Transaction Costs, and Tactical Disarmament*, 26 HARV. J.L. & TECH. 1, 3 (citing commentary that characterizes software patents as being “overbroad, weak, and indeterminate in scope”).

Figure 1: Cumulative abnormal returns at time of patent application, by subsequent validity status

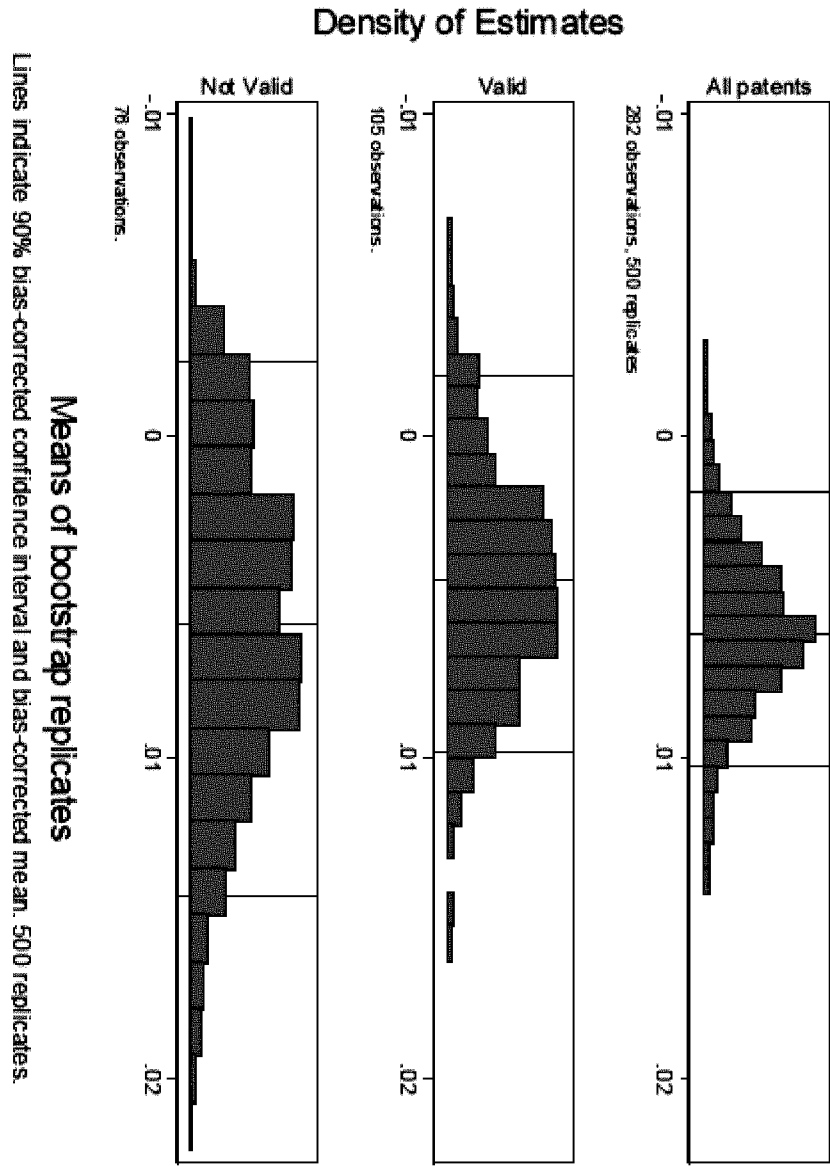


Figure 2: Cumulative abnormal returns at time of patent application, by subsequent infringement status

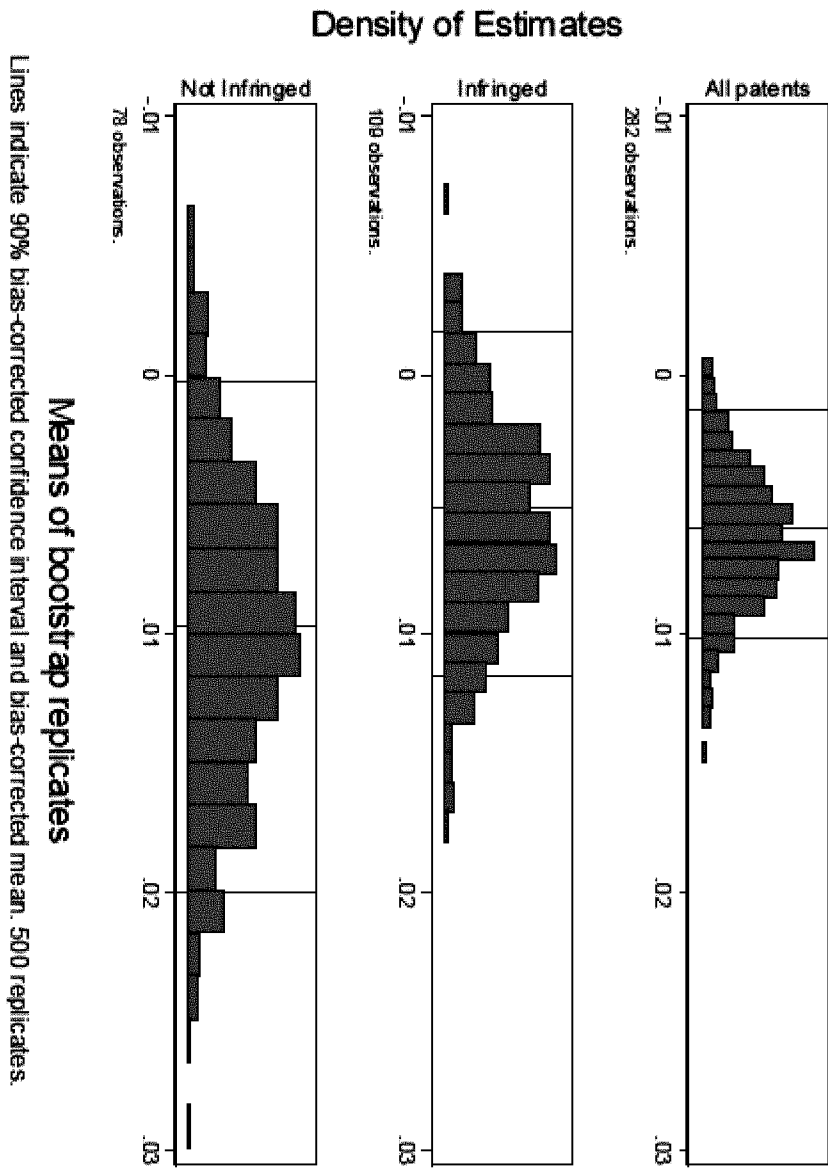


Figure 3: Cumulative abnormal returns at time of adjudication, by disposition

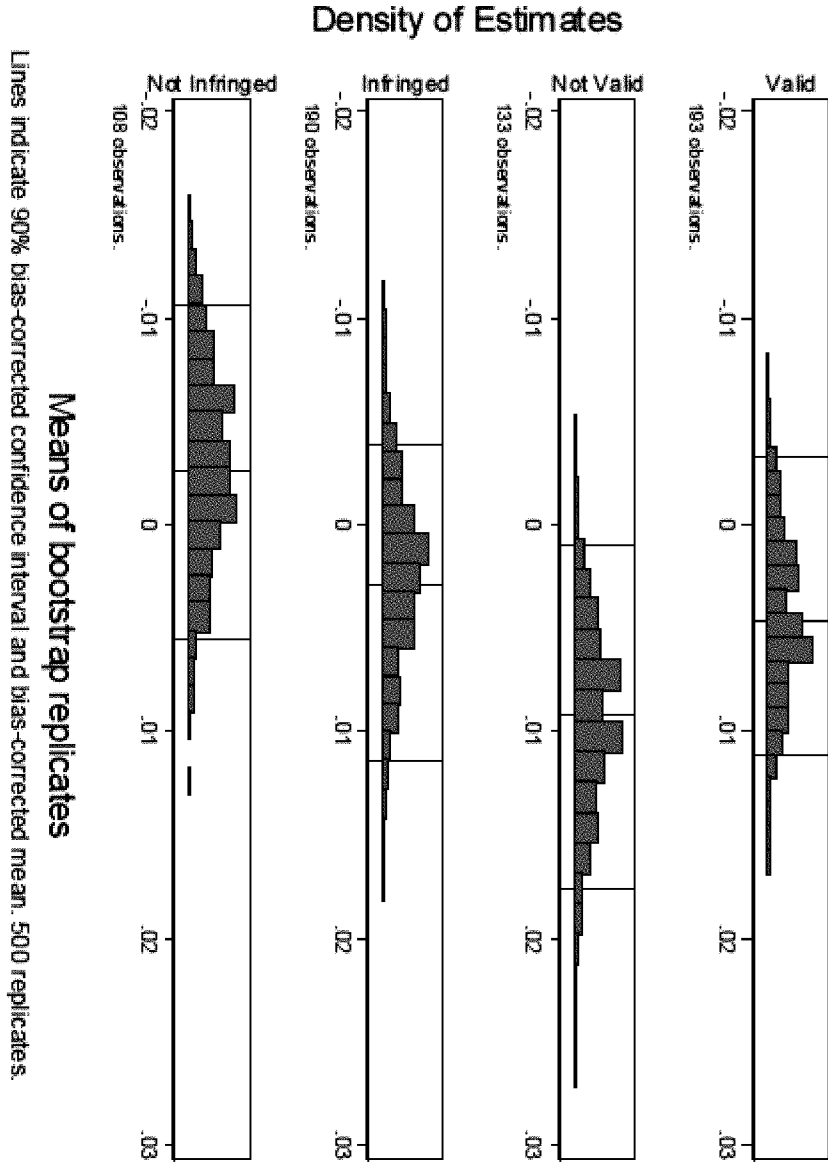


Table 1: Frequency of litigation for patents and firms

| | Total | Filed | Decided |
|------------------|---------|-------|---------|
| Firms | 2,699 | 568 | 158 |
| Patents | 417,735 | 1,252 | 413 |
| Cases | | | 390 |
| Patent-decisions | 2,252 | | 610 |

Table 2: Comparison of subsamples

| | | | |
|-------------------------|-----|-----|---------------------------|
| District Court | 277 | 198 | Appellate Court |
| 1982 and before | 125 | 350 | After 1982 |
| Plaintiff patentee | 427 | 48 | Defendant patentee |
| Single patent decisions | 209 | 266 | Multiple patent decisions |
| Valid | 193 | 133 | Not Valid |
| Infringed | 190 | 108 | Not Infringed |

475 observations total.

Table 3: Excess returns at time of patent grant, mean and confidence interval

| Event Window (days) | Obs | Application Date | | | Issue Date | | | Sum | | |
|------------------------|-----|------------------|-------|-------|---------------------------|--------|-------|-------|-------|-------|
| | | mean | 10% | 90% | mean | 10% | 90% | mean | 10% | 90% |
| 2 | 283 | 0.01 | -0.26 | 0.28 | (in percentage terms) | | | | | |
| 3 | 282 | 0.19 | 0.19 | 0.52 | -0.36 | -0.64 | -0.07 | -0.35 | -0.73 | 0.04 |
| 5 | 282 | 0.61 | 0.18 | 1.03 | 0.05 | -0.34 | 0.44 | 0.23 | -0.27 | 0.74 |
| 7 | 282 | 0.46 | 0.02 | 0.90 | 0.03 | -0.52 | 0.59 | 0.64 | -0.10 | 1.38 |
| 9 | 282 | 0.95 | 0.41 | 1.50 | -0.04 | -0.85 | 0.76 | 0.42 | -0.56 | 1.39 |
| 11 | 282 | 1.44 | 0.88 | 2.01 | 0.33 | -0.56 | 1.22 | 1.29 | 0.16 | 2.41 |
| bootstrap | 282 | 0.59 | 0.14 | 1.00 | 0.79 | -0.06 | 1.65 | 2.24 | 1.17 | 3.31 |
| | | | | | 0.08 | -0.41 | 0.89 | 0.76 | -0.13 | 1.59 |
| | | | | | (in thousands of dollars) | | | | | |
| bootstrap | 282 | 28119 | 746 | 55444 | 1499 | -17068 | 23255 | 30158 | -1501 | 58861 |

Observations restricted to those with both application date and issuance date data.
2 day window is day zero and day +1. All other windows are centered on day zero.
Bootstrap estimates are bias-corrected, replicates draw from all windows.

Table 4: Excess returns at time of patent grant, mean and confidence interval, by disposition

| Sample | Application Date | | | | Adjudication Date | | | |
|---------------|------------------|------|-------|------|-------------------|-------|-------|------|
| | obs | mean | 10% | 90% | obs | mean | 10% | 90% |
| All | 282 | 0.62 | 0.19 | 1.08 | -- | -- | -- | -- |
| Valid | 105 | 0.46 | -0.17 | 1.06 | 193 | 0.44 | -0.21 | 1.23 |
| Not Valid | 76 | 0.59 | -0.10 | 1.56 | 133 | 0.95 | 0.11 | 1.98 |
| Infringed | 109 | 0.53 | 0.11 | 0.91 | 190 | 0.28 | -0.54 | 1.05 |
| Not Infringed | 78 | 0.99 | -0.01 | 1.96 | 108 | -0.28 | -0.99 | 0.55 |

Bootstrap estimates are bias-corrected; replicates draw from all windows.

Table 5: Effects of case disposition on firm value

| Variable | [1] CAR2 EM | | | [2] CAR EM/bootstrap | | | [3] CAR EM/RE/bootstrap | | | [4] ln(dollars) EM/RE/bootstrap | | |
|---------------|-------------------|------------------|--|----------------------------|----------------|--|-------------------------------|-----------------------|--|---------------------------------------|-----------------------|--|
| | Coef. | 90% conf. int. | | Coef. | 90% conf. int. | | Coef. | 90% conf. int. | | Coef. | 90% conf. int. | |
| Valid | 0.63 (0.49) | -0.08 1.54 | | 0.44 (0.53) | -0.40 1.33 | | 1.59 (0.80) | ** 0.28 3.06 | | 1.28 (1.39) | -0.91 3.77 | |
| Not Valid | 0.59 (0.35) | * -1.25 -0.08 | | -0.52 (0.46) | -1.29 0.23 | | -1.43 (0.68) | ** -2.99 -0.40 | | -3.29 (1.28) | *** -5.72 -1.20 | |
| Infringed | 0.53 (0.50) | -1.54 0.10 | | -0.31 (0.53) | -1.23 0.52 | | -0.78 (0.73) | -1.97 0.37 | | 0.01 (1.39) | -2.24 2.47 | |
| Not Infringed | 0.15 (0.36) | -0.76 0.40 | | 0.09 (0.48) | -0.67 0.90 | | -1.79 (0.62) | *** -2.60 -0.78 | | -0.92 (1.42) | -3.34 1.30 | |
| Constant | 0.27 (0.34) | -0.29 0.83 | | 0.23 (0.42) | -0.45 0.90 | | 0.83 (0.52) | * 0.01 1.83 | | 0.80 (1.05) | -0.86 2.60 | |
| Sigma e | — | | | — | | | 1.35 | | | 2.78 | | |
| Sigma u | — | | | — | | | 2.83 | | | 4.75 | | |
| Rho | — | | | — | | | 0.82 | | | 0.74 | | |
| Chi2 | — | | | — | | | 280 | | | 133 | | |
| F | 2.21 | | | 9.69 | | | — | | | — | | |
| R2 overall | 0.010 | | | 0.010 | | | 0.012 | | | 0.019 | | |
| Observations | 475 | | | 475 | | | 475 | | | 475 | | |
| Replications | 1000 | | | 1000 | | | 1000 | | | 1000 | | |

Bootstrapped SE in parenthesis. Bias-corrected confidence intervals used to calculate significance level.

* indicates $p < 0.1$, ** indicates $p < 0.05$, *** indicates $p < 0.01$.

All coefficients and confidence intervals are bias-corrected.

Table 6: Excess returns to adjudication: interaction terms

| Variable | [1] CAR | | [2] CAR | |
|---------------|---------------------|---------------|--------------------|---------------|
| | EM/RE/Bootstrap | | EM/RE/Bootstrap | |
| | Coef | 90% conf int. | Coef | 90% conf int. |
| Valid | 1.59 ** (0.80) | 0.28 3.06 | 3.44 *** (1.23) | 1.31 5.79 |
| Not Valid | -1.43 ** (0.68) | -2.99 -0.40 | -0.60 (0.96) | -2.43 0.92 |
| Infringed | -0.78 (0.73) | -1.97 0.37 | 0.34 (1.34) | -1.68 2.76 |
| Not Infringed | -1.79 *** (0.62) | -2.60 -0.78 | -0.57 (0.99) | -2.28 0.95 |
| V/I | – | | -2.13 (1.66) | -5.90 0.51 |
| V/NI | – | | -4.93 ** (1.90) | -8.70 -1.83 |
| NI/V/I | – | | -3.45 (3.44) | -8.12 1.80 |
| NI/V/NI | – | | -0.18 (1.47) | -2.64 2.16 |
| Constant | 0.83 * (0.52) | 0.01 1.83 | -0.05 (0.74) | -1.23 1.14 |
| Sigma e | 1.35 | | 1.33 | |
| Sigma u | 2.83 | | 2.83 | |
| Rho | 0.82 | | 0.82 | |
| Chi2 | 280 | | 530 | |
| R2 overall | 0.012 | | 0.021 | |
| Observations | 475 | | 475 | |
| Replications | 1000 | | 1000 | |

Bootstrapped SE in paranthesis. Confidence intervals used to calculate significance.

* indicates $p < 0.1$, ** indicates $p < 0.05$, *** indicates $p < 0.01$.

All coefficients and confidence intervals are bias-corrected.

Table 7: Adjudications pre- and post-1982

| Variable | [1] | | [2] | |
|---------------|---------------------|----------------|--------------------|----------------|
| | Pre-1982 | | Post-1982 | |
| | Coef. | 90% conf. int. | Coef. | 90% conf. int. |
| Valid | 3.31 * (2.01) | 0.01 6.51 | 2.21 *** (0.85) | 0.90 3.90 |
| Not Valid | -0.93 (2.01) | -4.22 2.45 | -1.32 * (0.88) | -3.89 -0.12 |
| Infringed | -4.09 ** (1.57) | -6.95 -1.54 | -0.60 (0.88) | -2.04 0.80 |
| Not Infringed | -5.40 *** (1.27) | -7.96 -3.40 | -1.18 * (0.79) | -2.96 -0.02 |
| Constant | 1.50 (1.88) | -1.99 4.32 | 0.41 (0.61) | -0.52 1.55 |
| Sigma e | 0.80 | | 1.28 | |
| Sigma u | 3.13 | | 2.84 | |
| Rho | 0.94 | | 0.83 | |
| Chi2 | 716 | | 293 | |
| R2 overall | 0.009 | | 0.028 | |
| Observations | 125 | | 350 | |
| Replications | 1000 | | 1000 | |

Bootstrapped SE in paranthesis. Confidence intervals used to calculate significance.

* indicates $p < 0.1$, ** indicates $p < 0.05$, *** indicates $p < 0.01$.

All coefficients and confidence intervals are bias-corrected.

Table 8: Defendant and plaintiff patentees

| Variable | [1] | | [2] | |
|---------------|--------------------|----------------|--------------------|----------------|
| | Plaintiff patentee | | Defendant patentee | |
| | Coef. | 90% conf. int. | Coef. | 90% conf. int. |
| Valid | 1.67 ** (0.92) | 0.32 3.85 | -0.34 (1.14) | -2.23 1.45 |
| Not Valid | -1.47 * (0.81) | -3.84 -0.16 | -2.67 (1.65) | -5.37 0.12 |
| Infringed | -0.93 (0.94) | -2.72 0.47 | 1.22 * (0.67) | 0.15 2.31 |
| Not Infringed | -1.31 * (0.78) | -3.32 -0.15 | -1.70 ** (1.02) | -3.81 -0.29 |
| Constant | 0.72 (0.68) | -0.37 2.29 | 1.77 ** (0.94) | 0.35 3.45 |
| Sigma e | 1.36 | | 0.76 | |
| Sigma u | 2.51 | | 4.34 | |
| Rho | 0.77 | | 0.97 | |
| Chi2 | 243 | | 95 | |
| R2 overall | 0.026 | | 0.001 | |
| Observations | 427 | | 48 | |
| Replications | 1000 | | 1000 | |

Bootstrapped SE in paranthesis. Confidence intervals used to calculate significance.

* indicates $p < 0.1$, ** indicates $p < 0.05$, *** indicates $p < 0.01$.

All coefficients and confidence intervals are bias-corrected.