Essays on Patents and Patent Litigation

by

Thomas P. McGahee

(Under the direction of John L. Turner)

Abstract

Patents offer a unique window into the often abstract world of innovation because patented inventions leave a detailed paper trail. In this dissertation, I first show that the typical patent is actually of negligible value. I examine the relationship between market value and the patent yield from R&D and find that an additional patent per million dollars of R&D results in less than one tenth of a one percent increase in market value for the average firm in the manufacturing sector. Yet some patents are extremely valuable. For firms in the drugs and medical industry, the effect on market value of an additional patent per million dollars of R&D is nearly one-hundred times as large as that for the average firm. This contrast highlights the vast differences in value across patents with different characteristics. I argue that economists who study patent data must use any available signals of patent value to inform their research.

One such signal is involvement in litigation. In the second essay, I study citations to litigated patents to shed light on geographic patterns of knowledge flows for important inventions. Compared to a group of control patents, citations to litigated patents tend to be more local to both the inventor's state and to the trial state. Inventor-state localization rates for litigated patents are large and do not fade across time. Trial-state localization effects may increase with the onset and the conclusion of litigation; inventor-state localization effects do not. Also, litigation tends to geographically "follow" citations.

In the third essay, I study patent enforcement over the course of several decades and test the responses of litigation risk, duration, and outcomes to various patent characteristics and to significant changes in patent policy and precedent. I find that litigated patents differ significantly from typical patents in several observable ways. I also find that several patent characteristics are systematically related to the duration and outcome of litigation. With respect to patent policy and precedent changes, I find that "flash of genius" era litigation is disproportionately difficult for corporate patentees in terms of duration but not necessarily in outcomes. The Patent Act of 1952 realigns the duration of litigation for corporate and individual patentees but invites a rash of submarine patenting behavior.

INDEX WORDS: patents, patent litigation, patent citations, innovation, research, market value, knowledge flows

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B.A., The University of Georgia, 2002

A Dissertation Submitted to the Graduate Faculty
of The University of Georgia in Partial Fulfillment
of the
Requirements for the Degree

Doctor of Philosophy

Athens, Georgia

2011

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Acknowledgments

I owe a debt of gratitude to Dr. John Turner for his advice and support throughout my graduate study and research. I am also grateful for his invitation to assist with National Science Foundation grant SES-0751661 and for access to the original set of patent litigation data which he and Matthew Henry assembled. I would like to thank Dr. David Mustard and Dr. Scott Atkinson for their time and guidance as members of my committee. I would also like to thank the faculty of the Department of Economics for challenging me and supporting me throughout my time at the University of Georgia. Finally, I would like to thank my fellow students and colleagues for their encouragement and friendship. In particular, Lee Hu, Adam Jones and Neil Meredith made the journey much more fun than it might otherwise have been.

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Chapter 1

Introduction and Literature Review

Inventive activity is a key driver of economic growth (Solow 1957). Measuring the output of such activity has proven challenging, as created knowledge does not leave a "paper trail" carefully describing its size and scope the way physical and financial capital does (Krugman 1991). Patents offer a unique window into the often abstract world of inventive activity because patented inventions leave a very detailed paper trail. Economists use the rich data available in patent documents to test theories of economic growth, industrial organization, and law and economics. Patent data are useful for studying the private and social returns to R&D spending, the nature and geography of knowledge spillovers, strategic interaction between innovators and potential infringers, and the hazard and costs of patent litigation. In this dissertation, I make three important contributions to the study of patents and patent litigation.

In Chapter 2, I show that the typical patent is actually of negligible value. I examine the relationship between market value and the patent yield from R&D and find that an additional patent per million dollars of R&D results in less than one tenth of a one percent increase in market value for the average firm in the manufacturing sector. Yet some patents are extremely valuable. For firms in the drugs and medical industry, the effect on market value of an additional patent per million dollars of R&D is nearly one-hundred times as large as that for the average firm. Of course, valuable patents are not confined to the drugs and medical industry, but this contrast highlights the vast differences in value across patents with different characteristics. Rather than ignoring these differences, it is imperative that economists who study patent data use any available signals of patent value to inform their research. One such signal is the number of subsequent patents that cite a given patent as prior art. Trajtenberg (1990) estimates that social surplus gains from the invention and improvement of CT scanners are not correlated with simple patent counts but are strongly correlated with citation-weighted patent counts. Hall, Jaffe, and Trajtenberg (2005) estimate that an additional citation per patent in a firm's patent portfolio increases market value by nearly three percent, a result I confirm in this dissertation. Thus, counting the number of subsequent patents that cite a given patent produces a useful measure of its social and private value. Note, however, that each citing patent counts equally in the computation of that measure. Thus, the problem of assigning value to a patent is not solved but rather pushed onward to that patent's descendants. Leiva (2007) suggests tracing citation "trees" to measure patent value, using citations received by a patent, citations to those citations, and so on. He finds that such estimates of patent value are more consistent with those obtained from surveys of inventors (e.g. Harhoff et al. 2003; Sanders et al. 1958) than are estimates based on simple citation counts. Bessen (2008) offers evidence from a different source, patent renewal data, that citation counts may be a poor indicator of a patent's value. In contrast, however, he finds that involvement in litigation is a strong signal that a patent is valuable. He estimates that, all else equal, litigation signals that a patent is six times more valuable than a similar unlitigated patent. Patent litigation, as a signal of value, is therefore a potential solution to the problem I describe in Chapter 2: the typical patent is nearly worthless, and researchers have few useful criteria to separate the relatively few valuable patents from the rest.

In Chapter 3, I present an application of the use of litigation as a signal of patent value. Jaffe, Trajtenberg and Henderson (1993) use patent citation data to show that knowledge spillovers generated by an invention tend to be disproportionately local to the inventor even after controlling for industrial agglomeration. That is, geography plays a role in coordinating cumulative technological innovation. However, their study chooses a random sample of patents without conditioning on any measure of patent value. Because the typical patent is of negligible value, it is not surprising that the few forward citations it receives tend to be geographically local. In this study, I question whether the same geographic localization of knowledge flows is evident for patents known to be of economic significance. Surprisingly, I find that knowledge flows from inventions represented by litigated patents have at least as strong a tendency to be localized as those studied by Jaffe, Trajtenberg and Henderson. I also find, in contrast to their results, that this localization does not fade over time for litigated patents. This is the first evidence that for very valuable patents, the localization of knowledge spillovers is strong and persistent. This study is just one example of how litigation can be exploited as a signal of patent value to ensure that studies of technological change and innovation are conducted, when appropriate, on patents that matter.

The vast majority of patents are never the subject of a legal dispute. Lanjouw and Schankerman (2001) estimate that only 10.7 patent suits are filed for every 1,000 issued patents during 1980–1984. Certainly even the filing of a suit signals that a patented invention is at least important or influential enough to cause a dispute. Most are not. On the other hand, in recent years nearly 30 percent of patents in cases litigated to a decision are found invalid. How can litigation be a signal of value if 30 percent of litigated patents are essentially declared unenforceable? This dilemma reveals the necessity of distinguishing between the private value of a patent and the importance or social value of the underlying invention. For every litigated patent found to be invalid by the court, there are surely an untold number of undisputed patents which might be found invalid were they economically significant enough to cause a dispute. Thus, involvement in a dispute signals that a patent covers a relatively important invention regardless of the dispute's outcome. However, the extent to which an invention's importance or influence translates into *private value* for an inventor depends on the inventor's ability to enforce his patent rights in court—to "win." For the study of knowledge spillovers, the relevant requirement is economic significance or social value. Such a study examines the dissemination of knowledge from important inventions to others who produce cumulative innovation. For other applications, it may be more useful to condition the sample on patents revealed not only to be of economic significance but also to be of great private value.

In Chapter 4, I study patent enforcement over the course of several decades and test the responses of litigation risk, duration, and outcomes to various patent characteristics and to significant changes in patent policy and precedent. This essay constitutes a first look at the characteristics of a set of patents litigated to a court decision between 1929 and 2006. The data set is a descendent of the 1953-2002 data used by Henry and Turner (2006) and benefits from the recent work of those authors and myself to extend the data back to 1929 and forward to 2006. I compare litigated patents to a "matched" set of control patents and find that litigated patents differ significantly from typical patents in several observable ways. I also find that several patent characteristics are systematically related to the duration and outcome of litigation. With respect to patent policy and precedent changes, I begin with the "flash of genius" precedent set in *Cuno Engineering Co. v. Automatic Devices Co.*, 314 US 84 (1941). I find that "flash of genius" era litigation is disproportionately difficult for corporate patentees in terms of duration but not in outcomes. Prior research shows that rates of invalidity rose significantly in that era (Baum 1974; Webb 1957), but this study is the first to test for disproportionate effects for corporate patentees. Israel (2006) provides a review of political and legal commentary in the years following the *Cuno* decision. He provides compelling evidence of anti-corporate sentiment among appellate judges and Supreme Court justices in that era. In July of 1952, Congress passed the Patent Act of 1952, which served to revise and codify the laws relating to patents. Section 103 was widely interpreted to codify the earlier "skilled mechanic" test described in *Hotchkiss v. Greenwood*, 52 US 248 (1850), and to eliminate the "flash of genius" test from *Cuno*. I find that the Patent Act of 1952 realigns the duration of litigation for corporate and individual patentees but invites a rash of submarine patenting behavior. Graham (2009) describes the prevalence of application continuations among recent patents and describes three strategic uses. I find evidence that continuations are used more often by submarining applicants with litigious intent than by pioneers or defensive portfolio builders. The friendly stance towards continuations taken in the Patent Act of 1952 and in its interpretation brought about the widespread use of continuations among all U.S. patents but particularly among patents eventually litigated. Recent changes in U.S. patent policy may prove effective at reducing submarine patenting behavior, but it is yet too early to gauge their effectiveness. Submarine patenting remains a challenge to the economic premise of the patent system that 21st century patent policy must be sure to overcome.

Chapter 2

Patents, Citations and Market Value: A Reassessment[1]

[1]McGahee, Thomas P. To be submitted to the *Review of Economics and Statistics*.

2.1 Introduction

What do patent statistics measure? Griliches (1990) explores this question and wrestles with the inadequacy of patent counts as a measure of innovative output. He points to the work of Pakes (1985), who finds that, holding R&D spending constant, an additional patent application has no significant effect on a firm's market value. Griliches views the work of Trajtenberg (1990) as offering a better measure of innovative output, the number of subsequent patent citations received by a firm's patents. Trajtenberg estimates that social surplus gains from the invention and improvement of CT scanners are not correlated with simple patent counts but are strongly correlated with citation-weighted patent counts. Hall, Jaffe and Trajtenberg (2005) use patent citation data to study private returns to innovative activity. Their central result is that an additional citation per patent in the average firm's patent portfolio increases that firm's market value by 3%. However, they also find that a simple one-patent increase in the patent yield from R&D causes a 2% increase in market value. This result stands in contrast to Pakes (1985) and suggests that simple patent counts do in fact contain information about the success of innovative activity.

I re-examine the data and method Hall, Jaffe and Trajtenberg use to produce this result, and I find that a mistake in their approach causes them to significantly overestimate the importance of simple patent counts for explaining market value. In contrast to their results, I find that an additional patent per million dollars of R&D leads to less than one tenth of a one-percent increase in market value for the average firm. As an exception, I find that patents have a significantly larger effect on market value for firms in the drugs and medical industry, even larger than the effect Hall, Jaffe and Trajtenberg estimate for such firms. The effect of an additional drug patent per million dollars of R&D is one-hundred times that of an average patent.

This paper proceeds in Section 2.2 with a description of the data and the corrections I make to them. In Section 2.3, I review the model. In Section 2.4, I present the empirical results with and without the corrections in place. I then estimate corrected industry-specific effects in Section 2.5. I conclude in Section 2.6 with some implications of these results.

2.2 Data

The data I use below are publicly available on Bronwyn Hall's web site.[2] The data set contains patent-specific data, including technological class and forward-citations, from an early version of the NBER Patent Citations Data File (Hall, Jaffe and Trajtenberg 2001) matched to firm-specific data from Compustat, including market value, assets, and R&D expenditures. The patent data include all U.S. patents granted from 1965 to 1996 and all citations they received from 1976 to 1996. 50-65% of those patents assigned to corporations in the U.S. are successfully matched to firms in a 1976-1995 sample of Compustat data on publicly traded firms in the manufacturing sector (SIC 2000-3999). In total, 4,864 firms and 573,000 patents are represented in the matched data.

For a number of reasons, Hall, Jaffe and Trajtenberg (2005) focus on a ten-year period of data in the middle of the sample, from 1979-1988. These are the years for which their three measures of the value of innovation are most accurate. They build these measures by computing running stocks of R&D expenditures, patent applications, and subsequent citations to those patents, with each stock subject to a 15% depreciation rate. Beginning the analysis in 1979 allows the patent stock to rely on several years of prior history and allows the R&D stock a few prior years to begin accumulating. Restricting the analysis to 1988 and earlier leaves several later years for patents applied for during the period of interest to be granted. In these data, patents are counted by application year but not observed until they are granted. The typical patent spends about two years between application and grant. In addition, defining this period of interest leaves even the newest patents several years to accumulate observable citations.

[2] http://www.econ.berkeley.edu/~bhhall

All citations enter the citations stock in the cited patent's application year and thus serve to indicate the value or importance of a firm's patents that year. However, each citation is only observed once the citing patent is granted. Thus, citation counts to patents from different years are truncated at different ages in 1996. To correct for this truncation, Hall, Jaffe and Trajtenberg estimate the shape of a population "citation-lag distribution" assumed to be stationary across time and independent of overall citation intensity. They divide a citation count truncated at a particular age by the fraction of lifetime citations expected to be received by that age. Thus, citation counts used in this analysis can be interpreted as counts of lifetime citations. This procedure and the estimated citation-lag distribution are described in Hall, Jaffe and Trajtenberg (2001).

Following Hall, Jaffe and Trajtenberg (2005), I restrict attention to firms that obtain at least one patent during the period 1975-1988, allowing for the construction of a patent stock and a citation stock. Thus, the final sample includes domestic, publicly-traded, patenting firms in the manufacturing sector, observed from 1979 to 1988. There are 1,921 such firms and a total of 12,118 firm-year observations.

Table 2.1 contains descriptive statistics for the sample. All variables denoted in dollars are adjusted for inflation to 1992 dollars. Market value is the sum of equity and debt observed at the close of the year. The mean market value is about $916 million, while the median is just $77 million. Book value is the sum of net plant and equipment, inventories, and investments, and like market value, it is extremely skewed with a mean of $914 million and median of $65 million. The ratio of market value to book value is Tobin's q and has a mean of 1.735 and median of 1.092. The stocks of R&D, patents, and citations are also skewed with means well above their medians.

These data are used to compute three measures of innovation. R&D/Assets is the ratio of the stock of R&D expenditures to book value, a measure of R&D intensity. Patents/R&D is the "patent yield" of R&D, potentially offering information about the success of an R&D program. Of course, the distribution of value across patents is extremely skewed (Scherer

1965; Pakes and Schankerman 1984). However, the number of subsequent citations a patent receives may offer information about its private and social value (Harhoff et al. 1999; Trajtenberg 1990). Thus, Citations/Patents, the ratio of citations stock to patent stock may offer additional information about the success of a firm's innovative efforts.

Of course, Patents/R&D is undefined for observations with R&D stock equal to 0. It is in their treatment of this variable that Hall, Jaffe and Trajtenberg (2005) make a critical mistake. Those authors describe setting this variable to 0 when a firm has no R&D stock. They introduce a dummy for R&D stock equal to 0 for use in regressions to estimate the effect on market value of being a firm with patents but no R&D. The use of similar R&D dummies to solve specification problems is common in this line of research (e.g. Bound et al. 1984), but the mistake here is that Hall, Jaffe and Trajtenberg (2005) confuse the stock of R&D with the flow of R&D. A careful investigation of the data set reveals that the Patents/R&D variable is mistakenly set to 0 for any observation with no *flow* (current expenditure) of R&D, even for observations in which the *stock* of R&D is positive. There are 974 observations in which the flow of R&D is equal to 0 but the stock of R&D is positive, consisting solely of depreciated R&D expenditures from prior years. I correct the Patents/R&D variable by reassigning to it the true ratio of patent stock to R&D stock for these 974 observations. This correction to Patents/R&D raises the mean from 1.248 to 4.475 and the median from .507 to .679 for the 10,158 observations with positive R&D stock. The ratios of R&D/Assets and Citations/Patents are unaffected.

2.3 Model

How do these three measures of a firm's innovative activity relate to its market value? Hall, Jaffe and Trajtenberg (2005) base their model on the market value function defined by Griliches (1981). The model is

$$V_{it} = q_t(A_{it} + \gamma K_{it})$$

where V_{it} denotes market value of firm i at time t, A_{it} physical assets, and K_{it} intangible knowledge assets. q_t is the marginal shadow value of these assets, equalized across firms. γ measures the shadow value of knowledge assets relative to physical assets. Dividing through by A_{it} and taking logarithms yields the estimating equation:

$$\log Q_{it} = \log\left(\frac{V_{it}}{A_{it}}\right) = \log q_t + \log\left(1 + \gamma\frac{K_{it}}{A_{it}}\right) + \epsilon_{it}$$

where Q_{it} is Tobin's q. Hall, Jaffe and Trajtenberg (2005) model knowledge assets with the three measures described above. R&D/Assets measures R&D intensity, Patents/R&D measures the number of patents that result from the firm's R&D, and Citations/Patents contains information about the value of those patents. The estimating equation becomes:

$$\log Q_{it} = \log q_t + \log\left(1 + \gamma_1\frac{R\&D_{it}}{A_{it}} + \gamma_2\frac{PAT_{it}}{R\&D_{it}} + \gamma_3\frac{CITES_{it}}{PAT_{it}}\right) + \epsilon_{it} \tag{2.1}$$

where $R\&D$, PAT, and $CITES$ denote stocks of R&D, patents, and citations.

2.4 Estimation

Using nonlinear least squares, I estimate three variants of equation (2.1), each including year dummies and a dummy for those observations in which the stock of R&D is equal to 0, requiring Patents/R&D to be set to 0. The first specification includes just R&D/Assets and Patents/R&D. The second adds Citations/Patents. The third replaces Citations/Patents with dummies for various ranges of citations received per patent. I estimate each specification first using the uncorrected data to replicate the work of Hall, Jaffe and Trajtenberg (2005) and then with my corrections to the Patents/R&D variable in place. The results are presented in Table 2.2. Columns of corrected results are denoted with the letter c in addition to the specification number.

The corrected results are similar to the original estimates except for one clear difference. The coefficient on Patents/R&D collapses from between .025 and .030 down to .001 in each estimation. Though still statistically significant, the corrected coefficients reveal that the

Patents/R&D ratio plays a much smaller role in explaining market value than the uncorrected estimates suggest. Estimated coefficients on R&D/Assets remain large and statistically significant across specifications. The estimated coefficients for the Citations/Patents ratio and for the various dummies for 5−6, 7−10, 11−20, and over 20 citations per patent remain nearly unchanged after correction. Compared to the base category of receiving 0−4 citations per patent, there is no effect on market value of receiving 5−6, but receiving 7 or more increases market value by at least 10%. Receiving 11−20 citations per patent raises market value by 36%, and receiving more than 20 citations per patent leads to a 55% increase in market value.

To interpret the estimated coefficients in Table 2.2, Columns 2 and 2c, for the three ratios of interest, R&D/Assets, Patents/R&D, and Citations/Patents, I compute semi-elasticities of Tobin's q with respect to each of these variables,

$$\frac{\partial \log Q}{\partial (R\&D/A)} = \hat{\gamma}_1 \left(1 + \hat{\gamma}_1 \frac{R\&D}{A} + \hat{\gamma}_2 \frac{PAT}{R\&D} + \hat{\gamma}_1 \frac{CITES}{PAT} \right)^{-1}$$

and similarly for $PAT/R\&D$ and $CITES/PAT$. I report the results in Table 2.3, first from the uncorrected data and then with the corrections in place. The uncorrected results suggest that an additional patent per million dollars of R&D increases market value by 1.58% at the mean of the data and by 1.95% at the median. The corrected data reveal that such an increase in a firm's patent yield actually only increases market value by less than one tenth of one percent. That is, given R&D spending, simple patent counts add almost no useful information for explaining market value. The correction does not change the estimated effects of R&D/Assets or Citations/Patents on market value. An increase of one percentage point to a firm's R&D intensity increases market value by about .8%. An additional citation per patent increases market value by about 3%. Taken together, these results indicate that, after accounting for a firm's R&D spending, it is far more valuable for the firm's patent portfolio to be highly cited than for it to be large.

Suppose a firm files one additional patent application without any change to its R&D spending. At the mean of these data, where market value is $916 million, R&D stock is

$150 million, and patent stock is about 76, the uncorrected estimate of 1.58% above suggests that a single additional patent is worth about $96,000.[3] The corrected estimate of 0.07%, however, reveals that the value of the additional patent is actually only about $4,000. On the other hand, if that single additional patent receives just one citation more than average for that firm, market value increases by an additional $327,000.[4] Similarly if the additional patent receives one fewer citation than average, the firm's market value falls by $327,000. Considering the direct effect of $4,000 fairly negligible, these results indicate that, holding R&D constant, an additional patent application only affects a firm's market value to the extent that the quality of the additional patent is above or below average for that firm.

2.5 Industry-specific Effects

In Table 2.4, I present two additional specifications of the market value estimation which introduce industry-specific effects alongside the baseline estimates in Column 1. Column 2 includes dummies for the usual 6 industry sectors Hall, Jaffe and Trajtenberg (2001) suggest for use with the NBER patent data. They are Drugs and Medical, Chemical (excluding drugs), Computers and Communication, Electrical and Electronics, Metals and Machinery, and miscellaneous, low-tech industries. The results of this estimation for the uncorrected data are available in Table 5 of Hall, Jaffe and Trajtenberg (2005). My results confirm the high market premium for being in the Drugs or Computers sector as well as the decline in the coefficient on R&D intensity. Again, the primary difference in the corrected results is the collapse of the coefficient on the Patents/R&D ratio to .0011. In Column 3, I add interactions between the industry dummies and each of the other explanatory variables, R&D/Assets, Patents/R&D, Citations/Patents, and the R&D dummy. The effects of each ratio differ

[3] One additional patent increases Patents/R&D by 1/150,478,000. Market value increases by 916,326,000 $\times$ .0158 / 150,478,000 = 96,213.

[4] The estimated semi-elasticity with respect to Citations/Patents is .0275 at the mean. One citation more than average to one additional patent increases Citations/Patents by 1/77. Market value increases by 916,326,000 $\times$ .0275 / 77 = 327,259.

across industries. The estimate on patent yield increases only for Chemicals, rising to just .0066, and for Drugs and Medical, rising to a striking .2549.

For comparison to the semi-elasticities above, I compute that of market value with respect to Patents/R&D for firms in the Drugs and Medical industry. At the mean of the data for these firms, an additional patent per million dollars of R&D raises market value by 6.29%. At the median, the estimated increase is 8.63%, one hundred times the increase for the typical firm. Suppose a firm in the Drugs industry files one additional patent application without any change to its R&D spending. At the mean of the data for firms in that industry, where market value is $975 million, R&D stock is $213 million, and patent stock is 100, that additional patent increases market value by about $288,000. Thus, as an exception to the findings above for the typical firm, I find that patent applications are a useful measure of the success of R&D spending for firms in the Drugs industry. Furthermore, if the additional patent described above receives more citations than average for the firm, market value increases further still by $239,000 for each additional citation. Thus, both the size of a firm's patent portfolio and the quality of its patents have significant effects on market value for firms in the Drugs and Medical industry.

The estimates for the Computer industry are also interesting. The coefficient for R&D/Assets is just 0.25, compared to 1.35 for the average firm. The coefficient for Patents/R&D remains minimal, and that for Citations/Patents falls to .024, compared to .052 for the average firm. At the expense of these coefficients, the Computer industry dummy rises to indicate a 52% market value premium for being in the Computer sector, regardless of R&D, patents, or citations. While the coefficients on R&D, patents, and citations are relatively small, they are still statistically significant. For an alternative specification of the market value equation for computer hardware and software firms, see Hall and MacGarvie (2010). They estimate the changing effects of R&D, patents, and citations on market value from 1980−2002 and find that in more recent years, only R&D intensity remains an important predictor of market value for firms in this industry.

2.6 Conclusion

This paper serves to correct the results printed in Hall, Jaffe and Trajtenberg (2005). A careful examination of the data reveals that those authors make a critical mistake in their treatment of the Patents/R&D variable which leads them to seriously overestimate the importance of simple patent counts for explaining market value after controlling for R&D expenditures. R&D intensity remains an important determinant of market value, but patent applications are nearly useless as a measure of "success" for R&D spending. For the typical firm, I find that an additional patent per million dollars of R&D leads to less than one tenth of a one-percent increase in market value. This result is no doubt due to the well-known skewness of the distribution of value across patents. However, the citations a firm's patents receive are useful for measuring their value, and a firm's Citations/Patents ratio remains important to that firm's market value.

Holding R&D constant, an additional patent application only affects the typical firm's market value to the extent that the quality of the additional patent is above or below average for the firm. An additional patent application increases a firm's market value if that patent receives more citations than average. An additional patent decreases market value if it receives fewer citations than average. Thus, it is not the size of a firm's patent portfolio that counts but the quality of its patents.

As an exception to this rule, I find that the effect on market value of an additional patent per million dollars of R&D is one-hundred times larger for firms in the drugs and medical industry than for the average firm, raising market value by 6.3% at the mean. Patent quality as measured by citations remains important as well for these firms.

These results indicate that for most firms, citation-weighted patent counts may all but replace simple patent counts as measures of innovative output. Of course, patent citations may only be observed over the course of several years after an innovation occurs. Even the truncation adjustment developed by Hall, Jaffe and Trajtenberg (2001) requires a few years of data to produce accurate estimates of a patent's citation intensity. Thus, citation counts cannot be used to *predict* changes in market value. The connection between citation counts and market value serves instead to highlight how informative citations are for measuring the value of patents. After imposing my correction to the data, the need for such a measure of patent value is all the more apparent.

Table 2.1
Descriptive Statistics for Patenting Firms, 1979-1988

Variable	Mean	Median	Std. Dev.	Min.	Max.	N
Market value ($M)	916.326	77.409	3,669.628	.103	97,437.063	12,118
Book value ($M)	914.210	65.165	3,884.509	.185	84,902.000	12,118
Market-to-book value	1.735	1.092	2.122	.055	19.953	12,118
R&D stock ($M)[a]	179.512	11.709	885.580	.002	22,129.531	10,158
Patent stock	75.720	5.049	291.610	.033	5,085.173	12,118
Citations stock[b]	569.823	39.221	2,395.584	.003	51,300.586	12,007
R&D/Assets	.348	.157	.566	.000	4.995	12,118
Patents/R&D[a]	4.475	.679	29.769	.000	804.980	10,158
Citations/Patents	7.954	6.326	7.219	.000	222.227	12,118
Share of self-citations	.091	.056	.125	.000	1.000	12,118
D (R&D stock=0)	.162	.000	.368	.000	1.000	12,118
D (R&D flow=0)	.242	.000	.428	.000	1.000	12,118

[a] For observations with R&D stock $>$ 0

[b] For observations with Citations stock $>$ 0

Table 2.2
Market Value as a Function of R&D, Patents, and Citation Stocks

	1	1c	2	2c	3	3c
R&D/Assets	1.2743	1.2589	1.3624	1.3536	.9264	.9158
	(.0606)	(.0537)	(.0681)	(.0678)	(.0470)	(.0466)
Patents/R&D	.0268	.0010	.0303	.0013	.0253	.0010
	(.0062)	(.0004)	(.0072)	(.0005)	(.0056)	(.0004)
Citations/Patents			.0516	.0519		
			(.0038)	(.0038)		
Dummies for # of cites per patent:*						
5-6 (3,145 obs.)					.0057	.0075
					(.0180)	(.0181)
7-10 (3,993 obs.)					.0975	.1015
					(.0176)	(.0176)
11-20 (1,997 obs.)					.3531	.3572
					(.0231)	(.0232)
> 20 (573 obs.)					.5422	.5467
					(.0422)	(.0427)
D(R&D=0)	.0578	.0624	.0937	.0752	.0568	.0353
	(.0188)	(.0184)	(.0189)	(.0182)	(.0188)	(.0182)
R^2	.2213	.2183	.2544	.2519	.2554	.2523
Standard error	.6855	.6868	.6707	.6718	.6703	.6717

* Base category: 0-4 cites per patent, 2,410 observations.

Sample: 1921 patenting firms, 1979-88, 12,118 observations.

Nonlinear model with dependent variable: log Tobin's q.

Estimation method: nonlinear least squares.

All equations include a complete set of year dummies.

Heteroskedastic-consistent standard errors are shown in parentheses.

Table 2.3
The Effects of Innovative Activity on Market Value

Ratios evaluated at:	HJT Mean	Corrected Mean	HJT Median	Corrected Median
R&D/A	.3476	.3476	.1573	.1573
Pat/R&D	1.0461	3.7508	.3549	.4885
Cites/Pat	7.9545	7.9545	6.3265	6.3265
Semi-elasticities using estimates from column:	2	2c	2	2c
$\frac{\partial \log Q}{\partial (R\&D/A)}$	.7112	.7168	.8782	.8778
	(.0264)	(.0268)	(.0371)	(.0373)
$\frac{\partial \log Q}{\partial (Pat/R\&D)}$	.0158	.0007	.0195	.0009
	(.0037)	(.0002)	(.0046)	(.0003)
$\frac{\partial \log Q}{\partial (Cites/Pat)}$	.0269	.0275	.0332	.0337
	(.0015)	(.0016)	(.0019)	(.0019)

Heteroskedastic-consistent standard errors are shown in parentheses.
"HJT" refers to uncorrected data from Hall, Jaffe and Trajtenberg (2005).
Column numbers refer to estimates from Table 2.2.

Table 2.4
Industry-specific Effects

	1	2	3
D(Drugs)		.5444 (.0282)	-.1778 (.1236)
D(Chemical)		.0334 (.0201)	-.1399 (.0733)
D(Computer)		.3134 (.0221)	.5180 (.0492)
D(Electrical)		.1735 (.0212)	.1263 (.0654)
D(Metals & Machinery)		.0204 (.0163)	-.1395 (.0511)
R&D/Assets	1.3536 (.0678)	.6820 (.0535)	1.1369 (.2385)
× Drugs			.9293 (.4378)
× Chemical			-.2319 (.4105)
× Computer			-.8923 (.2432)
× Electrical			-.5173 (.3006)
× Metals & Machinery			.2596 (.2916)
Patents/R&D	.0013 (.0005)	.0011 (.0004)	.0016 (.0005)
× Drugs			.2533 (.0922)
× Chemical			.0050 (.0026)
× Computer			.0012 (.0022)
× Electrical			.0008 (.0006)
× Metals & Machinery			-.0016 (.0006)
Citations/Patents	.0519 (.0038)	.0358 (.0030)	.0148 (.0039)
× Drugs			.0856 (.0204)
× Chemical			.0445 (.0123)
× Computer			.0092 (.0058)
× Electrical			.0228 (.0116)
× Metals & Machinery			.0349 (.0094)
D(R&D=0)	.0752 (.0182)	.0832 (.0176)	.2067 (.0287)
× Drugs			.2243 (.1731)
× Chemical			-.1143 (.0642)
× Computer			-.3677 (.0892)
× Electrical			-.0563 (.0795)
× Metals & Machinery			-.1583 (.0430)
R^2	.2519	.2919	.3090
Standard error	.6718	.6547	.6463

Sample: 1921 patenting firms, 1979-88, 12,118 observations.

Nonlinear model with dependent variable: log Tobin's q.

Estimation method: nonlinear least squares.

Heteroskedastic-consistent standard errors are shown in parentheses.

All equations include a complete set of year dummies.

Base category is miscellaneous (low-tech industries).

Chapter 3

Patent Litigation and the Geography of Knowledge Flows[1]

[1]McGahee, Thomas P. and John L. Turner To be submitted to the *Journal of Law and Economics*.

3.1 Introduction

Inventive activity is a key driver of economic growth (Solow 1957). Measuring the output of such activity has proven challenging, as created knowledge does not leave a "paper trail" carefully describing its size and scope the way physical and financial capital does (Krugman 1991). Recorded patents offer perhaps the best window through which to learn about knowledge creation and dissemination, as they provide details about technological antecedents and descendants through their citation records. In past research, economists have used citation analysis to show that knowledge spillovers are geographically localized (Jaffe, Trajtenberg and Henderson 1993) and to identify aspects of the timing and nature of the "productivity slowdown" in the 1970s in the United States (Caballero and Jaffe 2002). One key difficulty limiting the extent to which citations can be used to study economic phenomena is the need to link citations to external data on economic outcomes related to patents, an often costly endeavor. Two notable papers show, by linking citations to estimates of social welfare stemming from CT scanners (Trajtenberg 1990) and to stock market returns (Hall, Jaffe and Trajtenberg 2005) that highly-cited patents generate, respectively, more social and private value.

Litigated patents offer an intriguing set of external data to which citations may be linked. Already, research has shown that litigated patents receive more citations on average than random patents (Lanjouw and Schankerman 2001), consistent with the intuition that patents worth litigating are more valuable on average. Studying localization effects for litigated patents therefore offers a promising way to test whether the localization of knowledge flows is as pronounced for more "important" innovations. Litigated patents offer additional useful information however. There is significant variability in both the geographic location and timing (in terms of patent age) of litigation, as well as the nature of decisions. In this paper we focus on the geographic variability.

Using unique data combining information from litigation decisions and patent citation records, we first show that litigated patents generate knowledge spillovers that do indeed show large, significant geographic localization effects. At the country, state and district[2] level, inventors listed on citations to litigated patents are significantly more likely to be local to cited inventors than are inventors on non-citing patents chosen to control for industrial agglomeration. The localization effects for litigated patents with 1975 application dates are significantly larger than those for identical-vintage cohorts of university and corporate patents analyzed by Jaffe, Trajtenberg and Henderson (1993). Localization effects for litigated patents from 1980 are at least as large as those for their university and corporate counterparts.

Our full data consist of 20-year citation profiles for a group of litigated patents with patent filing dates during 1975-86. Controlling for state fixed effects, we estimate a linear probability model of the likelihood of a citation coming from a particular state. We find significant inventor-state localization. The likelihood a citation comes from the inventor state is about 7 percentage points higher than for the average state. This localization effect does not depend on age or respond to the onset or conclusion of litigation. Hence, inventor-state localization does not fade across time for these litigated patents, in contrast to the findings of Jaffe, Trajtenberg and Henderson (1993). Interestingly, we also find significant trial-state localization–that is, citations to a litigated patent are significantly more likely to be local to the state in which the district court trial occurs than are control patents. The likelihood a citation comes from the trial state is about 6 percentage points higher than for the average state. The onset of litigation may increase the likelihood of citations in trial states by 2 percentage points, and the completion of litigation increases this likelihood by 3.5 percentage points. Trial-state localization may decrease with age, but the effect is not statistically significant. We repeat this estimation at the district level and find similar results.

These findings suggest that the location of litigation is correlated with the location of knowledge flows. To investigate this further, we restrict our attention to citations received prior to to the filing of litigation, and we carefully consider the relationship between the geog-

[2] By district, we mean the geographic area corresponding to a federal district court.

raphy of these pre-litigation citations and the future location of litigation. Again controlling for state fixed effects, we estimate a linear probability model of the likelihood of litigation occurring in a particular state. We find that when there is at least one citing patent invented prior to litigation in a given state, the conditional likelihood of future litigation in that state increases. For the inventor-state, the probability of litigation increases from 37.8 percent to 48.7 percent. For other states, the probability of litigation quadruples, from 1.2 percent to 4.8 percent. Again, we repeat this analysis at the district level and find similar results.

If spillovers from knowledge creation tend to be geographically localized, policy makers should account for these spillovers as they consider subsidizing local investment in research and development. The policy implications of the trial-state localization effects are more complex. On one hand, if knowledge flows lead to litigation, the cost of litigation mitigates the benefits of those knowledge flows. On the other hand, if disputes tend to bring attention to an innovation and increase knowledge flows, litigation may enhance knowledge diffusion and promote growth.

Our paper proceeds as follows. Section 3.2 describes the data. Section 3.3 gives descriptive statistics of these data. Section 3.4 compares characteristics of cohorts with 1975 and 1980 application dates to characteristics of similar cohorts from Jaffe, Trajtenberg and Henderson (1993). Section 3.5 considers a broader set of litigated patents. There, we study localization at both the inventor-state and trial-state levels and for pre-litigation, intra-litigation and post-litigation time periods. Section 3.6 describes full regression analysis of the determinants of the location of citations. In Section 3.7 we narrow our focus to pre-litigation citations and study the determinants of the location of litigation. Section 3.8 concludes.

3.2 Data

We combine patent litigation data collected from the *United States Patents Quarterly* (USPQ) with the NBER patent citation data. The full litigation data include all patents subject to at least one validity and/or infringement decision during 1953-2002 and published in the USPQ. Originally gathered by Henry and Turner (2006) to study the impact (on patent enforcement rates) of the 1982 establishment of the Court of Appeals for the Federal Circuit (CAFC), these litigation data have grown to include additional patent-specific information from the USPTO and filing dates from the ICPSR Federal Judicial Center data.[3] The NBER data include all citations listed in US patents granted between January 1, 1976 and December 31, 2006.[4]

While our data include, in principal, all citations from 1976-2006 for patents litigated during 1953-2002, we trim the data to minimize awkward truncation problems endemic to the analysis of patent citations (Hall, Jaffe and Trajtenberg 2001). To mitigate "left" truncation, we restrict attention to litigated patents—which we henceforth refer to as "subject" or "cited" patents—applied for during or after 1975.[5] To mitigate "right" truncation, we restrict attention to citing patents with application dates occurring no later than 20 years after the subject patent's application date (measured for each patent to the exact day). We also ignore subject patents with application dates after 1986.[6] We choose a 20-year window to correspond roughly to the time between subject patent application and expiration.

We partition citations into three timing categories, illustrated in Figure 3.1. *Pre-Litigation* citations have grant dates that occur prior to the filing of subject-patent litigation. *Intra-Litigation* citations include patents that have grant dates after the filing of subject-patent litigation and before the completion of the trial, as well as patents with application dates prior to the completion of litigation and grant dates after the completion of litiga-

[3]Part of the data augmentations were done to study the impact of the CAFC on forum shopping (Atkinson, Marco and Turner 2009) and part have been completed as part of NSF grant SES-0751661.

[4]The NBER data is hosted online at http://sites.google.com/site/patentdataproject. The combination of the USPQ and NBER data was completed specifically for this paper.

[5]We necessarily miss (a very small number of) citations by patents granted during 1975. We could avoid this problem entirely by starting with 1976 applications, but choose to include 1975 applications in our analysis to compare our results with Jaffe, Trajtenberg and Henderson (1993).

[6]It is impossible to eliminate right truncation entirely when timing inventions by their application dates, because some patents applied for prior to, say, 2006, are not granted until after 2006. Such patents are not in the NBER data and therefore do not make it into our data.

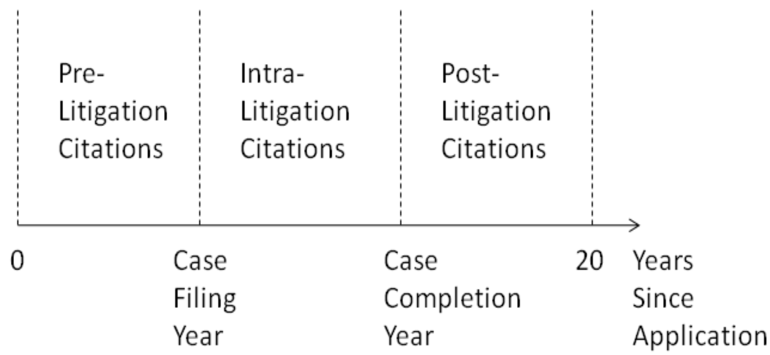

Figure 3.1: The Timing of Citations to Litigated Patents

tion.[7] *Post-Litigation* citations have application dates after the completion of subject-patent litigation.

The full USPQ data include utility, design, plant and reissue patents. We restrict attention to utility patents, which comprise about 90% of the total. These data also include a small fraction of patents for which we observe multiple litigations. Because we wish to study the relationship between trial location (and timing) and knowledge spillover location (and

[7]We define completion as the last observed decision date. Typically, this is either the date of the first decision in a case not litigated to an appeal or the date of the first appellate decision. Litigation in a small number of cases proceeds further.

timing), we remove such patents from the data.[8] We also remove a small number of patents involved in litigation at the international trade commission (ITC).[9]

After trimming, the data include 559 patents with U.S. inventors which receive 16,859 citations during the 20-year windows. We are interested primarily in geographic features of the citing patents. To distinguish geographic localization effects, it is necessary to control for geographic agglomeration of production by technology. We therefore follow Jaffe, Trajtenberg and Henderson (1993) by choosing a control patent for each citing patent. Each control is chosen by matching first technology class and application year exactly, then choosing the closest possible grant date. These controls allow us to test for geographic localization along multiple dimensions, most prominently inventor location and trial location. Trial location is recorded in the USPQ as a court district within a state. We do not observe which city within that district hosts the trial. We assign each patent to an inventor location by choosing the most common country amongst its inventors. For each patent so assigned to the United States, we then choose the state and the court district within that state most common to the patent's inventors, matching cities listed on the patent document to court districts using the United States Courts web site.[10] We resolve ties in favor of inventors who appear earlier on the patent document's list of inventors.

3.3 Descriptive Statistics

Consider first statistics on patent variables, reported in Table 3.1. The average litigated patent in our data has one or two inventors and is assigned to an entity distinct from the inventor(s) when granted. It has fifteen claims, cites about eight previous US patents and receives about 30 citations during the twenty years after its application date. The average

[8]The presence of multiple trial venues confounds indentification. Consider, for example, the difference in trial-state localization rates between pre-litigation and intra-litigation citations. If there are two different trial venues and two different filing dates, it is no longer possible to clearly define intra-litigation citations for both venues, given that the filing of litigation is likely to introduce publicity effects that may spill over to other venues.

[9]We are particularly interested in localization effects at the state level, and ITC cases are litigated in the District of Columbia.

[10]The search page is located at http://www.uscourts.gov/Court_Locator/CourtLocatorSearch.aspx.

application is neither a continuation nor a division of a previous application. For patents where there is a continuation or division, we recognize two distinct application dates, the *original* application date and the *current* application date. The average lag between current application and grant is just over two years. The average lag from the original application date, which traces the continuations and/or divisions back to the original application, is about a year longer. We follow the literature and treat the current application date as the basis for our data.

Consider next statistics on litigation, reported in Table 3.2. The average patent is about seven years old (from application date) when litigation is filed and about eleven years old when litigation is completed.[11] Around 43 percent of cases are litigated in a district court in the inventor state. 36 percent of cases are litigated in the inventor's home district.

Consider next statistics on the patents that cite our litigated patents, reported in Table 3.3. There are 15,211 distinct patents among the citing group. The average patent has two inventors and is assigned to an entity distinct from the inventor(s) when granted. It has about nineteen claims and cites about 33 previous US patents. The patent is about equally likely to be from the original application as from some non-original application (continuation 37%, division 13%). The average application lags are 2.31 years (current) and 3.72 years (original). Citing patents are, on average, newer than subject patents. The differences between the citing patents and subject patents (more claims, more backward references, etc.) are all consistent with intertemporal trends in the general patent population.

Consider finally statistics on the 16,859 cited-citing pairs, reported in Table 3.4.[12] About eleven percent of citations are self-citation, meaning that the citing patent has the same assignee as the litigated patent. Citations are less frequent during years 1-5 than in later periods. A 33-percent plurality of citations occur during years 11-15. The average citation occurs about eleven years after the subject patent application date. About 77 percent of

[11] We do not observe the filing year for 22 of our 559 patents. For the completion date, we use the date of the final recorded decision in the case.

[12] Some patents cite more than one of our litigated patents.

citations fall in the same NBER product category as the subject patent and about 50 percent fall in the same USPTO technology class. Twenty-one percent have the same inventor-state in common with the subject patent and 84 percent are domestic.

3.4 Comparison with Jaffe, Trajtenberg and Henderson (1993)

To illustrate some of the distinctive features of knowledge spillovers of litigated patents, we compare localization effects for 1975 and 1980 cohorts from our data with the analogous cohorts from Jaffe, Trajtenberg and Henderson (1993). To generate a direct comparison, we remove citations received after the end of 1989. Our remaining data with 1975 application dates include 54 patents receiving 595 citations. Our remaining data with 1980 application dates include 39 patents receiving 484 citations. We measure rates of localization for citing patents by calculating the proportion of citations that match the cited inventor's location at the state and country level. We then calculate analogous proportions for the controls. After removing self-citations, we test the equality of the rates of localization for citing and control groups using the same t-statistic as Jaffe, Trajtenberg and Henderson (1993).[13] We define net localization rates as the difference between citing and control rates of localization, and we calculate a t-statistic to test the statistical significance of the difference between net localization rates for citations to litigated patents and those rates reported by Jaffe, Trajtenberg and Henderson (1993) for various other sets of patents.[14]

[13] Let p_c be the probability that a citation is local to the cited inventor. Let p_o be the probability that a control is local to the cited inventor. We test H_o: $p_c = p_o$ using the test statistic:

$$t = \frac{\hat{p}_c - \hat{p}_o}{\sqrt{[\hat{p}_c(1-\hat{p}_c) + \hat{p}_o(1-\hat{p}_o)]/n}}$$

where $\hat{p}_c$ and $\hat{p}_o$ are the sample proportions of p_c and p_o. This statistic tests the equality of two independently drawn binomial proportions. It is distributed as t.

[14] Let p_{ci} and p_{oi} be the citation-matching and control-matching probabilities, respectively, for cited patents in group i. The test statistic is:

$$t = \frac{(\hat{p}_{ci} - \hat{p}_{oi}) - (\hat{p}_{cj} - \hat{p}_{oj})}{\sqrt{[\hat{p}_{ci}(1-\hat{p}_{ci}) + \hat{p}_{oi}(1-\hat{p}_{oi})]/n_i + [\hat{p}_{cj}(1-\hat{p}_{cj}) + \hat{p}_{oj}(1-\hat{p}_{oj})]/n_j}}$$

where i and j are the two groups of patents for which the statistic tests the equality of net localization rates. The statistic is distributed as t.

We report the results for the 1975 cohort, alongside reprinted analogous results from Jaffe, Trajtenberg and Henderson (1993), in Table 3.5. Excluding self-citations, 78% of citations to litigated patents are domestic, compared to about 64% of controls. 13.1% of citations, excluding self-citations, are local to the cited inventor's state, compared to only 4.3% of controls. The differences are statistically significant. We also compare the net localization rates of citations to litigated patents to the three categories from Jaffe, Trajtenberg and Henderson (1993). Compared to each of those cohorts, citations to litigated patents have higher rates of localization and net localization at both the state and country levels. The differences in net localization are all statistically significant. These differences are generally larger at the country level.

Results for the 1980 cohort of litigated patents are reported in Table 3.6. Again excluding self-citations, country localization rates for citations to litigated patents are a statistically significant 17.3% higher than for controls, and state localization rates are a statistically significant 7.7% higher than for controls. Country and state localization rates and net localization rates are also higher than for each Jaffe, Trajtenberg and Henderson (1993) category, but the differences in net localization rates are only statistically significant at the country level.

These results suggest that knowledge spillovers from patents that are more economically significant are subject to greater geographic localization at the country level and at least as strong localization at the state level. The main difference between the 1975 and 1980 cohorts is that the rate of state localization is higher for the 1975 litigated patents, relative to the Jaffe, Trajtenberg and Henderson (1993) cohorts, but not higher for the 1980 litigated patents. This differential may indicate a tendency of litigated patents' localization rates to remain constant or grow across time, in contrast to the fading localization rates identified by Jaffe, Trajtenberg and Henderson (1993) for their cohorts. We study this in more detail later in the paper.

3.5 The Location and Timing of Knowledge Flows

Litigated patents have additional, specific geographic information that may be important for understanding the geography of knowledge flows. In particular, the location of litigation may be different than the inventor's location. This information may reveal knowledge flows qualitatively distinct from the spillovers identified in past work. In addition, we observe the district of litigation, a finer geographic regional distinction.[15]

In this section, we consider the full (1975-86 applications) set of litigated patents and their citations. We divide subject patents according to in-region and out-of-region litigation and divide citations into pre-, intra- and post-litigation categories. To construct a pre-litigation category, it is necessary to know the filing year in the case. We lose 22 patents (which receive 921 citations) by restricting attention to such cases.

We then construct aggregate matching percentages by state and district for citations classified along these multiple dimensions. Extending the analysis by matching citations to districts within each state allows us to take a finer look at the extent of localization. The district is the most precise measure of trial location available to us. Each state has between one and four court districts for a total of 89 districts among the 50 states. Results at the state level are presented in Table 3.7. Results at the district level follow in Table 3.8. For all timing categories and at each level of analysis, we find the presence of statistically significant localization of knowledge spillovers to both inventor location and trial location.

Pre-litigation localization is of particular interest. We find that a significant geographic concentration of citations does tend to precede litigation in that area. For patents litigated out of their home district, 5.7% of citations but only 2.3% of controls are local to the trial district prior to the filing of litigation. The analogous difference for patents litigated out of state is similar, and both are statistically significant. Also prior to litigation, patents litigated in their home district receive 15.3% of their citations there, compared to just 3.2% of controls,

[15] Unfortunately, we do not observe the city where litigation takes place, so we are unable to compute rates of municipal localization.

but patents litigated away from home receive just 8.5% of pre-litigation citations and 2.3% of controls in their home district. Both differences are statistically significant, but clearly litigation at home tends to follow a higher concentration of local citations prior to litigation. This comparison also holds at the state level. The inventor-state citation localization rate, net of controls, is nearly twice as high before in-state litigation as it is before out-of-state litigation.

Trial-district localization increases after the filing of litigation. Excluding self-citations, trial-district localization rises from 5.7% to 7.8%. Net of controls, the rate rises from 3.4% to 5.1%. Trial-state localization also increases after filing and then increases further after litigation concludes. Lanjouw and Schankerman (2001) find that litigation has a "publicity effect" which causes an increase in total citations just after the filing of litigation (they do not estimate rates of localization). We provide some evidence that a trial may serve as a source of local publicity for a litigated patent, but the effect does not appear to quickly fade as they suggest.

The higher inventor-district and inventor-state localization rates for patents litigated at home persist through the filing and conclusion of litigation. There is no clear trend across geographic levels of analysis as litigation progresses. For cases litigated at home, net inventor-district localization falls from 12.1% to 9.2% over the course of litigation, but net inventor-state localization increases from 12.5% to 12.9%. For cases litigated away, net inventor-district localization falls from 6.2% to 4.3%, and net inventor-state localization falls from 6.7% to 5.6%.

3.6 Factors Affecting Patterns of Localization

The significant localization effects for litigated patents suggest that knowledge flows are correlated with the incidence of litigation. Additionally, the difference in the geography of citations between patents litigated at home and those litigated away suggests that the location of knowledge flows are correlated with the location of litigation. The analysis of the previous section is too crude, however, to draw any causal implications from these correlations or their trends over the course of litigation. Moreover, while the litigation-timing categories do tell us a bit about the effects of age on citation localization, our far-richer data permit more careful inquiry.

We use a linear probability regression model to estimate localization effects. We begin our analysis at the state level of localization. We specify the model as follows:

$$Y_{ij} = \alpha + \beta InvState_{ij} + \gamma TrialState_{ij} + \phi Control_{ij} + \eta_j + \varepsilon_i j \tag{3.1}$$

where the dependent variable Y_{ij} takes the value 1 if citation i is in state j and zero otherwise. The variable $InvState_{ij}$ takes value 1 if the inventor state for citation i is the same as state j and is zero otherwise. The variable $TrialState_{ij}$ takes value 1 if the trial state for citation i is the same as state j and is zero otherwise. The variable $Control_{ij}$ takes value 1 if the inventor state for the control citation for citation i is the same as state j and is zero otherwise. The variable η_j is the fixed effect for state j, which controls for heterogeneity in matching frequencies across states. The error $\varepsilon_i j$, independently and identically distributed Normal with mean zero and constant variance, primarily reflects unobservable random factors determining the location of inventive activity related to the subject patent. We exclude 1,766 self-citations from this analysis.

The results for the estimation of (3.1) are presented in Column 1 of Table 3.9. We cluster at the state level to calculate standard errors. All coefficient estimates are statistically significant at the 1% level. The estimate $\widehat{\beta} = .074$ implies that the citation matching frequency for a given state is 7.4 percentage points higher on average when that state is home to the cited inventor than when it is not. Consistent with past work on the localization of knowledge spillovers, we find that a patent's received citations are local to the site of invention. The estimate for $\widehat{\gamma} = .063$ implies that the citation matching frequency for a given state is 6.3 percentage points higher when that state hosts the trial than when it does not. Thus, we also conclude that citations are local to trial states.[16] Taken together, these results imply that the paper trail left by patent litigation reveals, to some extent, the pattern of knowledge spillovers.

The estimate $\widehat{\phi} = .027$ implies that the matching frequency for state j is 2.7 percentage points higher when the control for citation i is in state j. This indicates that our controls do capture some geographic industrial agglomeration.

We now turn our attention to both age and litigation effects. Jaffe, Trajtenberg and Henderson (1993) report evidence that inventor-specific localization rates decline as a patent ages. Lanjouw and Schankerman (2001) find that the filing of litigation has a brief "publicity effect" on citations. To test for these effects, we first construct dummy variables for citations occurring during litigation ("InLit") and for citations occuring after the completion of litigation ("PostLit"), and we introduce a measure of the cited patent's age at the time of each citation ("Age"), computed by dividing the number of days between the application dates of the cited and citing patents by 365. Next, we interact these three variables with $InvState_{ij}$ and $TrialState_{ij}$. Hence, we add six new variables to the regression.

The results for this estimation are presented in Column 2 of Table 3.9. All coefficients from the estimation of (3.1) remain significant at the 1% level. The estimate of β is nearly unchanged, and the interactions with $InvState_{ij}$ are all statistically indistinguishable from zero. Thus, in contrast to Jaffe, Trajtenberg and Henderson (1993), we find no fading of inventor-specific localization. Additionally, we find no publicity effect tied to the inventor state.

The estimate of γ is lower but still statistically significant, now measuring trial-state localization for only pre-litigation citations. Consider the new variables interacted with $TrialState_{ij}$. Intra-litigation citations are 2 percentage points more likely to be local to the trial state than pre-litigation citations, but the effect is not statistically significant. Post-litigation citations are 3.5 percentage points more likely to be local to the trial state, and

[16] When a term interacting inventor-state and trial-state dummies is included, the coefficient estimate is positive, implying a complementarity. However, this estimate is not significantly different from zero.

the effect is statistically significant. The coefficient on age is small, negative and statistically insignificant. Hence, we provide evidence that trial-specific localization is evident prior to the filing of litigation, grows as litigation progresses, and does not significantly fade across time.

The third column includes as controls the fraction of a patent's citations that are self-citations, $FracSelf$, and a dummy for whether the citing and cited patents come from the same technological class, $SameClass$. Both variables were statistically significant determinants of citation geography in the estimations reported in Table IV of Jaffe, Trajtenberg and Henderson (1993). Our estimates, shown in Column 3, are robust to the inclusion of these variables.

In Table 3.10, we present the results of extending this analysis to the district level. In Column 1, the estimated coefficients on $InvDistrict$, $TrialDistrict$, and $Control$, defined analogously to their state-level counterparts, are all statistically significant but slightly smaller than the state-level estimates. For example, the citation matching frequency for a given district is 5.3% higher if that district hosts the cited patent's trial. The inventor-district effect is 6.2%. In Column 2, we again add age and litigation interaction terms. The trial-district effect prior to litigation is 4.9%. It increases during litigation by a statistically significant 2.1%. The conclusion of litigation increases the trial-district effect by 2.3%, but this effect is not statistically significant. The coefficient on age is once again small and statistically insignificant. We also again find no statistically significant effect of age or the onset or conclusion of litigation on the inventor-district effect.

3.7 Factors Affecting Trial Location

In this section, we seek better understanding of trial-specific localization effects. We are particularly interested in explaining why pre-litigation citations show localization to the trial state. Clearly, neither these citations nor their location are *caused* by the trial. Rather, it is natural to ask if they offer some predictive power for the location of litigation.

Consider Table 3.11, which shows how the likelihood of litigation in a given state depends on the pattern of pre-litigation citations. Of the 537 patent cases considered in the previous section, 13 are "born" into litigation and are excluded from this section. For each of the remaining 524 patent cases, we observe whether litigation occurs in one inventor state and 49 other states. Thus, we have 524 inventor state observations and 25,676 non-inventor state observations. Litigation occurs in the inventor state about 42% of the time, and in any given other state about 1.18% of the time on average. For a typical non-inventor state j, litigation occurs about 1.04% of the time when there are no pre-litigation citations made in state j. The likelihood of litigation in state j increases by more than a factor of five, to 5.40%, when there is at least one pre-litigation citation in state j. The typical inventor state hosts litigation about 41.0% of the time when there are no pre-litigation, inventor-state citations. The likelihood of inventor-state litigation increases by about one sixth, to 47.7%, when there is at least one inventor-state citation.

The lower section of Table 3.11 includes similarly computed statistics for controls. When there is at least one control in a typical non-inventor state j, the probability of litigation is 2.84%, versus 1.11% with no controls. Thus, controls in state j do increase the likelihood of litigation, but the multiplicative increase is half that for citations. A similar effect is apparent in the inventor-state controls; when there is at least one control in the inventor state, the probability of hosting litigation is 43.9%, just higher than the 42.1% when there are no controls.

Table 3.12 contains a similar breakdown of litigation frequencies by district rather than state. We observe whether or not each of the 524 patent cases are filed in each of 89 court districts, including one inventor district for each case. Thus, we have 524 inventor district observations and 46,112 non-inventor district observations. Overall, litigation occurs in the inventor district about 35.7% of the time, and in any given other district about 0.73% of the time on average. A typical non-inventor district with no pre-litigation citations hosts litigation 0.65% of the time, but this frequency rises seven-fold, to 4.64%, when there is at least one citation. The presence of a control in a non-inventor district raises the probability of litigation by much less, from 0.70% with none to 1.92% with at least one. The typical inventor district hosts litigation 34.6% of the time when there are no pre-litigation citations but 40.9% of the time when there is at least one. One or more controls in the inventor district raise the likelihood of hosting litigation only slightly from 35.6% to 36.4%.

We see in these statistics that knowledge flows to a given state and district, indicated by citations, tend to attract litigation. To a lesser extent, even a control patent falling in a given state and district appears to increase the likelihood of litigation there. A control patent's location in a given state and district indicates that innovative activity technologically related to the citing patent is taking place in that area. It is not surprising that this is correlated with litigation, as companies are more likely to become involved in patent litigation with companies using similar technology. However, the geographic correlation between control patents and litigation could also be explained by a tendency for more populated, more industrialized states and districts to host more innovative activity and more patent litigation. To distinguish the real effects of citations and controls from pure state or district effects, we turn to linear regression with fixed effects.

Consider the following linear probability model of trial location:

$$Z_{ij} = \alpha + \beta InvState_{ij} + \gamma AnyCite_{ij} + \delta AnyControl_{ij} + \phi AnyCite_{ij} AnyControl_{ij} + \eta_j + \varepsilon_i j$$

where the dependent variable Z_{ij} takes the value 1 if litigation for patent i occurs in state j and zero otherwise. The first two variables control for home-state effects, shown by Atkinson, Marco and Turner (2009) to be a significant determinant of litigation location.[17] $InvState_{ij}$ takes value 1 if the inventor state for patent i is the same as state j and is zero otherwise. The variable $AnyCite_{ij}$ takes value 1 if there are any pre-litigation citations to patent

[17]Note that we do not control for forum shopping, one of the main subjects considered by Atkinson, Marco and Turner (2009). Nearly all of our litigation filings occur in 1978 or later, after forum shopping by circuit on the basis of validity ceases.

i made by inventors in state j, and is zero otherwise. The variable $AnyControl_{ij}$ is similarly constructed for control citations. We interact these terms to more carefully consider geographic agglomeration. The variable η_j is the fixed effect for state j, which controls for heterogeneity in the frequencies of litigation across states.[18] The error $\varepsilon_i j$, independently and identically distributed Normal with mean zero and constant variance, primarily reflects unobservable random factors determining the location of inventive activity related to the subject patent. For this analysis we exclude 57 cases in which the holder of the litigated patent is the defendant, as the location of such trials is unlikely to be determined by the same factors.

The results are presented in Column 1 of Table 3.13. Again, standard errors are clustered at the state level. After accounting for state fixed effects, we find that the location of a control patent does not attract litigation. The coefficient estimate on $AnyControl_{ij}$ is very small and statistically insignificant. The estimates on all other variables are statistically significant. The inventor state is about 38 percentage points more likely to host litigation than an otherwise identical state. Litigation is an additional 4.4 percentage points more likely in state j when there is a pre-litigation citation in state j. These numbers are similar but not entirely consistent with the descriptive statistics from Table 3.12. Factoring in the constant term, the estimates imply average inventor-state litigation likelihoods of 39.3 percent with no pre-litigation inventor-state citations and 43.7 percent with at least one. They imply average non-inventor-state-j litigation likelihoods of 1.1 percent without pre-litigation citations in state j and 5.5 percent with at least one. Interestingly, when there is both a citation and a control in state j, this eliminates the effect of the citation. Hence, when a citation is likely due to geographic agglomeration of industry, that citation appears to have no effect on the conditional likelihood of litigation in that state. Rather, it is a citation which is geographically unexpected given its industry and technology that may attract litigation.

[18] Atkinson, Marco and Turner (2009) show that these fixed effects have some limited explanatory power. In particular, patents whose inventors are located in the Tenth Circuit tend to be litigated elsewhere.

One assumption implicit in the model above is that the effect of a citation in state j does not depend on whether state j is the cited inventor's state. We relax this assumption by interacting the citation and control variables with the inventor-state dummy. The results of this model are presented in Column 2. The estimates change little from those in Column 1, and the estimated coefficients on the added interaction terms are all statistically insignificant. The additional likelihood of hosting litigation predicted by a citation received in state j does not appear to depend on whether state j is the cited inventor's state.

We now turn to a specification that assumes the attraction of litigation to a given state depends not simply on whether or not the litigated patent received citations there but rather on how many citations were received there. Columns 3 and 4 reflect estimations of equations where $AnyCite_{ij}$ is replaced with $CitationsPerYear_{ij}$, the number of pre-litigation citations to litigated patent i made by inventors in state j divided by the number of years elapsed between the year of application for the litigated patent and the year litigation was filed.[19] The coefficient estimates identify the effect of an additional citation per year received in state j prior to litigation on the likelihood of state j hosting litigation. The effects remain positive and highly significant. An additional citation per year in state j increases the likelihood of litigation in state j by 22.7 percentage points. Again the controls, now a yearly measure as well, only have predictive power when interacted with the citations variable, and the coefficient on their interaction is negative and significant. The -43.1 percentage point effect of the interaction may seem more than large enough to cancel out the 22.6 percentage point effect of the citations. Indeed, if a litigated patent had both one citation and one control patent per year in a given state, this would be true, but that scenario is rather extreme. In our data, no litigated patent has even one control patent per year in any state. The average number of controls per year in observations for which the interaction term is nonzero is about

[19]While simply dividing a citation count by the cited patent's age may seem crude, we found the predicted likelihoods of hosting litigation that result from this method to be nearly identical to those estimated after normalizing citation counts by age using the cumulative lag distribution simulated by Hall, Jaffe and Trajtenberg (2001). We use the simpler method because the interpretation of estimated coefficients is more straightforward.

0.14 (roughly one control patent per seven years). At that number of controls, the total effect of an additional citation per year, including its interaction with controls, is still strong at 16.6 percentage points. Taking this together with the results from our original specification, it remains clear that a citation's effect on the location of litigation does depend on the extent to which that citation is geographically unexpected.

When $InvState_{ij}$ is interacted with the yearly citation and control variables in Column 4, the estimated coefficients on its interaction terms are statistically insignificant. Again we find that the tendency of citations to attract litigation is independent of whether those citations are received in the cited inventor's state.

We extend this analysis to the district level and report the results in Table 3.14. The fixed effects now account for regional variation in population and industrialization with greater geographic precision, and we take our study of the determinants of trial location to be the most precise level for which we have data. The inventor district effect is about 33%, somewhat less than the inventor state effect but still quite large and statistically significant. The effects of $AnyCite_{ij}$ and $CitationsPerYear_{ij}$ are again statistically significant and about as strong as at the state level for each estimation. The direct effects of controls remain statistically insignificant. In Columns 1 and 2, in contrast to the state-level analysis, the estimated effect of both a citation and a control in a given district does not cancel out the effect of the citation, though the interaction coefficient is again negative and statistically significant. The estimated coefficient on the continuous interaction term for citations and controls per year in Column 3 is again negative but now statistically insignificant. These results are in line with our conclusion from the state analysis that the tendency of citations to attract litigation depends on the extent to which they are geographically unexpected given their technological class. However, these results confirm that even geographically expected citations have some predictive power for the location of litigation.

3.8 Conclusion

In this paper, we explore the geographic patterns of citations to litigated patents. Earlier studies show that knowledge spillovers from an innovation tend to be somewhat localized near where that innovation took place (e.g. Jaffe, Trajtenberg and Henderson 1993), but none test the relationship between this localization and the value of the innovation. If spillovers are only localized for patents of little value, then the discovery that they are localized is of little value. We extend the study of knowledge spillover localization to a special set of patents, those that have been litigated to a decision. The choices of these patent holders to file and persist through costly litigation reveals that these patents are especially valuable. We conclude from our study that spillovers from innovations represented by litigated patents have at least as strong a tendency to be localized as those studied by Jaffe, Trajtenberg and Henderson. We also find, in contrast to their results, that this localization does not generally fade over time for litigated patents. This is the first evidence that for very valuable patents, the localization of knowledge spillovers is strong and persistent.

We also examine whether citations attract litigation. Our study reveals that litigation does tend to geographically follow citations. This may be interpreted as evidence that citations are indeed a true measure of knowledge spilling over. In claiming infringement, the patent holder explicitly claims that knowledge has spilled over to the alleged infringer. We also found that the tendency of citations to attract litigation depends on the extent to which those citations are geographically unexpected given their industry and technology. This interesting finding is worth investigating further with a model that more explicitly accounts for geographical agglomeration of various technologies and industries.

Our data include additional information we do not exploit above but which would be useful to study. For example, we observe validity decisions in each case (i.e., whether a patent is held valid or invalid). Patent validity is a bona fide if somewhat crude external measure of value. Patents found invalid become worthless by definition at the time of the court's final decision. All else equal, then, valid patents are worth more than invalid patents.

With these data, we can investigate the response of citations to validity decisions. Showing that valid patents receive more citations has important implications for estimates of the value of citations in market value regressions. Specifically, if litigation outcomes are excluded from the right-hand side of such regressions, then citations are endogenous with respect to patent value—a patentee who wins a suit has more valuable equity and received more future citations.

We also observe citations made by the cited patent's alleged infringers. When a citation is made by an alleged infringer, one can be more certain that knowledge has indeed spilled over. Either the alleged infringer directly acknowledged a connection to the subject patent or, in the case of an examiner-added citation, it has a written record (in its own patent document) of the connection. Studying the frequency and timing of alleged infringer citations may shed light on the frequencies of copying, which Cotropia and Lemley (2009) argue is extremely uncommon, and inadvertent infringement. We look forward to further progress in this area.

Table 3.1
Descriptive Statistics: Litigated Patents

Variable	Mean	Std. Dev.	Min.	Max.	N
Inventor in CA	0.16	0.37	0	1	559
Inventor in IL	0.10	0.30	0	1	559
Inventor in NY	0.08	0.28	0	1	559
Inventor in TX	0.06	0.24	0	1	559
Inventor in NJ	0.05	0.23	0	1	559
Grant Lag	2.13	1.22	0.51	11.6	559
Grant Lag from Original Application	3.21	2.75	0.63	24.79	559
Continuation	0.30	0.46	0	1	559
Division	0.10	0.30	0	1	559
Number of Claims	15.29	15.10	1	162	559
Number of Inventors	1.65	0.97	1	8	559
Assigned Other Than to Inventor	0.74	0.44	0	1	559
Inventor State Same As Assignee	0.80	0.40	0	1	559
Tech Category = Chemical	0.17	0.38	0	1	559
Tech Category = Computer	0.09	0.29	0	1	559
Tech Category = Drugs	0.14	0.35	0	1	559
Tech Category = Electrical	0.12	0.32	0	1	559
Tech Category = Mechanical	0.18	0.38	0	1	559
Tech Category = Other	0.30	0.46	0	1	559
Utility References	8.47	7.47	0	86	559
Design References	0.06	0.35	0	4	559
Foreign References	0.97	2.66	0	42	559
Median Reference Age	9.68	9.96	0	62	554
Oldest Reference Age	33.58	27.30	0	117	554
Citations in First 20 Years	30.27	40.32	0	323	559

The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly.* In this table we restrict attention to patents with application dates between 1975-86. Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website.

Table 3.2
Descriptive Statistics: Litigation

Variable	Mean	Std. Dev.	Min.	Max.	N
Litigation in Inventor State	0.43	0.50	0	1	559
Litigation in Inventor District	0.36	0.48	0	1	559
Age of Patent When Litigation Filed	7.23	4.64	0	20	537
Age of Patent When Litigation Decided	11.39	4.72	2	25	559

The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly.* In this table we restrict attention to patents with application dates between 1975-86. Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website.

Table 3.3
Descriptive Statistics: Citing Patents

Variable	Mean	Std. Dev.	Min.	Max.	N
Inventor in CA	0.16	0.37	0	1	15211
Inventor in NY	0.06	0.23	0	1	15211
Inventor in TX	0.05	0.21	0	1	15211
Inventor in IL	0.05	0.21	0	1	15211
Inventor in MA	0.05	0.21	0	1	15211
Grant Lag	2.31	1.27	0.36	16.27	15211
Grant Lag from Original Application	3.72	2.82	0.37	27.34	15211
Continuation	0.37	0.48	0	1	15211
Division	0.13	0.33	0	1	15211
Number of Claims	18.56	17.76	1	505	15211
Number of Inventors	2.27	1.76	0	22	15211
Assigned	0.85	0.35	0	1	15211
Inventor State Same As Assignee	0.72	0.45	0	1	10387
Chemical	0.13	0.34	0	1	15211
Computer	0.16	0.37	0	1	15211
Drugs	0.25	0.43	0	1	15211
Electrical	0.11	0.31	0	1	15211
Mechanical	0.13	0.33	0	1	15211
Other	0.21	0.41	0	1	15211
Utility References	33.27	53.13	0	770	15211
Design References	0.24	1.16	0	36	15211
Foreign References	5.48	14.11	0	236	15211
Median Reference Age	7.36	5.69	0	85	15211
Oldest Reference Age	35.58	29.24	0	189	15211

The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly*. In this table we restrict attention to the first 20 years of citations to patents with application dates between 1975-86. Citing patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website.

Table 3.4
Descriptive Statistics: Citations (Cited-Citing Pairs)

Variable	Mean	Std. Dev.	Min.	Max.	N
Self-Citation	0.11	0.31	0	1	16859
Citation Lag	11.17	4.99	-2.45	20	16859
Cite Lag 1-5	0.14	0.35	0	1	16859
Cite Lag 6-10	0.26	0.44	0	1	16859
Cite Lag 11-15	0.33	0.47	0	1	16859
Cite Lag 16-20	0.27	0.44	0	1	16859
Same Tech Category	0.77	0.42	0	1	16859
Same Tech Class	0.50	0.50	0	1	16859
Same Tech Subclass	0.10	0.29	0	1	16859
Same Inventor District	0.16	0.37	0	1	16859
Same Inventor State	0.21	0.41	0	1	16859
Same Inventor Country	0.84	0.37	0	1	16859
Citing Inventor in Trial State	0.18	0.39	0	1	16859
Citing Inventor in Trial District	0.11	0.32	0	1	16859

The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly*. In this table we restrict attention to the first 20 years of citations to patents with application dates between 1975-86. Citing patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website.

Table 3.5
Geographic Matching Rates, 1975 Applications, Citations Through 1989

	Litigated (USPQ)	University (JTH 1993)	Top Corporate (JTH 1993)	Other Corporate (JTH 1993)
Number of citations	595	1759	1235	1050
Matching by country				
Overall citation matching percentage	79.3	68.3	68.7	71.7
Citations excluding self-cites	78.0	66.5	62.9	69.5
Controls	64.2	62.8	63.1	66.3
t-statistic (vs. controls)	5.14	2.28	-0.1	1.61
t-statistic (vs. JTH)		3.23	4.23	3.15
Matching by state				
Overall citation matching percentage	17.0	10.4	18.9	15.4
Citations excluding self-cites	13.1	6.0	6.8	10.7
Controls	4.3	2.9	6.8	6.4
t-statistic (vs. controls)	5.27	4.55	0.09	3.50
t-statistic (vs. JTH)		3.16	4.51	2.18

The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly.* Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website. Data in this table pertain to cited patents with application dates during 1975 and to citations received through 1989. The data in Columns 2-4 come from Table III of Hall, Jaffe and Trajtenberg (1993). The first t-statistic tests for equality between citation and control rates of localization. The second t-statistic tests for equality between the net localization rates for the litigated set and each other set. Self-citations are excluded from t-statistic calculation. See text for details.

Table 3.6
Geographic Matching Rates, 1980 Applications, Citations Through 1989

	Litigated (USPQ)	University (JTH 1993)	Top Corporate (JTH 1993)	Other Corporate (JTH 1993)
Number of citations	484	2046	1614	1210
Matching by country				
Overall citation matching percentage	77.1	71.4	74.6	73.0
Citations excluding self-cites	74.1	69.3	68.9	70.4
Controls	56.8	58.5	60.0	59.6
t-statistic (vs. controls)	5.41	7.24	5.31	5.59
t-statistic (vs. JTH)		1.84	2.33	1.74
Matching by state				
Overall citation matching percentage	24.8	16.3	27.3	18.4
Citations excluding self-cites	16.1	10.5	13.6	11.3
Controls	8.4	4.1	7.0	5.2
t-statistic (vs. controls)	3.46	7.90	6.28	5.51
t-statistic (vs. JTH)		0.55	0.45	0.64

The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly*. Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website. Data in this table pertain to cited patents with application dates during 1980 and to citations received through 1989. The data in Columns 2-4 come from Table III of Hall, Jaffe and Trajtenberg (1993). The first t-statistic tests for equality between citation and control rates of localization. The second t-statistic tests for equality between the net localization rates for the litigated set and each other set. Self-citations are excluded from t-statistic calculation. See text for details.

Table 3.7
State Localization for 1975-86 Cohorts, 20-year Citation Profiles

	Pre-Litigation	Intra-Litigation	Post-Litigation
In-State Litigation			
Number of citations	955	2678	3540
Inventor-state citation matching percentage	24.0	25.7	30.4
Citations excluding self-cites	17.8	18.6	21.9
Controls	5.3	6.2	9.0
t-statistic	8.34	13.17	14.16
Out-of-State Litigation			
Number of citations	1512	3701	3552
Inventor-state citation matching percentage	18.1	16.6	15.1
Citations excluding self-cites	10.6	11.3	10.9
Controls	3.9	6.4	5.3
t-statistic	6.73	7.02	8.30
Trial-state citation matching percentage	7.9	11.0	11.5
Citations excluding self-cites	8.0	9.7	10.6
Controls	4.2	4.3	4.3
t-statistic	4.11	8.64	9.67

The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly.* Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website. In this table we restrict attention to cited patents with application dates between 1975-86. The t-statistics test for equality between citation and control rates of localization.

Table 3.8
District Localization for 1975-86 Cohorts, 20-year Citation Profiles

	Pre-Litigation	Intra-Litigation	Post-Litigation
In-District Litigation			
Number of citations	790	2021	2434
Inventor-district citation matching percentage	21.9	20.5	18.2
Citations excluding self-cites	15.3	14.8	13.2
Controls	3.2	2.9	4.0
t-statistic	8.16	13.17	11.20
Out-of-District Litigation			
Number of citations	1677	4358	4658
Inventor-district citation matching percentage	15.7	14.4	15.3
Citations excluding self-cites	8.5	8.5	7.5
Controls	2.3	3.3	3.2
t-statistic	7.55	9.80	8.53
Trial-district citation matching percentage	5.6	8.0	7.9
Citations excluding self-cites	5.7	7.8	7.8
Controls	2.3	2.8	2.8
t-statistic	4.78	9.92	10.19

The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly.* Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website. In this table we restrict attention to cited patents with application dates between 1975-86. The t-statistics test for equality between citation and control rates of localization.

Table 3.9
Estimates of a Linear Probability Model of a Citation's Location by State

	1	2	3
Constant	0.013***	0.013***	0.013***
	(0.000)	(0.000)	(0.000)
InvState	0.074***	0.073***	0.071***
	(0.012)	(0.016)	(0.018)
× InLit		−0.001	0.000
		(0.014)	(0.014)
× PostLit		0.006	0.008
		(0.028)	(0.030)
× Age		−0.000	−0.000
		(0.001)	(0.001)
TrialState	0.063***	0.046***	0.045***
	(0.015)	(0.016)	(0.014)
× InLit		0.020	0.021
		(0.015)	(0.015)
× PostLit		0.035*	0.038*
		(0.019)	(0.019)
× Age		−0.001	−0.001
		(0.002)	(0.002)
Control	0.027***	0.027***	0.027***
	(0.004)	(0.004)	(0.004)
FracSelf	Out	Out	In
SameClass	Out	Out	In
n	14172	14172	14172
R^2	0.032	0.032	0.033

Standard errors are in parentheses, clustered by state.

* p<.10, ** p<.05, *** p<.01

The dependent variable Y_{ij} takes the value 1 if citation i is in state j and zero otherwise. We observe Y_{ij} in 50 states for each of 14,172 citations and use fixed effects by state. The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly.* Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website. In this table we restrict attention to the first 20 years of citations to litigated patents with application dates between 1975-86.

Table 3.10
Estimates of a Linear Probability Model of a Citation's Location by District

	1	2	3
Constant	0.008***	0.008***	0.008***
	(0.000)	(0.000)	(0.000)
InvDistrict	0.062***	0.067***	0.058***
	(0.009)	(0.018)	(0.017)
× InLit		−0.004	−0.005
		(0.016)	(0.016)
× PostLit		−0.018	−0.018
		(0.022)	(0.022)
× Age		0.000	0.000
		(0.002)	(0.002)
TrialDistrict	0.053***	0.049***	0.041***
	(0.014)	(0.013)	(0.012)
× InLit		0.021*	0.019
		(0.012)	(0.012)
× PostLit		0.023	0.021
		(0.018)	(0.017)
× Age		−0.001	−0.001
		(0.002)	(0.002)
Control	0.026***	0.026***	0.026***
	(0.005)	(0.005)	(0.005)
FracSelf	Out	Out	In
SameClass	Out	Out	In
n	14172	14172	14172
R^2	0.016	0.016	0.017

Standard errors are in parentheses, clustered by district.

* p<.10, ** p<.05, *** p<.01

The dependent variable Y_{ij} takes the value 1 if citation i is in district j and zero otherwise. We observe Y_{ij} in 89 districts for each of 14,172 citations and use fixed effects by district. The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly.* Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website. In this table we restrict attention to the first 20 years of citations to litigated patents with application dates between 1975-86.

Table 3.11
Litigation State Frequency Conditional on Pre-Litigation Citations and Controls

	Cites > 0 in State j?	N	Litigation Match (%)
j = Inventor State	No	417	41.0
	Yes	107	47.7
$j \neq$ Inventor State	No	24880	1.04
	Yes	796	5.40
	Controls > 0 in State j?	N	Litigation Match (%)
j = Inventor State	No	458	42.1
	Yes	66	43.9
$j \neq$ Inventor State	No	24760	1.11
	Yes	916	2.84

The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly*. Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website. In this table we restrict attention to pre-litigation citations to litigated patents with application dates between 1975-86.

Table 3.12
Litigation District Frequency Conditional on Pre-Litigation Citations and Controls

	Cites > 0 in District j?	N	Litigation Match (%)
j = Inventor District	No	436	34.6
	Yes	88	40.9
$j \neq$ Inventor District	No	45206	0.65
	Yes	906	4.64
	Controls > 0 in District j?	N	Litigation Match (%)
j = Inventor District	No	480	35.6
	Yes	44	36.4
$j \neq$ Inventor District	No	45070	0.70
	Yes	1042	1.92

The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly*. Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website. In this table we restrict attention to pre-litigation citations to litigated patents with application dates between 1975-86.

Table 3.13

Estimates of a Linear Probability Model of Trial Location by State

	1	2	3	4
Constant	0.011***	0.012***	0.011***	0.012***
	(0.001)	(0.001)	(0.001)	(0.001)
InvState	0.382***	0.368***	0.379***	0.373***
	(0.038)	(0.037)	(0.037)	(0.040)
AnyCite	0.044***	0.036***		
	(0.012)	(0.010)		
× InvState		0.071		
		(0.046)		
AnyControl	0.001	−0.001		
	(0.007)	(0.005)		
× InvState		0.048		
		(0.087)		
AnyCite × AnyControl	−0.045**	−0.037***		
	(0.018)	(0.014)		
× InvState		−0.098		
		(0.117)		
CitationsPerYear			0.226***	0.167**
			(0.067)	(0.065)
× InvState				0.220
				(0.164)
ControlsPerYear			−0.028	−0.011
			(0.061)	(0.052)
× InvState				−0.237
				(0.443)
CitationsPerYear × ControlsPerYear			−0.431*	−0.368
			(0.229)	(0.220)
× InvState				0.201
				(1.028)
n	467	467	467	467
R^2	0.175	0.176	0.177	0.177

Standard errors are in parentheses, clustered by state.

* p<.10, ** p<.05, *** p<.01

The dependent variable Z_{ij} takes the value 1 if litigation for patent i occurs in state j and zero otherwise. We observe Z_{ij} in 50 states for each of 467 litigated patents and use fixed effects by state. The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly.* Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website. In this table we restrict attention to pre-litigation citations to litigated patents with application dates between 1975-86 and to cases in which the patent holder is the plaintiff.

Table 3.14
Estimates of a Linear Probability Model of Trial Location by District

	1	2	3	4
Constant	0.007***	0.007***	0.007***	0.007***
	(0.001)	(0.000)	(0.001)	(0.000)
InvDistrict	0.330***	0.322***	0.328***	0.324***
	(0.035)	(0.032)	(0.034)	(0.033)
AnyCite	0.040***	0.036***		
	(0.011)	(0.008)		
× InvDistrict		0.050		
		(0.071)		
AnyControl	−0.000	0.000		
	(0.005)	(0.004)		
× InvDistrict		−0.014		
		(0.084)		
AnyCite × AnyControl	−0.029**	−0.030**		
	(0.014)	(0.013)		
× InvDistrict		0.028		
		(0.126)		
CitationsPerYear			0.209***	0.187**
			(0.060)	(0.056)
× InvDistrict				0.104
				(0.210)
ControlsPerYear			−0.026	0.005
			(0.038)	(0.035)
× InvDistrict				−0.292
				(0.660)
CitationsPerYear × ControlsPerYear			−0.152	−0.659
			(0.436)	(0.442)
× InvDistrict				2.052
				(1.380)
n	467	467	467	467
R^2	0.125	0.125	0.126	0.127

Standard errors are in parentheses, clustered by district.

* p<.10, ** p<.05, *** p<.01

The dependent variable Z_{ij} takes the value 1 if litigation for patent i occurs in district j and zero otherwise. We observe Z_{ij} in 89 districts for each of 467 litigated patents and use fixed effects by district. The source for these data is all district court validity and infringement decisions in U.S. patent cases, during 1953-2002, whose opinions are published in the *United States Patents Quarterly.* Patent variables come from the NBER data set and from the U.S. Patent and Trademark Office website. In this table we restrict attention to pre-litigation citations to litigated patents with application dates between 1975-86 and to cases in which the patent holder is the plaintiff.

Chapter 4

From Flash of Genius to the Federal Circuit: An Analysis of Patent Enforcement in the 20th Century[1]

[1]McGahee, Thomas P. To be submitted to the *Journal of Law, Economics and Organization*.

4.1 Introduction

Article I, Section 8, of the United States Constitution empowers Congress to "promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries." Two important economic principles together motivate the institution of intellectual property protection. First, technological change through inventive activity is a key driver of economic growth (Solow 1957). Second, inventive activity will be underprovided unless inventors expect exclusive rights to their inventions (Clark 1907). The patent system is designed to encourage economic growth by addressing the public good problem inherent to invention.[2] These principles provide a filter through which to view patent policy and judicial precedent. Do patents, as defined by patent policy and upheld by the courts, simply offer a reward for imagining something first, or do they provide an incentive to contribute to technological progress? In this paper, I examine how patent policy and enforcement relate to two trends in patenting behavior that take place over the course of the twentieth century: the rise of the corporate research program and the rash of submarine patenting by litigious patentees. The former illustrates the success of the patent system; entire research and development departments and organizations are built and continue to operate on the presumption of intellectual property protection. The latter illustrates a failure of the patent system. A submarine patent, intended by the patentee to remain hidden until someone produces a similar, "infringing" technology, does nothing to promote the progress of science and useful arts but only hinders such progress.

I conduct the first test of whether significant changes in patent policy and precedent in the 20th century have disproportionate effects on the enforcement of corporate patents relative to those of individual inventors in terms of litigation risk, duration, and outcomes. I also consider the extent to which these policy changes may be responsible for the increase in submarine patenting activity. This paper is the first to examine the characteristics of a comprehensive set of data on patents litigated between 1929 and 2006 to a published court

[2] Khan (1995) provides evidence of this sentiment among judges in the early 19th century.

decision on validity or infringement. The data set is an extension of the 1953–2002 data gathered from the *United States Patents Quarterly* by Henry and Turner (2006) and later used by Atkinson et al. (2009). I compare litigated patents to a "matched" set of control patents and find that litigated patents differ significantly from typical patents in several observable ways, including their rates of corporate ownership and continuation use. I find that these and other patent characteristics are also related to the duration and outcome of litigation. By studying how these relationships respond to policy changes, I evaluate whether specific patent policy changes contribute to the success or failure of the patent system to encourage technological innovation.

I find that the "flash of genius" requirement for patent validity set forth by the Supreme Court in *Cuno Engineering Co. v. Automatic Devices Co.*, 314 US 84 (1941), tends to disproportionately prolong the course of litigation for corporate patentees relative to individual inventors. Specifically, the effect of corporate ownership on the probability of an appeal rises by 24 percentage points in the flash of genius era. This result holds even when I control for the effect of declaratory judgment suits, which begin after the Declaratory Judgment Act of 1934. Priest (1980) describes the probability of an appeal as dependant on the extent to which litigants differ in their expectations of success. Thus, a potential explanation for this result is that shifting judicial attitudes and precedents concerning corporate patenting in the flash of genius era may have increased the divergence of litigants' expectations of success.[3] The Patent Act of 1952 rejects the flash of genius test and the dependency of patent validity on the manner in which an invention is conceived. I find that it reverses the flash of genius effect on the duration of corporate litigation. To the extent that corporate patentees are disproportionately penalized in the flash of genius era, such a penalty reveals the failure of the patent system to maintain its focus on stimulating technological innovation.

The Patent Act of 1952 also codifies the legality of patent application continuations which modify or resubmit earlier applications while maintaining the original application's

[3]Lanjouw and Schankmeran (2004) compare the predictions of divergent expectations and asymmetric information models and find evidence that patent litigation is driven primarily by divergent expectations.

priority date. Earlier justification for continuations relies on judicial precedent set in *Godfrey v. Eames*, 68 US 317 (1863). I find that the Patent Act of 1952 improves trial outcomes for patents issued from continuations relative to ordinary patents. I also find that cases litigated to a decision soon after the Patent Act become less likely to involve continuations than those decided prior to the Act. Appealing again to Priest's model of selection into litigation and appeal, these results suggest that litigants' expectations of success in disputes over continuations may have converged upon the codifying of the continuation procedure into law. However, this continuation-friendly legal environment gives rise to explosive growth over time in the use of continuations, particularly among patents eventually litigated. I provide evidence that the relationship between continuation use and litigation in recent decades is due to submarine patenting behavior rather than other possible explanations and conclude that one long-run effect of the Patent Act has been to inadvertently bring about a rash of submarine patenting.

This paper proceeds as follows. Section 4.2 provides a review of the primary policy changes of interest. Section 4.3 describes the data. In Section 4.4, I provide descriptive statistics for patent characteristics, and I summarize decision rates across policy eras. In Section 4.5, I present an econometric analysis of selection into litigation using the pooled sample of litigated and control patents. Then, conditional on litigation to a decision, I estimate the effects of various patent characteristics and policy changes on the probabilities of at least one appeal and of various findings on validity and infringement. I conclude in Section 4.6.

4.2 History

Congress passed the first United States patent statute in 1790, not long after the ratification of the Constitution. It allowed an inventor to seek a patent for any "sufficiently useful and important" invention. The Patent Act of 1793 included the requirement that a patentable invention must be "new and useful." The first precedent resembling the modern requirement of non-obviousness was set in *Hotchkiss v. Greenwood*, 52 US 248 (1850). In that case, the

Supreme Court ruled that a patentable invention should require more ingenuity than that of "an ordinary mechanic acquainted with the business" and distinguished the work of an inventor from that of a skilled mechanic in the field. In 1941, Supreme Court Justice William Douglas delivered the opinion in *Cuno*, stating that to be patentable, a "new device, however useful it may be, must reveal the flash of creative genius, not merely the skill of the calling." The opinion goes on to prescribe that "Strict application of that test is necessary lest in the constant demand for new appliances the heavy hand of tribute be laid on each slight technological advance in an art." The ruling is the most famous of several Supreme Court decisions from that time period advocating strict requirements for patentability which together came to set a powerful precedent. Analyses of patent cases from the period following the *Cuno* decision show that rates of invalidity even among lower court decisions rose significantly (Baum 1974; Webb 1957).

The context for the rising standard of patentability was one of anti-monopoly sentiment and distrust of large corporations.[4] At the request of President Franklin Roosevelt, Congress established the Temporary National Economic Committee (TNEC) in 1938 to study the effects of market power concentration on American industry. Roosevelt included patent laws as an area of concern, particularly as to whether the patent system suppressed innovation by creating industrial monopolies (Anderson, 1941). The final report of the TNEC, published in 1941, asserts the following:

> "All inventions ... fall into three rather distinct classes: First, creations which exhibit individual insight; second, derivative processes, worked out by professional staffs, equipped with laboratory facilities; third, variations upon a basic design such as a dozen workmen would independently contrive. The mark of the first is genius; of the second, professional competence; of the third, mechanical ability. It was patience on the part of the man of genius which the Constitution wished

[4]Israel (2006) provides a review of political and legal commentary at the time of the *Cuno* decision.

to reward; the mere display of capacity to contrive has been repeatedly frowned upon by the United States Supreme Court" (Hamilton, 1941, p. 156).

It was this vision of a heroic "man of genius" to which Douglas was likely alluding in the *Cuno* opinion; Douglas was among the original members of the TNEC. The distinction drawn between individual insight and the work of laboratory staffs made clear the distrust of big business working its way into the patent system. In 1944, Judge Thurman Arnold, who as an Assistant Attorney General had led the TNEC investigation into patents, delivered an opinion in *Potts v. Coe*, 140 F.2d 470, which stated plainly his belief that patents "are not intended as a reward for the collective achievements of a corporate research organization." He admitted that "routine experimentation in the great corporate laboratories can produce results beyond the imagination of twenty years ago," but characterized such results as "the product not of inventive ability but of the financial resources and organizing ability of those who operate the laboratories." He concluded that "to give patents for such routine experimentation on a vast scale is to use the patent law to reward capital investment, and create monopolies for corporate organizers instead of men of inventive genius."

In the context of the economic premise for intellectual property rights I describe above, this distinction between the patience of the inventive genius and the financial resources of corporate laboratories is immaterial. Whether the private cost of inventive activity is the time of an inventor or the capital of a firm, the investment of either depends on the extent to which the individual or firm expects to capture the returns from successful inventions. The investment of either also serves to promote the progress of science, technological innovation and therefore economic growth. Khan (1995) studies nearly 800 patent litigation cases in the early 19th century and finds that judges in that era consistently held to that view of the patent system as fostering economic growth by motivating inventors based on expected returns. One hundred years later, as evident in the opinions above, the Supreme Court and others redirected court precedent from encouraging economic growth to protecting the solitary "man of genius" from the encroaching corporate machine.

In July of 1952, Congress passed the Patent Act of 1952, which served to revise and codify the laws relating to patents. Section 103 was widely interpreted to codify the "skilled mechanic" test described in *Hotchkiss* and eliminate the "flash of creative genius" test from *Cuno*. It states:

> "A patent may not be obtained ... if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made."

The second sentence served both to eliminate the requirement of a definite moment of creative inspiration and to dismiss any distinction between the work of the solitary inventor and the collaborative efforts of the corporate laboratory. By the time the act was passed, fear of the inevitable corporate control over technological innovation had largely dissipated. Jewkes et al. (1958, p.37) surveyed what was then becoming the modern view of inventive activity and summarized that view as follows:

> "The individual inventor is becoming rare; men with the power of originating are largely absorbed into research institutions of one kind or another, where they must have expensive equipment for their work. Useful invention is to an ever-increasing degree issuing from the research laboratories of large firms which alone can afford to operate on an appropriate scale ... The consequence is that invention has become ... less the result of intuition or flashes of genius and more a matter of deliberate design. The growing power to invent, combined with the increased resources devoted to it, has produced a spurt of technical progress to which no obvious limit is to be seen ... Something is actually occuring in the world of technology which is ... bringing about improved standards of living."

Patent enforcement was strengthened further in 1982 when Congress established the Court of Appeals for the Federal Circuit (CAFC). The CAFC was given jurisdiction over all patent cases appealed from U.S. district courts. Henry and Turner (2006) show that the patent-friendly stance taken by the CAFC has significantly reduced rates of invalidity. They find that patentees in the CAFC era have been three times more likely than before to overturn a lower court finding of invalidity upon appeal. In response, they find that lower courts have begun to rule patents invalid half as often, and appeals of invalid decisions have risen by 25 percent. Atkinson et al. (2009) find evidence that the anticipation of the CAFC's establishment also effectively put an end to the practice of forum shopping across court venues based on non-uniformity of validity rates.

In this study, I conduct the first test of whether the significant changes in patent policy and precedent of the 20th century have had disproportionate effects on corporate patentees relative to individual inventors in terms of litigation risk, duration, and outcomes. My goal is to determine whether the "flash of genius" precedent succeeded at deterring the enforcement of corporate patents and whether the Patent Act of 1952 effectively reversed any anti-corporate effects from that precedent. The balance of the CAFC's impact between corporate and individual patentees is also of interest. Corporate ownership has become increasingly common among patents since the 1950's. The empirical framework in this study allows me to test whether patent policy has become increasingly friendly to corporate patentees over the same period, first through the Patent Act of 1952 and then perhaps through the CAFC.

It is my contention that the anti-corporate sentiment of the "flash of genius" era is inconsistent with the economic premise of the patent system. To the extent that corporate patentees may be disproportionately penalized in that era in terms of litigation risk and outcomes, I contend that such a penalty constitutes a failure of the patent system to maintain its focus on stimulating technological innovation and economic growth. The patent right is to be an incentive for investment in the "Progress of Science and the useful Arts," whether that investment is the time and toil of an individual or the financial resources and organizing ability of a firm.

There is another potential explanation for the increase in invalidity rulings in the 1940's. The Declaratory Judgment Act of 1934 gave accused patent infringers the right to preempt their accusers and initiate litigation. Prior to its enactment, a patent holder could hold the threat of a lawsuit over the head of a potentially infringing party indefinitely, and the accused infringer could not initiate legal action to determine the extent of his liability to the patent holder. Under the threat of future litigation, the accused infringer faced a choice between continuing under this uncertainty or abandoning the potentially infringing enterprise. These conditions allowed the patent holder to unduly exert influence, by threatening future patent enforcement, over competitors whose activity might have been cleared of infringement if the dispute were to go to court. In addition, the patent in question might have been ruled invalid if the dispute were litigated. The Declaratory Judgment Act limited the patent holder's ability to exert such influence indefinitely by allowing accused infringers to initiate the litigation of a dispute.

Moore (2001) finds that patents disputed in declaratory judgment suits are much more likely to be be found invalid than those at issue in infringement suits filed by the patent holder. She argues that the party who chooses the forum and timing of the suit has a critical advantage. Alleged infringers gained the ability to initiate litigation and control these factors in 1934, which could contribute to an increase in invalidity rulings around the time of the *Cuno* decision. Also, unless patent holders responded to the Act by reducing threats of patent enforcement, the Act may have increased the probability of litigation for a given patent as potential infringers gained the right to initiate suits. It is unclear how these changes in the probability of litigation and invalidity may have disproportionately influenced corporate patent holders or patents issued from continuations. I am careful to control for the influence of declaratory judgments on litigation risk and outcomes in the analysis below.

Another important development in patent law during the course of the twentieth century was the codification in the Patent Act of 1952 of the practice of accepting application continuations. Continuations allow patent applicants to restart the examination process with an updated application while maintaining the original application's priority date. Applicants may use continuations to revise the claims from an original application in response to either the patent examiner's comments or recent technological developments which relate to the invention. Continuations are unique to the U.S. patent system. Prior to 1952, the use and defense of continuations relied on judicial precedent set in *Godfrey v. Eames*, 68 US 317 (1863).

Graham (2009) describes three strategic uses for continuations. The first entails using an initial application to lay claim to pioneering research while continuing to revise both the invention and the language of the claims describing it. Indeed, the continuation procedure is designed to encourage pioneering inventors to adopt patent protection. However, in both Graham's data and mine, patents issued from continuations include nearly twice as many references to related prior art as ordinary patents, evidence that the typical continuation does not represent pioneering research.

The second strategic use amounts to badgering patent examiners into granting low-quality patents by repeatedly submitting continuations of rejected applications. The goal is to build a large portfolio of patents for use in cross-licensing and bargaining as a defensive measure against potential litigation. Hall and Ziedonis (2001) find that firms in the semiconductor industry follow this strategy.

The third strategy involves establishing a priority date with an initial application and then filing multiple continuations in order to delay the patent from being issued. While the application remains under examination, historically kept secret by the U.S. patent office, other firms may bring similar technology to market without knowledge of the patent's existence. The holder of the "submarine" patent can even revise his claims to more closely match the infringing product or process with another continuation. When the patent finally issues, the patentee can sue for infringement.

Revisions to U.S. patent law made in 1995 and 1999 reduce but do not eliminate the incentive to follow this submarining strategy. For patent applications filed since 1995, patent protection now extends for 20 years from initial application rather than 17 years from grant. This change reduces the incentive to submarine in industries with long product life cycles. For those filed since 1999, the U.S. patent office now makes most applications public after 18 months, but applicants can avoid this by submitting a statement that they do not intend to file an application for the same invention at any foreign patent office that requires publication. The changes of the late 1990's are too recent to affect many patents involved in cases adjudicated by 2006.[5] Therefore, for this study I expect the relationship between continuations and litigation to be balanced by submariners prone to litigation and defensive patentees attempting to avoid it, the primary policy "change" for which I intend to study the response of continuations is the Patent Act of 1952. I also test for any disproportionate effects of the CAFC on the enforcement of patents issued from continuations.

4.3 Data

For this study I examine a comprehensive set of patent litigation data which includes virtually all patents subject to a decision on validity or infringement published in the *United States Patents Quarterly* (USPQ) between 1929 and 2006. The data set is a descendent of the 1953–2002 data gathered by Henry and Turner (2006) and benefits from the recent work of those authors and myself to extend the data back to 1929 and forward to 2006. Decisions not based on validity or infringement, fewer than 10 percent of all cases published in the USPQ, are excluded. Some examples include venue challenges and decisions based on fraud,

[5]Among litigated patents in the USPQ data issued since 1990, only 17 percent have original application dates subject to the 1995 change, and only 2 percent are subject to the 1999 change. However, these are necessarily patents with short grant lags due to truncation. A patent application beginning in the late 1990's and subject to continuations is unlikely to issue, become involved in a suit, and be adjudicated by 2006. The average grant lag and the prevalence of continuations among adjudicated patents may decline because of these changes, but 2006 is too early to tell.

patent misuse or inequitable conduct. Henry and Turner (2006) provide the full list of criteria for exclusion from the data set. Patent validity and infringement decisions published in the USPQ include a sample of district court decisions, nearly all such appellate court decisions, and a small number of decisions from the U.S. Court of Claims and International Trade Commission. District and other lower court decisions are matched to appellate and subsequent decisions for the same case using the USPQ and case histories from *Westlaw*. A total of 8,555 unique patents are involved in 6,244 distinct cases. Some patents are involved in multiple cases, and some cases involve multiple patents. The unit of observation for this study is a particular patent in a particular case (a "patent case"). There are a total of 9,329 patent cases.[6]

To compare the characteristics of litigated patents to typical patents, I construct a control group. For each patent, I randomly choose a control patent from among the set of all U.S. patents (litigated and non-litigated) with a common 3-digit U.S. Patent Classification (USPC) assignment and an issue date within one month of the litigated patent's issue date. This allows me to compare a range of patent characteristics between litigated and matched patents while controlling for technology and cohort effects.[7]

Patent-specific data for litigated and matched patents are collected directly from the patent documents. The full text and images of patent documents are viewable at the United States Patent and Trademark Office (USPTO) web site.[8] I classify each litigated and control patent according to the six technological categories described in the National Bureau of Economic Research (NBER) Patent Citations Data File (Hall, Jaffe and Trajtenberg 2001): Computers and Communication, Drugs and Medical, Chemical (non-drug), Electrical and Electronic, Mechanical, and Miscellaneous (low-tech industries).

[6]The full data include another 30 patent cases for which the USPQ does not record the full patent number.

[7]This approach is similar to that of Lanjouw and Schankerman (2001) but differs in two ways. I match on USPC assignments rather than International Patent Classification (IPC) assignments because IPC assignments are not included on patents in the early years of the data. I use issue year rather than application year because the USPTO web site's advanced search allows filtering by issue year but not by application year for patents issued prior to 1976.

[8]http://www.uspto.gov

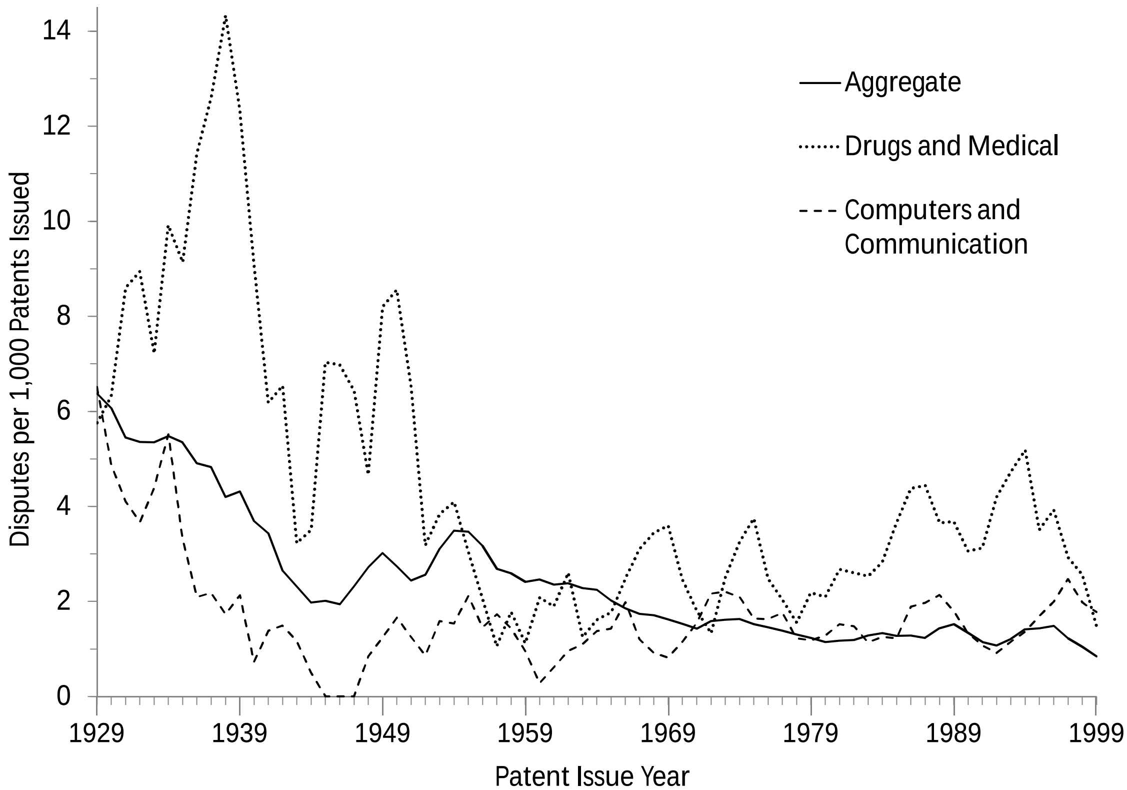

Figure 4.1: Disputes Litigated to a Decision per 1,000 Patents Issued

Figure 4.1 shows estimates of the number of patent disputes litigated to a decision per thousand patents issued each year. The aggregate rate is the rate of litigation across all patents. Industry-specific rates for Chemical, Electrical, Mechanical, and Miscellaneous patents are not shown because each closely follows the aggregate rate but consistently remains just under it. Rates are three-year moving averages adjusted for truncation and underreporting of district court decisions. Nearly all appellate court decisions are published in the USPQ, but only a sample of district court decisions are published. Thus, I must account for underreporting of cases which reach a decision in a district court but which do not proceed to an appeal. For each issue year, I first restrict attention to district court decisions which are published ("reported") in the USPQ and compute the percentage of these for which I also observe an appeal. I then divide the total number of appellate decisions by this percentage to produce an estimate of the total number of patent cases involved in litigation to at least a district court decision.[9] Rates for each year in the 1980's and 1990's are adjusted for truncation using the lag distribution of patents issued twenty years earlier.

For each technological category, I estimate the highest rates of litigation in the 1930's. Nearly 1 in every 100 patents issued in the 1930's in the Drugs and Medical sector is litigated to a decision, and the overall rate that decade is about 1 in every 200.[10] In the 1940's, both the number of patents issued in each sector and the rate of litigation among those patents falls significantly. Patenting picks up again in the 1950's; changes in litigation rates vary by sector. The overall rate through the 1940's and 1950's is about 2.8 patent cases per thousand patents issued. Following the 1950's, litigation rates fall steadily through the 1990's with two exceptions. The litigation rate in the Computers and Communication category rises in the 1970's to remain at about 1.6 patent cases per thousand patents through the 1990's, the highest rate in that sector since the 1930's. Drugs and Medical patents face the highest litigation rate in all but the late 1950's and early 1960's when the rate dips close to only 1 case per thousand patents. Following that low, the rate grows over the decades and reaches an average of 3.2 per thousand in the 1990's. Rates in every category slip in the most recent years reported; attempts to correct for truncation are likely least effective in those years.

4.4 Descriptive Statistics

Patent variables and descriptive statistics for litigated and control patents are listed in Table 4.1. I include a simple z-statistic to test the statistical significance of the difference in means between litigated patents and controls. I use a 5 percent significance level to interpret the statistic unless otherwise noted.

[9] This estimate will be biased downward if published district court decisions are inherently more likely to be appealed than unpublished district court decisions.

[10] Patents classified as "Drugs and Medical" in the 1930's and earlier are typically patents for medical devices, e.g. respirators, leg braces, bandages, syringes, etc.

For each patent I determine whether the patentee is an individual or a firm by whether the patent document lists an assignee other than the inventor. For convenience, I refer to patents assigned other than to the inventor as "corporate" patents. The rate of corporate ownership among litigated patents in the USPQ data is 63 percent. The corporate ownership rate for control patents is similar at 62 percent. Figure 4.2 shows the increase in corporate ownership rates over time, dated by patent issue year. Both the litigated and control rates range from about 30 percent prior to 1920 to over 80 percent in the 2000's. Growth in corporate ownership appears to hit a snag in the 1940's but starts up again by the late 1950's. These trends may be related to anti-corporate sentiment in the flash of genius era. If patents become more difficult to enforce for corporate patentees, firms may shift toward relying more on other forms of intellectual property protection such as trade secrets.

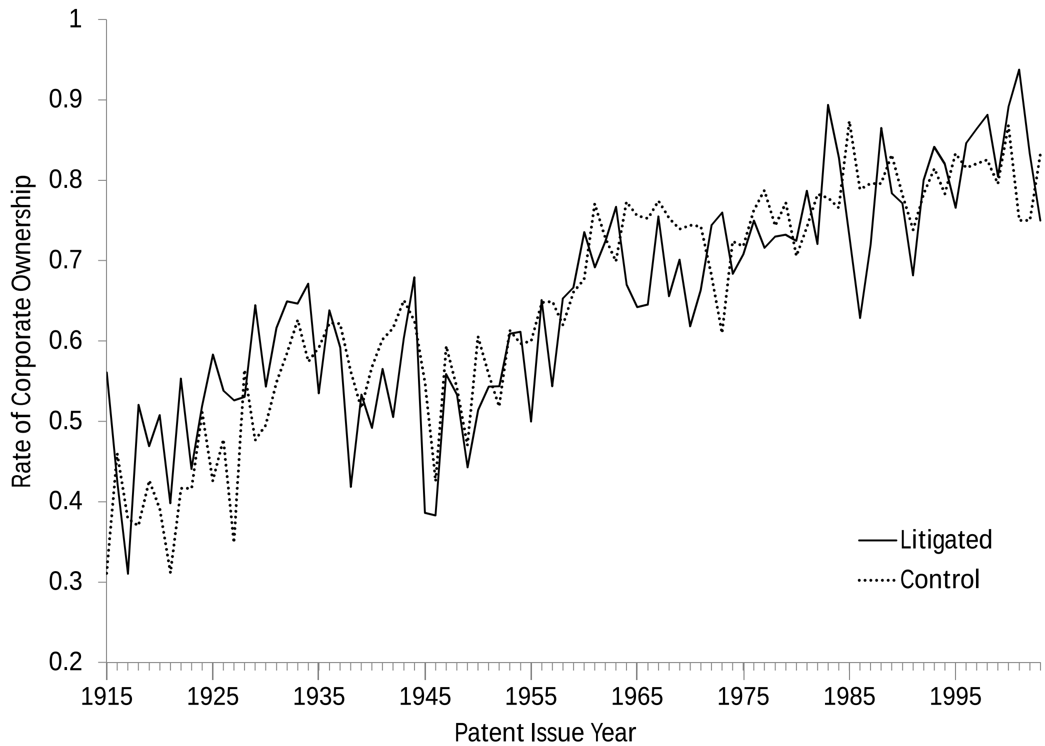

Figure 4.2: Corporate Ownership Rates by Patent Issue Year

I determine country of ownership by the address listed for the assignee on each patent. For patents not separately assigned, I use the address of the first inventor listed on the patent. The fraction of U.S. patents which have foreign owners among patents in the control group is 17 percent. The analogous fraction for litigated patents is just 7 percent. The difference is statistically significant. These statistics confirm the finding of Lanjouw and Schankerman (2001) that foreign-owned patents are less likely to be litigated. Their results further suggest that higher litigation costs may lead foreign owners to selectively litigate only cases they are relatively likely to win. I test the effects of foreign ownership on case outcomes in Section 4.5.3.

A patent application is required to list all inventors who are responsible for an invention, and each inventor is listed on the patent document when it issues. As shown in Table 4.1, the mean number of inventors listed on litigated patents is identical to that for the controls, an average of 1.37 inventors per patent. Figure 4.3 shows that over the sample period, the mean number of inventors grows from about 1.1 to 2.3 inventors per patent for both litigated and controls. This growth is largely due to the increasing number of corporate patents and the increasing number of inventors listed on corporate patents. The average number of inventors on patents owned by individuals only modestly increases from 1.1 in the 1910's to 1.3 in the 2000's. The same numbers for corporate patents are 1.1 and 2.5, respectively.[11]

Allison et al. (2004) find that litigated patents spend more time between application and grant than typical patents. They suggest two possible explanations. First, litigated patents are more likely than typical patents to be issued from continuations and divisional applications, and these procedures can add years to the time a patent spends under examination. However, they find that even among patents which issue directly from original applications, litigated patents tend to have longer grant lags. Another explanation is that litigated patents tend to be more complex—to have a larger number of claims and references. It may simply take more time to process more complex applications. Somaya (2003) suggests an additional

[11] Differences in these statistics between litigated patents and controls are negligible.

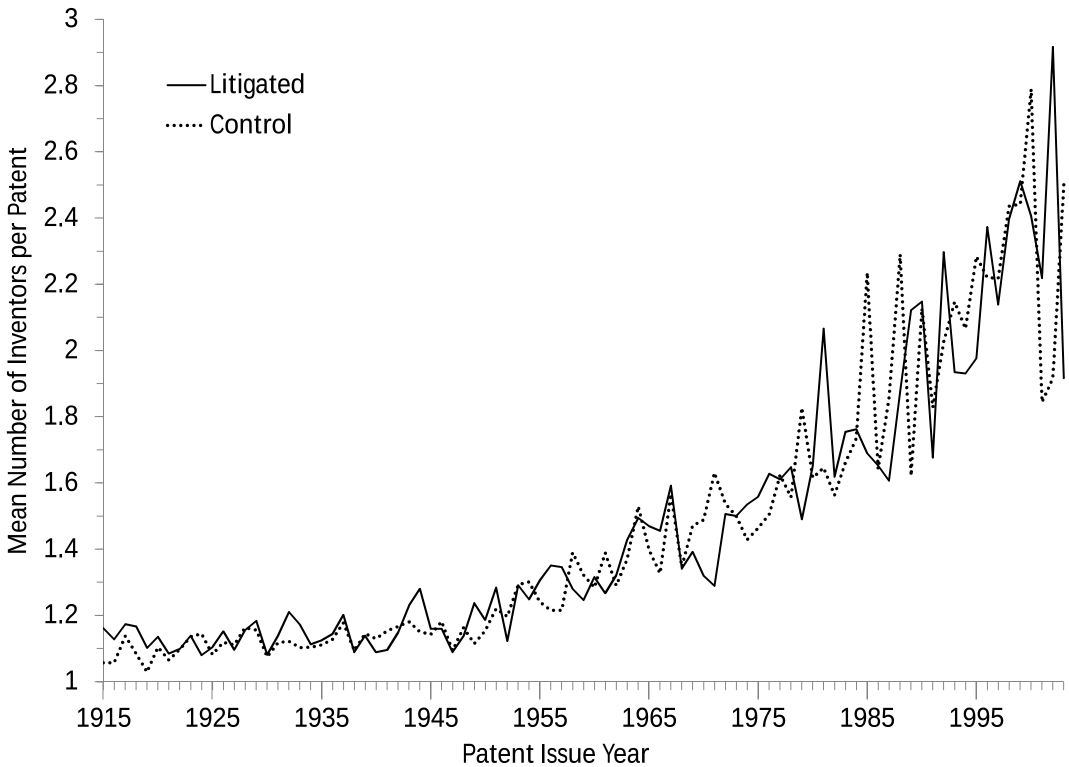

Figure 4.3: Mean Number of Inventors by Patent Issue Year

explanation after finding the same relationship in his own study. Greater uncertainty about the scope or validity of a patent's claims may increase the lag between application and grant as well as the likelihood of litigation. For possibly all of these reasons, litigated patents tend to have relatively long grant lags. I measure the grant lag as the time in years between the filing of the patent's original application and the issuance of the patent. As shown in Table 4.1, patents litigated to a published decision have an average grant lag of about 3.5 years. The average for the controls is 2.7. The difference is statistically significant.

Litigated patents are twice as likely to issue from continuations as their controls. The fraction of patents issued after at least one continuation is 14 percent among litigated and 7 percent among control patents. Figure 4.4 shows the fraction of patents issued each year which have at least one continuation. Continuations are more common among litigated patents nearly every issue year. Continuations are also becoming increasingly common over time. The increase appears to begin in the early 1950's, near the time that the Patent Act of 1952 first codified the practice of accepting continuation applications into law. As described above, the earlier acceptance of continuations relied on judicial precedent. The growth in continuation use is especially strong among litigated patents. Since the 1950's, the increase in continuations has been roughly twice as large among litigated patents as among their controls. Together, this evidence suggests that continuations may be used more often to hide submarine patents than by defensive patentees, and litigious use is increasing over time. While it is too early to test the impact of the patent law revisions of the late 1990's, this evidence clearly demonstrates the need for such changes.

One alternative explanation for the high rates of continuation use among litigated patents is that pioneering inventors may be likely to use continuations, as described by Graham (2009), and they may be likely to face litigation due to the uncertainty involved in young fields of research. In Table 4.2, I compare the mean number of backward references among patents issued from continuations to the same measure for ordinary patents which issue directly from an original application. I also compare the median age of prior art cited by each kind of patent. I list standard errors in parentheses to allow for a difference in means test.[12] Among both litigated patents and controls, patents issued from continuations cite statistically significantly more prior art. This casts doubt on how frequently continuations may be used by pioneering inventors. In addition, though continuations do tend to cite younger patents, the difference is smaller for litigated patents than for controls. This suggests that any pioneering use of continuations which may be taking place does not appear to attract litigation.

[12]The test statistic for the significance of the difference in means is the difference divided by the square root of the sum of squared standard errors. It is distributed approximately standard normal for this number of observations.

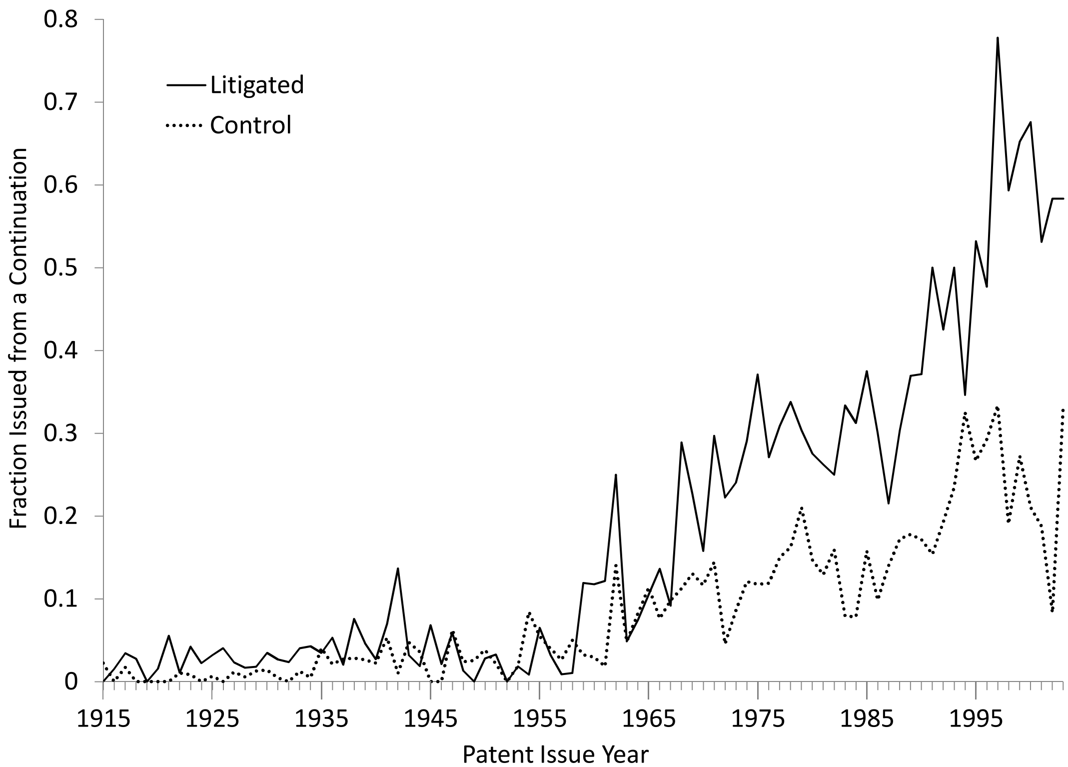

Figure 4.4: Fraction of Patents Issued from a Continuation

Divisional applications are also more common among litigated patents, as shown in Table 4.1. 7 percent of litigated patents and 4 percent of controls issue from divisions. This is interesting because divisional applications are created at the request of the patent examiner, not the applicant. When the examiner considers an application to contain two or more distinct inventions, he can require the applicant to divide the additional claims into a separate application. As with a continuation, a divisional application maintains the priority date from the original, but the applicant does not directly control his ability to file divisions. Still, Allison et al. (2004) describe anecdotal evidence from patent examiners that some applicants intentionally file broad applications to provoke a request for division. This strategic use of divisions may explain their correlation with litigation. However, there is some evidence that divisions simply piggyback their way into litigation. In this data, a divisional patent goes to court with an average of 3.1 other patents involved in the same case. Ordinary patents and continuations each go to court with an average of 2.2 other patents.

Patent examiners assign each patent one or more technological class codes defined by the U.S. Patent Classification System. These codes categorize patents to facilitate searches for related prior art. Patents with a larger number of classification codes represent inventions which relate to a larger number of technological areas. For each patent, I count the number of different assignments at the 3-digit "class" level as a measure of its technological breadth. Using the International Patent Classification (IPC) system, Lerner (1994) finds that biotechnology patents with more class assignments are significantly more likely to be litigated. He argues that these patents face more potential infringers because of their breadth. Lanjouw and Schankerman (2001; 2004) show that Lerner's results are not representative for typical patents. Comparing large samples of litigated patents in all fields to control groups, they find that technological breadth, whether computed using IPC or USPC assignments, has the opposite effect on the probability of litigation. They suggest that firms may find it more difficult to detect infringement of broad patents and that this effect dominates any increase in the number of potential infringers. Litigated patents in the USPQ data have an average of about 2 USPC assignments; controls have 2.25. The difference is statistically significant and provides further evidence that Lerner's results are not representative.

Each patent is composed of a set of claims that describe the novel features of the invention and define exactly what is included in the property rights assigned to the patent holder. Lanjouw and Schankerman (2001) interpret the number of claims as a measure of a patent's scope or breadth, and they find that litigated patents tend to have significantly more claims than patents in their control group. Moore (2003) rejects the idea that breadth is related to the number of claims, arguing that the same invention could be documented in one broad claim or fifty narrow claims. She suggests that a higher number of claims reflects only the willingness of the applicant to pay higher legal fees associated with drafting and prosecuting those claims. Harhoff et al. (2003b) estimate a positive and significant relationship between claims and patent value as reported by surveyed patent holders. The mean numbers of claims presented in Table 4.1 confirm that patents litigated to a published decision include significantly more claims than their controls. Litigated patents have an average of 12.6 claims while their controls have only 8.1.

There is mixed evidence on the relationship between the probability of litigation and the number of backward references in a patent. Lanjouw and Schankerman (2004) find a negative and statistically significant relationship between litigation risk and backward references per claim. They argue that patents with fewer references are more likely to be in younger technological fields, which are subject to greater uncertainty about how the court will rule, and this leads to a higher likelihood of litigation. In contrast, Allison et al. (2004) find that litigated patents cite significantly more prior art than typical patents. They argue that a larger number of backward references signals a higher likelihood of validity and therefore of value. In general, their evidence supports the idea that more valuable patents are more likely to be litigated. In the USPQ data, patents litigated to a decision list an average of 10.3 backward references. Controls average 7.2. I also capture the median reference age for each patent in order to separately test the relationship Lanjouw and Schankerman (2004) describe between the age of a patent's technological field and its risk of litigation. The median patent cited by litigated patents is an average of 12.6 years old at the time it is cited. For controls, the average is 12.9 years. The difference is small and statistically insignificant, suggesting that younger fields do not necessarily face a higher risk of litigation.

Because the control group is matched by technological class assignments, the fraction of controls which fall into each NBER technological category tends to mirror the same figure for litigated patents. Rather than include redundant statistics for controls, at the bottom of Table 4.1, I compare the technological distribution of litigated patents to the distribution for the full population of patents issued between 1915 and 2003. Patents in the following categories are under-represented among litigated patents: Chemical (non-drug), Computers and Communication, and Electrical. Categories over-represented among litigated patents relative to the population include: Drugs and Medical, Mechanical, and Miscellaneous (low-tech).

Table 4.3 presents the fraction of patent cases in each policy era for which the patent holder is the defendant. For the most part, such cases are filings for declaratory judgment, but a handful of these cases are typical patent infringement suits in which the defendant counterclaims for infringement of his own patent by the plaintiff. For convenience, I refer to all patentee-defendant cases as declaratory judgments below. I omit cases decided prior to the Declaratory Judgment Act of 1934. I classify patent cases by decision dates into those made prior to the *Cuno* decision in November, 1941, those made between then and the Patent Act of 1952, those made between the Patent Act and the establishment of the CAFC, and those made since its establishment. I divide patent cases by ownership and by application history to determine the extent to which various kinds of patents are disproportionately subject to declaratory judgment suits.

Across eras, the patent holder is more likely to be the defendant in patent cases involving assigned patents than in those involving unassigned patents. Thus, corporate ownership appears to be positively related to the risk of a declaratory judgment suit, conditional on involvement in litigation. There is also a clear spike in the frequency of declaratory judgment suits in the flash of genius era for both assigned and unassigned patents. The fraction of patent cases with patentees as defendants jumps from 4.5 percent among assigned patents in the earliest era to 17.2 percent among those in the flash of genius era. The analogous jump among unassigned patents is from 2.9 percent to 12.5 percent. The frequency of declaratory judgments then falls across eras for both assigned and unassigned patents. In the CAFC era, 9.4 percent of corporate patentee cases and 8.3 percent of those involving unassigned patents are declaratory judgments.

Declaratory judgments are more common among patent cases involving continuations in all but the earliest era, in which just 1.6 percent of patent cases involving patents issued from continuations are declaratory judgments. The rate among ordinary patents in that era is 3.9 percent. In the flash of genius era, patent cases involving continuations are declaratory judgments much more frequently than those involving ordinary patents. The rates are 25.4 percent for continuations and 14.6 percent for ordinary patents. These rates fall across eras to 11.1 percent for continuations in the CAFC era and 8 percent for ordinary patents. The correlations between declaratory judgments and both corporate ownership and continuations require careful treatment of declaratory judgment cases in the analysis below. In each estimation in Section 4.5, I account for these correlations and separate out their effects on the risk and outcomes of litigation.

The vast majority of adjudicated patent cases reach one of three decisions regarding validity and infringement. When a patent is found "invalid," the court is essentially ruling that the patent should have never been granted. An alleged infringer may attempt to convince the court that at the time the patent application was filed, the invention was either obvious or not novel and thus failed to meet the legal requirements for patentability. The question of infringement becomes moot when a patent is declared invalid because the court's decision effectively revokes the exclusivity of the patent holder's rights to the invention. When a patent is found "not infringed," the court is ruling that the alleged infringer's product or process does not fall within the scope of the patent holder's claims. The patent retains validity, but a "not infringed" decision effectively clarifies the scope of patent protection to exclude the alleged infringement in dispute. The patent holder wins only if a patent is found both "valid and infringed." The alleged infringer is then ordered to compensate the patent holder for damage caused by the infringement.

Table 4.4 presents statistics on case outcomes by policy era. I classify patent cases by decision dates as above but no longer omit cases decided prior to the Declaratory Judgment Act. I include both patentee-plaintiff and patentee-defendant cases. I summarize district court decisions that fall within each era only for cases for which I observe the initial district court decision in the USPQ. I exclude cases for which I learn about the district court decision through a published appellate court decision in order to avoid overestimating the rate of appeal and the similarities between district court decisions and final outcomes. I also summarize the final observed decision in each case, not excluding those for which only the appellate decision is published in the USPQ.

Looking first at final decisions of invalidity, the rate goes from 45 percent in the early era to 61 in the flash of genius era. This is consistent with the tightening of the standards for patentability promulgated by the Supreme Court in that era. I can attribute very little of the increase in invalidity to the concurrent increase in declaratory judgment suits; the rate of invalidity among only patentee-plaintiff suits rises similarly from 44 to 60 percent (not shown in the table). The following era, marked by the Patent Act of 1952, does little to reverse the change in the invalidity rate. It does however reduce the probability of losing on infringement, bringing the patentee's probability of winning back up to 27 percent from its dip to just 18 percent in the flash of genius era. The establishment of the CAFC reverses the earlier trends in both validity and infringement by pushing the rate of invalidity down to just 29 percent, a new low, and the rate of "not infringed" decisions to a new high of 39 percent. District court decisions follow the same patterns across eras, but the patentee win rate does not fall below 27 percent even in the flash of genius era. The rate of appeal rises with each era, making the biggest jump upon the CAFC's establishment. The effects of the CAFC shown here are consistent with the findings of Henry and Turner (2006).

4.5 Estimation

Lanjouw and Schankerman (2001) present an estimation of the effects of various patent characteristics on the risk of litigation using a sample of lawsuits filed between 1975 and 1991, and they find several statistically significant relationships. However, the expense of litigation varies greatly across cases, with legal fees largely determined by how far a case progresses, and their study restricts attention only to the initial filing of suits. In a follow-up study, Lanjouw and Schankerman (2004) test for relationships between patent characteristics and litigation outcomes for cases filed between 1978 and 1999. They find little evidence that patent characteristics are related to the stage at which a suit is settled or to the court's decision if no settlement is reached. However, 75 percent of the suits in their data are settled prior to a pretrial hearing, and another 20 percent are settled before a court decision. With the comprehensive data set described above which by construction focuses strictly on patents litigated all the way to a decision, I am able to reassess the relationships between various patent characteristics and case outcomes as well as the responses of those relationships to significant policy changes.

First, I use the pooled sample of litigated patents and their controls to estimate the effects of various characteristics on the probability of litigation to a published decision. Conditional on a published district court decision, I then estimate the effects of these characteristics on the probability of at least one appeal. I use this measure rather than duration in months because, as Lanjouw and Schankerman (2004) note, legal costs vary more directly with the number of stages through which litigation proceeds than with actual duration, which depends heavily upon court resources and external factors. Focusing on a first appeal also allows me to limit the extent of truncation issues. Finally, I estimate the effects of various patent characteristics on the probabilities of various decisions on validity and infringement, again conditional on litigation to a published decision. In each estimation, I allow the effects of corporate ownership and continuation history to vary across significant changes in patent policy and precedent. I accomplish this by interacting each of these variables with dummy variables which indicate the onset of each era. The interaction terms capture the changes in the effects of corporate ownership and continuations on litigation risk and outcomes in each era relative to the preceding era. Congress passed the Declaratory Judgment Act of 1934 on June 14, 1934. The "D.J. Act of 1934" era dummy is set to 1 for cases decided in June of 1934 or later. Supreme Court Justice William Douglas delivered the opinion in *Cuno Engineering* *v. Automatic Devices* on November 10, 1941. The "Flash of Genius" era dummy is set to 1 for cases decided in November of 1941 or later. Congress passed the Patent Act of 1952 on July 19, 1952. The "Patent Act of 1952" era dummy is set to 1 for cases decided in July of 1952 or later. The CAFC was established on October 1, 1982. The "CAFC" era dummy is set to 1 for cases decided in October of 1982 or later. Thus, by design, the effect estimated for each policy change is a permanent effect, but it may be cancelled out by the estimated effect of a future policy change. Note that I only use the era indicators for interaction effects; they do not enter directly into any regression. This is because they would be identical between litigated patents and their controls in the first estimation, and they are obviated by the full sets of decision year dummies in the following estimations.

4.5.1 Litigation to a Published Decision

I model patent j's latent propensity to be involved in litigation to a published decision conditional on patent j belonging to the pooled sample as follows:

$$\begin{aligned}\text{Litigated}_j^\star = \delta + \text{Assigned}_j \left(\eta + \lambda X_j^{\text{Era}}\right) + \text{Continuation}_j \left(\psi + \theta X_j^{\text{Era}}\right) \\ + \beta X_j^{\text{Patent}} + \varepsilon_j \end{aligned} \tag{4.1}$$

where Assigned_j is a binary indicator for whether the patent is assigned other than to the inventor. This indicates the patent is what I refer to as a "corporate" patent above. The effect of Assigned_j depends on the policy era into which the litigated patent and its control together fall. η measures its baseline effect in the earliest era. λ is a vector of interaction effects between Assigned_j and the vector of era dummies, X_j^{Era}. An era dummy for the earliest era is omitted. The effect of each era's onset is permanent in the sense that each era dummy is set to 1 for a patent observed any time after its onset. That is, unless the effect of a future policy change counteracts it, the effect of each policy change persists indefinitely. Continuation_j is a binary indicator for whether patent j has at least one continuation in its application history.[13] ψ is the baseline effect of a continuation in the earliest era. The elements in θ measure the effects of policy changes on the effect of a continuation. X_j^{Patent} is a vector of additional patent-specific variables. The error term ε_j is independently and identically distributed normal with mean zero and constant variance. It primarily reflects unobservable factors determining the probability of litigation. I do not observe $\text{Litigated}_j^\star$. Instead I observe

$$\text{Litigated}_j = \begin{cases} 1 & \text{if } \text{Litigated}_j^\star \geq 0 \\ 0 & \text{if } \text{Litigated}_j^\star < 0. \end{cases} \tag{4.2}$$

Table 4.5 presents the results of a probit estimation of the model above. The sample consists of patents involved in any validity or infringement decision published in the USPQ between 1929 and 2006 and the control patents matched to these litigated patents. Patents involved in multiple cases are included only once in the sample. Patents issued prior to 1947 do not include reference lists. I set backward references and median cited patent age equal to zero and set a pre-references indicator variable equal to 1 to provide a separate intercept for these patents. Among the 17,110 patents in the estimation sample, by construction, the rate of litigation to a published decision is approximately 50 percent and does not vary by technological category. The rate of litigation to a decision for the patent population is approximately 0.21 percent and does vary by technology. Thus, in addition to parameter estimates and marginal effects for a randomly drawn patent in the sample, the table includes conversion factors to compute marginal effects for a randomly drawn patent in the population. The appropriate factor depends on technological category. As a scale for comparison, the table also includes population probabilities of litigation to a decision for patents in each technological category. I describe the procedure for computing these population probabilities and

[13] I treat Continuation_j as exogenous in this analysis because in general it is determined well before the decision to litigate. However, it may suffer from endogeneity if applicants make decisions about whether to file continuations based on their intent to litigate in the future. I separately estimate a bivariate probit model for each era to address the endogeneity issue and note any substantial differences from the primary results in the discussion below. I find evidence of endogeneity bias only for CAFC-era estimates. Details of the bivariate probit estimations are in Appendix B.

conversion factors in Appendix A. I discuss the results below in terms of sample marginal effects and then conclude with a comment about the scale of population effects.

In the earliest era, the effect of corporate ownership on the probability of litigation is small and statistically insignificant. There is no statistically significant change in the effect of corporate ownership upon the passing of the Declaratory Judgment Act of 1934. In the flash of genius era, the partial effect of corporate ownership becomes statistically significant at about -4 percentage points (($\chi^2(1)$=5.26, p-value $< .05$). If corporate patent holders expect more difficult litigation in the flash of genius era, they may be less inclined to attempt enforcement through litigation.[14] The Patent Act of 1952 has no disproportionate effect on corporate patents, but the partial effect falls by an additional 6 percentage points upon the establishment of the CAFC. Thus, the finding of Lanjouw and Schankerman (2001) that corporate patentees are less likely to file litigation than individual patent holders, all else equal, holds by only a small margin until relatively recently. The effect more than doubles in the CAFC era. They examine patents involved in lawsuits filed between 1975 and 1991 and attribute their result to firms' having greater advantages in reaching settlement agreements and having larger patent portfolios to use in negotiations. The pro-patent environment ushered in by the CAFC surely increased the value of those portfolios and likely increased their usefulness in negotiations.

In the earliest era, the probability of litigation to a published decision is 19.4 percentage points higher for patents in the sample issued from continuations than for ordinary patents, all else equal. The effects of the Declaratory Judgement Act and the flash of genius precedent on that difference are statistically insignificant. The effect of a continuation drops by 10.9 percentage points in the era following the Patent Act of 1952. It then rises by 7 percentage points after the establishment of the CAFC. These estimated changes are statistically signif-

[14] In an unreported alternative specification, I omit all Patentee-Defendant cases and their controls as well as the declaratory judgment era interaction terms and find that the effect of corporate ownership on the probability of patentee-plaintiff litigation falls statistically significantly in the flash of genius era. This is further evidence that corporate patent holders became less inclined to file litigation in the flash of genius era. However, I report the results of the full model to study changes, if any, in the overall risk of litigation.

icant at .10 and .05 significance levels, respectively. With the Patent Act expressly codifying the legality of application continuations, its enactment may have reduced the divergence in expectations about trial outcomes between patent holders and alleged infringers in disputes over continued patents. This explanation is consistent with Priest's (1980) conception of litigation's dependence on divergence in litigants' expectations. This does not explain why litigation has increased in more recent decades for continued patents. In general, the CAFC's establishment only further reduced uncertainty about trial outcomes (Atkinson et al. 2009). The recent increase in litigious use of continuations may simply reflect the deliberate attempts of some patentees to pursue a submarine patenting strategy as described in Section 4.2.

It is important to note that the era indicators here are defined by decision date. An increase in submarine patenting following the Patent Act could take decades to go from original patent applications through multiple continuations eventually to grants, litigation, and finally to decisions. Among patent cases in the sample involving continuation patents applied for during the first 10 years after the Patent Act of 1952, roughly one third are not decided until the CAFC era. Two thirds of those from the following decade are not decided until the CAFC era. Thus, the finding above must be interpreted carefully. Cases decided soon after the Patent Act become less likely to involve continuations than those decided prior to the Act, likely because of convergence of expectations about their validity and therefore a greater likelihood that disputes can be settled outside of court. However, it is clear from Figure 4.4 that the growth since the Patent Act in continuation use among patents eventually litigated has been twice as large as that among controls. While the short-run effect of the Patent Act was to reduce the number of existing patents issued from continuations being litigated to a decision, the long-run effect appears to be an open invitation for continuation use in general and for litigious submarine patenting in particular.

In Appendix B, I address the potential for endogeneity bias in these estimates. I show that evidence of interdependence between the patentee's decision to file a continuation and his decision to litigate is extremely weak until after the Patent Act of 1952. In the CAFC era, there is strong evidence that the decisions are interdependent. The evidence suggests that the correlation between continuations and litigation in recent decades does not reflect a direct effect of issuance from a continuation per se. Instead, unobservable characteristics of some patent holders cause them to be more likely both to file continuations and to litigate. This is consistent with the idea that patent applicants in recent decades have begun to take advantage of the continuation procedure as part of a plan to eventually litigate the patent. I control for the interdependence of these decisions using a bivariate probit estimation, and I find that the direct effect of a continuation on litigation in the CAFC era is in fact negative and statistically significant. The relationship between continuations and litigation in recent years may thus be interpreted as follows. When a patent applicant decides to file a continuation, he often does so with the intention to litigate the patent in the future. This leads to the positive, statistically significant relationship in Table 4.5. Continuations may also result from rejection of an original application by the patent examiner. These continuations are exogenous in the sense that they are not related to the applicant's intent to litigate. They are prompted by the examiner's decision, though the applicant could also choose to abandon the application. Thus, to the extent that a continuation is exogenously determined, it may reflect a low quality patent, initially rejected by the patent office. Such patents may be less likely to face litigation simply because of the smaller size of the stakes.

Issuance from a divisional application and longer application-to-grant lag lengths also increase the likelihood of litigation. The sample partial effect of a division is 10.7 percentage points. This may be evidence of the intentional manipulation of divisional requests by submariners as described by Allison et al. (2004). Alternatively, the effect may just reflect greater uncertainty about validity; a divisional application typically covers an invention which even the applicant did not believe warranted its own patent. The grant lag length is computed by dividing the number of days between the filing of the patent's original U.S. patent application and the issuance of the patent by 365. The sample marginal effect at the mean is 2.3

percentage points per additional year, and the effect is statistically significant. The regression results suggest that the relationship between grant lag and litigation risk remains even when application history and numbers of claims and references (measures of patent complexity) are held constant. The remaining connection may be that which Somaya (2003) describes between uncertainty about validity and both longer lag lengths and higher litigation risk. In Section 4.5.3, I test whether grant lag is related to the risk of invalidity.

As expected, foreign-owned patents are litigated far less often than domestic patents. The sample partial effect is statistically significant at -25.6 percentage points. The effect of multiple inventors is small and statistically insignificant. All else equal, the likelihood of litigation increases with the number of claims in the patent but decreases with the number of technological classifications. Both effects are statistically significant. An increase in the number of claims by one standard deviation (about 12 claims) raises the probability of litigation for the average patent in the sample by about 12 percentage points. An increase in classifications by one standard deviation (just over 1 class) lowers the probability of litigation by 6.7 percentage points. Thus, patents litigated to a published decision tend to be relatively narrow technologically but painstakingly detailed into numerous claims. This may indicate that litigated patents tend to represent complex though narrow inventions or that for an invention of a given complexity, an applicant may attempt to bolster enforceability by breaking its description into more claims if he expects it to be valuable. I test the relationship between claims and case outcomes in Section 4.5.3.

Citing more prior art may also reflect an attempt to strengthen enforceability under an expectation of litigation. Patents with more references are more likely to be litigated, and the effect is statistically significant. At the mean for patents issued since 1947, an increase in backward references of one standard deviation (about 14 references) raises the sample probability of litigation by about 5 percentage points. I test the propensity for litigation in younger research areas separately by including the median reference age as a regressor. The marginal effect is small but statistically significant. A one standard deviation increase (about 11 years) in median reference age lowers the sample probability of litigation by about 1.2 percentage points. Thus, litigation rates are only slightly higher for patents in younger fields. This casts further doubt on the pioneering explanation for higher litigation rates among patents issued from continuations.

Note that the marginal effects described above are for randomly drawn patents from the sample. Using the aggregate conversion factor of .00839, the estimated population partial effect of a continuation in the earliest era, for example, is about 0.162 percentage points. This increase may seem small, but note that the overall probability for a randomly drawn patent from the population to be litigated to a decision is only 0.210 percent. In fact, a continuation application raises the estimated population probability by roughly 80 percent at the mean. Overall, the model predicts that a patent drawn from the population with the average characteristics of the litigated set is about 60 percent more likely to be litigated than one drawn with the average characteristics of the controls.

4.5.2 Probability of an Appeal

Conditional on litigation to a published district court decision, I model patent case j's latent propensity to proceed to at least one appeal as follows:

$$\begin{aligned}\text{Appeal}_j^\star = \delta &+ \text{Assigned}_j\left(\eta + \lambda X_j^{\text{Era}}\right) + \text{Continuation}_j\left(\psi + \theta X_j^{\text{Era}}\right)\\ &+ \text{PatenteeDefendant}_j\left(\phi + \pi \text{Assigned}_j + \zeta \text{Continuation}_j\right)\\ &+ \beta X_j^{\text{Patent}} + \gamma X_j^{\text{Trial}} + \varepsilon_j \qquad (4.3)\end{aligned}$$

where patents are classified into eras by district court decision date. Again, each era interaction effect for corporate ownership and for continuations measures the additional effect that variable gains in that era relative to the preceding era. The Declaratory Judgment Act does not define a separate era in this regression. Instead, I include $\text{PatenteeDefendant}_j$ to capture whether the patent holder is the defendant in patent case j, typically indicating a declaratory judgment suit. The sample is conditional on litigation to at least a district court decision, and I take the role of the patent holder in the suit as given. I allow the effect of $\text{PatenteeDefendant}_j$ to vary with corporate ownership and continuation history. X_j^{Patent} includes all of the patent characteristics from the previous section as well as the patent's age at the time of the district court decision and technological category dummies. With the sample now conditional on involvement in litigation, age and industry are no longer controlled by construction as in the previous section. Elements in X_j^{Trial} include the number of patents involved in the suit, binary indicators for various lower court outcomes, and full sets of district court circuit and decision year dummies. The error term ε_j is independently and identically distributed normal with mean zero and constant variance. It primarily reflects unobservable factors determining the probability of an appeal conditional on litigation to a published district court decision. I do not observe $\text{Appeal}_j^\star$. Instead I observe

$$\text{Appeal}_j = \begin{cases} 1 & \text{if } \text{Appeal}_j^\star \geq 0 \\ 0 & \text{if } \text{Appeal}_j^\star < 0. \end{cases} \tag{4.4}$$

For this estimation, I restrict the sample to litigated patents involved in lower court decisions published no later than 2002, to avoid truncation, in the USPQ. There are 6,396 patent cases that meet these criteria. Just more than half of these persist to an appeal. I present the estimation results in Table 4.6.

The partial effect of corporate ownership is statistically insignificant at about −3 percentage points in the earliest era. The flash of genius precedent leads to a statistically significant 24-percentage-point increase in the partial effect of corporate ownership on the probability of an appeal. Thus, the flash of genius era is characterized by a disproportionate amount of corporate patent cases proceeding to an appeal relative to cases involving individual patentees, all else equal. This effect is not due to the increasing number of declaratory judgment cases in this era or their tendency to involve corporate patents. Patentee-Defendant cases are more likely to proceed to an appeal, but the estimation controls for their effect with a Patentee-Defendant indicator variable. The 7-percentage-point effect is statistically significant at a .10 significance level. The effect does not appear to vary across ownership or continuation history. Neither interaction effect is statistically significantly different from 0. The increase in appeals among corporate patent cases may instead be due to increasing divergence in expectations between litigants about the enforceability of corporate patents in the flash of genius era. The duration of litigation is a measure of the degree to which litigants' expectations differ because legal fees serve as transaction costs for reaching an agreement. Longer legal battles reflect greater differences in expectations about how the court will rule, and shifting judicial attitudes and precedents concerning corporate patenting may be responsible for destabilizing those expectations.

The Patent Act of 1952, which rules out the flash of genius precedent, reverses the imbalance by reducing the effect of corporate ownership by 21 percentage points. This leaves the overall effect of corporate ownership not statistically significantly different from zero in the era between the Patent Act and the CAFC. Corporate patentees in the CAFC era are again significantly more likely to face an appeal, but the partial effect is smaller at about 9 percentage points. Above I find that corporate patentees are less likely to be involved in litigation to any published decision in the CAFC era. It may be that cases which do persist to a decision are characterized by particularly strong disagreement or differences in beliefs between parties, which may lead to a higher probability of appeal.

In the early eras, the effect of issuance from a continuation is small and statistically insignificant. The effect changes from about 9 percentage points to -8 across the flash of genius precedent, but both the change and the levels before and after the change are statistically insignificant. Between the enactment of the Patent Act and the establishment of the CAFC, continuations are statistically significantly less likely to face an appeal than ordinary patents, by about 14 percentage points at the mean ($\chi^2(1)=12.29$, p-value $< .01$). Interestingly, the establishment of the CAFC erases this effect and leaves patents issued from continuations no less likely to face an appeal than typical patents, conditional on litigation with all else equal. It appears that the Patent Act era offered a particularly friendly environment for patents issued from continuations, with reduced risk of both litigation and an appeal conditional on litigation. This friendly environment may be responsible in part for the boom in continuation use that appears in Figure 4.4 to trace back to the Patent Act.

Older patents are less likely to proceed to an appeal, perhaps because with less of the patent term left to enforce, the stakes are smaller. The effect is small though. At the sample mean, a one standard deviation increase in the age of the litigated patent (the number of years between grant date and district court decision date) is about 5.3 years and would increase the estimated probability of appeal by less than 2 percentage points. An additional patent involved in the suit raises the probability of appeal for the average patent case by a little more than one percentage point. A greater number of patents involved may indicate higher stakes for the patentee, increasing the duration of litigation.

The probability of an appeal tends to increase with grant lag length. As noted above, longer grant lags may reflect greater uncertainty about the validity of a patent. Litigants' asymmetric beliefs about that validity may persist even after a lower court decision. An appeal is also more likely for patents with more claims and more technological classifications. Both effects are statistically significant but small. The other estimates are all statistically insignificant except for the category dummies. Conditional on litigation, patents in the miscellaneous, low-tech base category are statistically significantly less likely to face an appeal than patents in any other category. All else equal, the highest estimated conditional probabilities of an appeal are for patents in Computers and Communication and in Drugs and Medical. Compared to low-tech patents at the mean, the partial effects are 20 percentage points for the Drugs and Medical category and 13 percentage points for Computers. The effect for drug patents is likely due to the size of the stakes. The typical drug patent is worth one-hundred times the value of a typical patent (McGahee 2011). The large effect for computer patents may seem surprising because they are not litigated to a decision less often than low-tech patents. However, Allison et al. (2004) show that patents in that category are indeed among the most likely to be involved in suits filed (along with drug patents). Taken together, the evidence suggests that cases involving computer patents have a higher than average probability of settlement prior to a decision. The cases that do reach a decision may involve significant asymmetries between parties and may therefore face a higher probability of appeal.

4.5.3 Final Decisions on Validity and Infringement

I use a multinomial probit model to estimate the effects of various patent and trial characteristics on the conditional probabilities of a patent case reaching each one of three decisions: valid and infringed, not infringed, and invalid. Conditional on litigation to a published decision, I model patent case j's latent propensities to proceed to each one of these three possible decisions as follows:

$$\begin{aligned}\text{Decision}^{\star}_{ij} = \delta_i &+ \text{Assigned}_j \left(\eta_i + \lambda_i X_j^{\text{Era}}\right) + \text{Continuation}_j \left(\psi_i + \theta_i X_j^{\text{Era}}\right) \\ &+ \text{PatenteeDefendant}_j \left(\phi_i + \pi_i \text{Assigned}_j + \zeta_i \text{Continuation}_j\right) \\ &+ \beta_i X_j^{\text{Patent}} + \gamma_i X_j^{\text{Trial}} + \varepsilon_{ij} \qquad (4.5)\end{aligned}$$

where i denotes the potential decision. Explanatory variables are defined as in the previous estimation with the following exceptions. Patents are classified into eras by final observed decision date. Patent age at decision is now measured to the final observed decision. X_j^{Trial} now includes only the number of patents involved in the suit and full sets of trial circuit and final observed decision year dummies.[15] The ε_i terms reflect unobservable factors determining the probabilities of each potential outcome conditional on litigation to a published decision. They are distributed trivariate normal with mean zero and covariance matrix Ω. I do not observe $\text{Decision}^{\star}_{ij}$. Instead I observe

$$\text{Decision}_j = \underset{i}{\text{argmax}}\{\text{Decision}^{\star}_{ij}\}. \qquad (4.6)$$

[15] I include trial circuit dummies based on evidence of nonuniformity in validity rates found by Atkinson et al. (2009). Decision year dummies capture overall fluctuations in decision rates over time and across policy eras.

I restrict attention to the final observed decision in each patent case, observing opinions published in the USPQ through 2006. I do not condition the sample on publication of the original lower court decision as required in the analysis of the probability of an appeal. There are a total of 9,308 patent cases in the sample that reach one of these three decisions. 28 percent of these reach a decision of valid and infringed. 24 percent are found not infringed. 48 percent are ruled invalid. Patents involved in the 21 patent cases excluded from this estimation are each simply declared valid without an observed ruling on infringement.

Parameter estimates are presented in Table 4.7 using valid and infringed as the base outcome. For brevity I do not present decision year or trial circuit dummy parameters in the table. Marginal effects follow in Table 4.8, and trial circuit effects are included. Compared to individually owned patents, corporate patents are 7.4 percentage points more likely to be found valid and infringed in the earliest era, all else equal. The increase is drawn equally from the probabilities of being found not infringed and invalid. That corporate patentees are more likely to win is not surprising. Corporate owners likely have more experience and perhaps lower legal costs than many individual patentees for expertly drafting strong patents and successfully defending them in court. However, I describe above how the flash of genius era was characterized by a heroic view of the individual inventor and anti-corporate sentiment among some judges. Although corporate patents in that era are subject to prolonged litigation, there is little evidence that the flash of genius precedent had disproportional effects on final decisions. The interaction term's partial effect on the probability of a valid and infringed decision is nearly zero and statistically insignificant. The era interaction effects for corporate ownership after the Patent Act of 1952 and in the CAFC era are also statistically insignificant. The advantage of corporate ownership for a winning outcome are thus consistent across multiple changes in patent policy. As expected, foreign patentees are also more likely to win. The partial effect of foreign ownership on a decision of valid and infringed is statistically significant at about 9 percentage points. The effect of the number of inventors is positive but only marginally significant.

In the earliest era, there are no statistically significant differences in decision probabilities for patents issued from continuations. In the flash of genius era, patents issued from continuations are about 10 percentage points less likely to win than ordinary patents holding all else equal, but the difference is not statistically significant. The Patent Act of 1952 raises the probability of winning for patents issued from continuations by 19 percentage points more than the concurrent rise for ordinary patents, which is captured by the decision year dummies. The interaction effect for the CAFC era is negative but statistically insignificant. Essentially, the evidence suggests that the era between the Patent Act of 1952 and the CAFC in 1982 was especially friendly towards continuations. Relative to ordinary patents with all else equal, patents issued from continuations face the least risk of litigation, the smallest probability of a case extending to appeal, and the highest probability of winning in that era. This friendly environment for continuations is surely responsible in part for their proliferation in the second half of the 20th century.

Atkinson et al. (2009) note using the more recent decades of observations in these data that patents involved in patentee-defendant cases have a 10-percentage-point lower probability of being found valid. In this estimation, the marginal effect of the patentee-defendant dummy on the probability of invalidity is just 6.3 percentage points, but there is a significant interaction effect with the continuation dummy of 14.4 percentage points.[16] The interaction effect with corporate ownership is statistically insignificant. The large, significant increase in the likelihood of invalidity for patentee-defendant cases involving continuations reveals the importance of the accused infringer's right to file a declaratory judgment in the fight against submarine patenting.

Divisional applications appear to have no effect on case outcomes.[17] All else equal, patents with longer grant lags are statistically significantly less likely to win, particularly on validity.

[16] In an unreported alternative specification, I omit the interaction effects and compute a marginal effect of roughly 10 percentage points for the patentee-defendant dummy.

[17] This result is not due to the omission of era interactions. In an unreported estimation, I restrict the sample to decisions since 1952 and find that a continuation statistically significantly increases the probability of winning, but a division has no significant effects across decisions.

An increase of one standard deviation (about 2.8 years) from the mean reduces the estimated probability of winning by about 1.6 percentage points. This constitutes weak evidence to support the connection Somaya (2003) describes between a patent's grant lag length and doubts about its validity. Uncertainty about validity may be what leads patents with longer grant lags to be litigated more often even when application history and patent complexity are held constant.

The results confirm that patents with more claims are more likely to be found valid and infringed, all else equal. An increase in the number of claims by one standard deviation (about 17 claims) from the mean raises the estimated probability of winning by about 3 percentage points. Breaking an invention down into many individual claims does appear to slightly bolster the strength of the patent in court. Thus, it is rational for a patent applicant who anticipates that his invention will be relatively valuable to be willing to pay higher fees to draft and prosecute more individual claims to document that invention. A higher number of technological classifications also increases the probability of winning, particularly on infringement, all else equal. Both claims and classifications may to some extent be capturing measures of breadth which are relevant to the likelihood of infringement.

Citing more prior art narrows the scope of what specifically is protected under the new patent, essentially leaving less to infringe. On the other hand, the difficulty of proving invalidity should increase with the number of backward references; the court generally considers patents referenced as prior art to be cleared from invalidating a patent by the PTO during examination (Allison et al. 2002). Indeed I find that patents with more backward references, all else equal, are more likely to be found not infringed and less likely to be found invalid. The effects are small but statistically significant. The effects balance to produce virtually no change in the probability of a valid and infringed decision. Again I include median backward reference age in the regression to separately test the effects of the age of a patent's technological field. The evidence suggests that patents in newer technological fields are slightly more likely to be found invalid. The effect is small but statistically significant. An increase of one standard deviation (11 years of age) from the mean decreases the probability of being found invalid by about 2.3 percentage points.

Turning to the results for technological categories, patents in Computers and Communication, all else equal, have the lowest estimated probability of winning and the highest probability of being found not infringed. These results along with the longer duration estimated above for computer patent cases suggest that enforcing these patents is relatively costly and difficult. This is consistent with other findings that patents in this category have less of a relationship with the patenting firm's market value than patents in any other technological category (McGahee 2011). All else equal, chemical patents are the most likely to win and the least likely to be found invalid. This may be due to the exactness with which claims for new chemical compounds are written, though other types of claims may be more ambiguous. Drugs and medical patents face validity outcomes similar to those in the miscellaneous base category, but they are statistically significantly less likely to lose on infringement. Outcomes for mechanical and electrical patents are mostly similar to outcomes for the base category, miscellaneous (low-tech).

The effect of patent age at decision on invalidity is consistent with that estimated by Atkinson et al. (2009). An additional year of decision age reduces the likelihood of invalidity by just under 1 percentage point. The direction of the effect is reasonable; the longer a patent survives without being ruled invalid, the less likely it is to eventually be ruled invalid. An additional patent involved in the case raises the likelihood of a "valid and infringed" ruling by just under 1 percentage point. The size of this effect is smaller than Atkinson et al. estimate using the more recent half of these data, but the direction is the same. An additional patent increases the size of the stakes for the patentee and may lead to a stronger enforcement effort. Trial circuits effects on validity are also similar to those estimated by Atkinson et al. The 3rd Circuit is the most likely to find a patent invalid, all else equal, at about 10 percentage points more likely than the base 4th Circuit. The 5th Circuit and particularly the 10th Circuit are the least likely to find a patent invalid. The partial effects are about

−11 and −16 percentage points, respectively. Interestingly, all of the circuit effects on the probability of a "not infringed" decision are small and statistically insignificant, confirming that differences in patent enforcement rates across circuits are unique to the validity inquiry.

4.6 Conclusion

The construction of this comprehensive set of data on patents litigated to a published decision over the course of several decades permits a rich analysis of the relationships between patent characteristics and litigation. In a first look at these data, I show that several characteristics of patents and patentees are systematically related to litigation risk, duration, and outcomes. I also find that certain types of patents were disproportionately affected by changes to patent policy and precedent over the course of the 20th century. In particular, I find that the "flash of genius" requirement for patent validity set forth by the Supreme Court in *Cuno Engineering Co. v. Automatic Devices Co.*, 314 US 84 (1941), disproportionately prolonged the course of litigation for corporate patentees relative to individual inventors but had no disproportionate affect on decisions. This result holds even after controlling for the increase in that era of declaratory judgment suits, which are prone to involve corporate patents and to proceed to appeals. The Patent Act of 1952 rejected the flash of genius test and the dependency of patent validity on the manner in which an invention is conceived. I find that it reversed the flash of genius effect on the duration of corporate litigation and improved case outcomes equally for corporate and individual patentees. I conclude that the anti-corporate sentiment among the courts in the flash of genius era increased the likelihood of appeals by destabilizing expectations about the enforceability of corporate patents. To the extent that corporate patentees were disproportionately penalized in the flash of genius era, I argue that such a penalty reveals a failure of the patent system to maintain its focus on stimulating technological innovation.

The Patent Act of 1952 also codified the legality of patent application continuations. I find that it reduced the probability with which existing patents issued from continuations were litigated to a decision, relative to ordinary patents, and it reduced case durations and improved trial outcomes for such patents as well. The friendly stance towards continuations taken in the Patent Act of 1952 and in its interpretation brought about the widespread use of continuations among all U.S. patents but particularly among patents eventually litigated. I find some evidence that continuations are used more often by submarining applicants with litigious intent than by pioneers or defensive portfolio builders. Clearly, a submarine patent, intended by the patentee to remain hidden until someone produces a similar, "infringing" technology, does nothing to promote technological innovation but only hinders it. One effective tool against submarine patents appears to be the declaratory judgment. Declaratory judgment cases are more likely to reach a ruling of patent invalidity, and the effect is even larger for cases involving patents issued from continuations. Unfortunately, as Lanjouw and Schankerman (2001) note, declaratory judgment filings are subject to underprovision because of the positive externalities generated by a successful challenge of patent validity. Recent changes in U.S. patent policy may also prove effective at reducing submarine patenting behavior, but it is yet too early to gauge their effectiveness. Submarine patenting remains a challenge to the economic premise of the patent system that 21st century patent policy must be sure to overcome.

Additional results include that across all policy eras, corporate patentees are more likely to win than individual inventors, all else equal. Corporate owners may have lower legal costs for drafting strong patents and defending them in court. Lanjouw and Schankerman (2001) describe how a given patentable invention may be more valuable in the hands of a firm than an individual solely based on settlement advantages and reputation effects. Corporate patent holders' higher probability of winning in court only adds to their advantage. Foreign patent holders appear to selectively litigate cases they are likely to win. Foreign nationality is associated with a lower probability of litigation and a higher probability of winning. Among technological categories, chemical patents are the most insulated from litigation risk. They have nearly the lowest probability of litigation, and they have the highest probability of winning when they are involved in litigation. Drugs and medical patents are the most often litigated, but computers and communication patents face the most appeals and the lowest chance of winning. These findings likely reflect the size of the stakes involved with drug patents and help explain the insignificant relationship between patent portfolio and market value in the computer industry (McGahee 2011).

These results demonstrate the wide variation among patents with different characteristics in their exposure to litigation risk. The variance in risk across ownership and technological fields may be suggestive of the need for different approaches to encouraging innovation and protecting intellectual property in different industries and across different types of inventors. This is not to suggest that patent policy should arbitrarily seek to align the different risks and burdens of patent enforcement which different inventors may naturally face. Any attempt to influence such differences must be firmly grounded in an understanding of the patent system's purpose to encourage economic growth by addressing the public good problem inherent to inventive activity. And any such attempt is only desirable to the extent that the differences in enforcement challenges faced by different inventors present an impediment to technological innovation and economic growth.

Table 4.1
Summary of Patent Characteristics

	Litigated		Control			
	Mean	SD	Mean	SD	N	z-Statistic
Assigned	0.63	0.48	0.62	0.48	8,555	0.58
Foreign	0.07	0.25	0.17	0.38	8,555	-21.11
Number of Inventors	1.37	0.81	1.37	0.85	8,555	0.30
Continuation	0.14	0.34	0.07	0.25	8,555	15.82
Division	0.07	0.25	0.04	0.19	8,555	9.26
Application-to-Grant Lag	3.46	2.80	2.70	1.81	8,555	21.19
Claims	12.59	16.74	8.06	8.17	8,555	22.53
Number of USPC Codes	1.99	1.14	2.25	1.26	8,555	-14.34
Backward References	10.30	17.47	7.23	7.97	4,607	10.83
Median Reference Age	12.62	10.76	12.86	11.90	4,607	-1.03
	Litigated		Population			
NBER Technological Category	Mean	SD	Mean	SD	N[a]	z-Statistic
Chemical (non-Drug)	0.12	0.33	0.16	0.37	8,555	-12.26
Computers and Comm.	0.04	0.21	0.08	0.27	8,555	-16.00
Drugs and Medical	0.06	0.24	0.05	0.22	8,555	3.46
Electrical	0.10	0.30	0.15	0.35	8,555	-13.70
Mechanical	0.25	0.43	0.24	0.43	8,555	1.91
Miscellaneous	0.42	0.49	0.32	0.47	8,555	19.84

Observations include 8,555 patents involved in validity or infringement decisions published in the *United States Patents Quarterly* between 1929 and 2006 and 8,555 control patents matched to those litigated patents. Controls are matched within one month of issue date and with at least one common USPC classification. Patents issued prior to 1947 do not include a list of references.

[a]Population statistics come from the 6,009,453 patents issued between 1915 and 2003. This number is used along with the count of 8,555 litigated patents to compute z-statistics for technological categories.

Table 4.2
Mean Number of References and Median Reference Age by Application History

	Control		Litigated	
	Ordinary	Continuation	Ordinary	Continuation
Backward References	6.8	10.3	8.3	17.4
	(0.10)	(0.55)	(0.15)	(0.96)
Median Reference Age	13.1	10.9	12.8	11.8
	(0.18)	(0.42)	(0.18)	(0.28)

The sample consists of patents issued since 1947 which are involved in validity or infringement decisions published in the *United States Patents Quarterly* by 2006 and control patents matched to those litigated patents. "Ordinary" patents are those which issue directly from an original application. Standard errors are in parentheses.

Table 4.3
Fraction of Patent Cases in which Patentee Is Defendant

	June 1934– Oct. 1941	Nov. 1941– June 1952	July 1952– Sep. 1982	Oct. 1982– Dec. 2006
Fraction with Patentee-Defendant				
Among Assigned	.045	.172	.137	.094
Among Unassigned	.029	.125	.095	.083
Among Continuations	.016	.254	.142	.111
Among Non-continuations	.039	.146	.119	.080

The sample consists of patent cases which reach a decision on validity or infringement published in the *United States Patents Quarterly* with decision dates that fall between the enactment of the Declaratory Judgment Act of 1934 and the end of 2006. Patent cases are sorted by final observed decision date.

Table 4.4
Litigation Outcomes by Era

	Jan. 1929–Oct. 1941	Nov. 1941–June 1952	July 1952–Sep. 1982	Oct. 1982–Dec. 2006
District Court Decisions[a]				
Observations	2,070	936	2,325	1,065
Valid & Infringed	.363	.274	.311	.355
Not Infringed	.219	.171	.128	.360
Invalid	.418	.555	.561	.285
Rate of Appeal	.441	.534	.550	.651
Final Observed Decisions[b]				
Observations	2,857	1,238	2,973	2,261
Valid & Infringed	.300	.178	.266	.318
Not Infringed	.254	.210	.130	.388
Invalid	.446	.612	.604	.294

[a]These statistics are based on district court decisions on validity and infringement published in the USPQ. I exclude cases for which only the appellate court decision is published regardless of whether it describes the district court outcome.
[b]These statistics are based on the final observed decision in each patent case. Cases for which I only observe the appellate court decision are included.

Table 4.5
Probit Estimation of Litigation on Patent Characteristics

	Parameters	Sample Marginal Effects
Assigned	.0241 (.0483)	.0095 (.0190)
× D.J. Act of 1934	-.0571 (.0539)	-.0226 (.0213)
× Flash of Genius	-.0632 (.0483)	-.0252 (.0192)
× Patent Act of 1952	-.0065 (.0491)	-.0026 (.0196)
× CAFC	-.1462 (.0368)***	-.0582 (.0146)***
Foreign	-.6667 (.0332)***	-.2559 (.0116)***
Number of Inventors	-.0153 (.0141)	-.0061 (.0056)
Continuation	.5087 (.2524)**	.1936 (.0946)**
× D.J. Act of 1934	.2799 (.3354)	.0892 (.1100)
× Flash of Genius	-.3702 (.2553)	-.1212 (.0818)
× Patent Act of 1952	-.2868 (.1724)*	-.1092 (.0648)*
× CAFC	.1863 (.0823)**	.0720 (.0320)**
Division	.2718 (.0481)***	.1065 (.0183)***
Application-to-Grant Lag	.0565 (.0051)***	.0225 (.0020)***
Claims	.0235 (.0013)***	.0094 (.0005)***
# of USPC Codes	-.1502 (.0088)***	-.0599 (.0035)***
Backward References	.0075 (.0022)***	.0030 (.0009)***
Median Reference Age	-.0027 (.0012)**	-.0011 (.0005)**
Constant	.0963 (.0424)**	
Number of observations	17,110	
Percent correctly predicted	62.56	
Log-likelihood value	-10,885.9	
McFadden R-squared	.0816	

NBER Technological Category	Probability of Litigation to Decision in the Population	Conversion Factors to Compute Population Marginal Effects
Aggregate	.002102	.008392
Chemical (Non-Drug)	.001458	.005856
Computers and Communication	.001655	.006617
Drugs and Medical	.003362	.013425
Electrical and Electronic	.001397	.005599
Mechanical	.001990	.007977
Miscellaneous	.002928	.011678

Dependent variable is involvement in litigation to a decision. Observations include patents involved in any validity or infringement decision published in the *United States Patents Quarterly* between 1929 and 2006 and their controls. For patents issued prior to 1947, references and median reference age are necessarily set to 0 and a pre-reference dummy is set to 1. Marginal effects are calculated at the sample mean. For dummy variables, the partial effect on the probability of an outcome is the increase in that probability with a change in the dummy variable from 0 to 1. The partial effect of each era-interaction dummy is computed with prior era-interaction dummies set to 1 and future era-interaction dummies set to 0. Population probabilities and conversion factors for marginal effects are calculated as described in Appendix A. Standard errors are shown in parentheses. * $p<.10$, ** $p<.05$, *** $p<.01$

Table 4.6
Probit Estimation of an Appeal

	Parameters	Marginal Effects
Assigned	-.0746 (.0600)	-.0296 (.0238)
× Flash of Genius	.6199 (.0967)***	.2421 (.0365)***
× Patent Act of 1952	-.5332 (.0959)***	-.2102 (.0369)***
× CAFC	.2420 (.1005)**	.0949 (.0386)**
Foreign	.0659 (.0716)	.0261 (.0283)
Number of Inventors	.0241 (.0279)	.0096 (.0111)
Continuation	.2413 (.1991)	.0945 (.0763)
× Flash of Genius	-.4339 (.2797)	-.1710 (.1068)
× Patent Act of 1952	-.1660 (.2165)	-.0662 (.0861)
× CAFC	.3906 (.1303)***	.1500 (.0472)***
Division	.0754 (.0685)	.0299 (.0270)
Application-to-Grant Lag	.0404 (.0073)***	.0161 (.0029)***
Claims	.0025 (.0014)*	.0010 (.0006)*
Number of USPC Codes	.0309 (.0143)**	.0123 (.0057)**
Backward References	-.0005 (.0026)	-.0002 (.0011)
Median Reference Age	-.0016 (.0022)	-.0006 (.0009)
Chemical	.1582 (.0538)***	.0624 (.0210)***
Computers and Communication	.3407 (.0951)***	.1314 (.0350)***
Drugs and Medical	.5285 (.0884)***	.1982 (.0300)***
Electrical	.1611 (.0577)***	.0635 (.0225)**
Mechanical	.2549 (.0426)***	.1003 (.0165)***
Patentee-Defendant	.1841 (.1024)*	.0724 (.0397)*
× Assigned	-.0916 (.1223)	-.0365 (.0488)
× Continuation	.1317 (.1768)	.0519 (.0690)
Patent Age at D.C. Decision	-.0082 (.0035)**	-.0033 (.0014)**
Number of Patents Involved	.0287 (.0077)***	.0114 (.0031)***
D.C. Found Not Infringed	-.1748 (.0474)***	.0696 (.0189)***
D.C. Found Invalid	-.0625 (.0386)	-.0249 (.0153)
Constant	-.2881 (.1791)	
Number of observations	6,396	
Percent correctly predicted	63.08	
Log-likelihood value	-4099.4	
McFadden R-squared	.0729	

Dependent variable is involvement in an appeal, given involvement in litigation to a decision on validity or infringement. Observations include patents involved in district court decisions published between 1929 and 2002, to avoid truncation, in the USPQ. For patents issued prior to 1947, references and median reference age are set to 0 and a pre-reference dummy is set to 1. Regression includes full sets of district court circuit and decision year dummies. Marginal effects are calculated at the mean. For dummy variables, the partial effect on the probability of an outcome is the increase in that probability with a change in the dummy variable from 0 to 1. The partial effect of each era-interaction dummy is computed with prior era-interaction dummies set to 1 and future era-interaction dummies set to 0. Partial effects of each technology dummy are computed with other technology dummies set to 0. The base category is miscellaneous (low-tech). Standard errors are shown in parentheses. * $p<.10$, ** $p<.05$, *** $p<.01$

Table 4.7
Multinomial Probit of Trial Outcome on Patent Characteristics

	Parameter Estimates	
	Not Infringed	Invalid
Assigned	-.3282 (.0791)***	-.2700 (.0747)***
× Flash of Genius	.0086 (.1537)	-.0606 (.1407)
× Patent Act of 1952	.0315 (.1590)	.1664 (.1398)
× CAFC	.0053 (.1354)	-.0222 (.1274)
Foreign	-.2281 (.0861)***	-.4158 (.0836)***
Number of Inventors	-.0351 (.0296)	-.0551 (.0295)*
Continuation	.0269 (.2262)	-.0617 (.2104)
× Flash of Genius	.5272 (.4060)	.4229 (.3837)
× Patent Act of 1952	-.9387 (.3765)**	-.5590 (.3444)
× CAFC	.1973 (.1925)	.0788 (.1566)
Division	-.0691 (.0896)	-.0350 (.0829)
Application-to-Grant Lag	.0191 (.0091)**	.0225 (.0086)***
Claims	-.0066 (.0015)***	-.0062 (.0015)***
Number of USPC Codes	-.0728 (.0200)***	-.0340 (.0183)*
Backward References	.0072 (.0020)***	-.0014 (.0024)
Median Reference Age	-.0015 (.0030)	-.0070 (.0027)***
Chemical	-.1334 (.0740)*	-.2746 (.0680)***
Computers and Comm.	.2928 (.1143)***	-.0156 (.1141)
Drugs and Medical	-.2602 (.1042)**	-.0913 (.0985)
Electrical	.0633 (.0817)	.0502 (.0743)
Mechanical	.1093 (.0585)*	.0241 (.0537)
Patentee-Defendant	.0368 (.1602)	.2212 (.1411)
× Assigned	.2959 (.1883)	.1018 (.1660)
× Continuation	-.2320 (.2326)	.5924 (.2133)***
Patent Age at Decision	.0100 (.0047)**	-.0175 (.0045)***
Number of Patents Involved	-.0305 (.0108)***	-.0295 (.0096)***
Constant	-.8004 (.2388)***	-.4261 (.2297)*
Trial Circuit Dummies	Included	Included
Number of observations	9,308	
Percent correctly predicted	54.56	
Log-likelihood value	-8,914.5	
McFadden R-squared	.0911	

Dependent variable is the final decision in a patent-case. "Valid and Infringed" is the base outcome. For patents issued prior to 1947, references and median reference age are necessarily set to 0 and a pre-reference dummy is set to 1. The regression includes a full set of decision year dummies. Observations include all validity and infringement decisions published in the *United States Patents Quarterly* between 1929 and 2006. Marginal effects follow in Table 4.8. Standard errors are shown in parentheses. * p<.10, ** p<.05, *** p<.01

Table 4.8
Marginal Effects of Patent Characteristics on Outcome Probabilities

	Valid and Infringed	Not Infringed	Invalid
Assigned	.0740 (.0168)***	-.0389 (.0163)**	-.0351 (.0196)*
× Flash of Genius	.0092 (.0338)	.0107 (.0296)	-.0199 (.0353)
× Patent Act of 1952	-.0303 (.0335)	-.0164 (.0305)	.0467 (.0352)
× CAFC	.0032 (.0297)	.0044 (.0279)	-.0076 (.0338)
Foreign	.0947 (.0211)***	.0015 (.0180)	-.0961 (.0220)***
Number of Inventors	.0124 (.0067)*	-.0004 (.0062)	-.0119 (.0079)
Continuation	.0075 (.0497)	.0153 (.0469)	-.0228 (.0552)
× Flash of Genius	-.1095 (.0764)	.0634 (.0797)	.0462 (.0897)
× Patent Act of 1952	.1909 (.0960)**	-.1276 (.0494)***	-.0633 (.0852)
× CAFC	-.0312 (.0359)	.0364 (.0436)	-.0052 (.0442)
Division	.0123 (.0198)	-.0113 (.0177)	-.0011 (.0218)
Application-to-Grant Lag	-.0055 (.0020)***	.0013 (.0019)	.0042 (.0023)*
Claims	.0016 (.0003)***	-.0007 (.0003)**	-.0009 (.0004)**
# of USPC Codes	.0124 (.0043)***	-.0124 (.0041)***	-.0001 (.0048)
Backward References	-.0004 (.0005)	.0019 (.0004)***	-.0015 (.0006)**
Median Reference Age	.0013 (.0006)**	.0006 (.0006)	-.0019 (.0007)***
Chemical	.0595 (.0169)***	.0062 (.0156)	-.0657 (.0181)***
Computers and Comm.	-.0270 (.0249)	.0767 (.0262)***	-.0497 (.0295)*
Drugs and Medical	.0396 (.0240)*	-.0462 (.0189)**	.0066 (.0260)
Electrical	-.0141 (.0172)	.0078 (.0167)	.0063 (.0195)
Mechanical	-.0143 (.0125)	.0227 (.0121)*	-.0084 (.0141)
Patentee-Defendant	-.0394 (.0320)	-.0233 (.0294)	.0627 (.0353)*
× Assigned	-.0440 (.0374)	.0581 (.0405)	-.0141 (.0421)
× Continuation	-.1082 (.0389)***	-.0362 (.0404)	.1444 (.0505)***
Patent Age at Decision	.0020 (.0010)*	.0049 (.0010)***	-.0068 (.0012)***
Number of Patents Involved	.0077 (.0023)***	-.0030 (.0022)	-.0047 (.0026)*
Circuit 1	-.0555 (.0256)**	.0424 (.0286)	.0132 (.0317)
Circuit 2	-.0505 (.0191)***	.0190 (.0202)	.0315 (.0234)
Circuit 3	-.0790 (.0190)***	-.0248 (.0201)	.1039 (.0243)***
Circuit 5	.0896 (.0263)***	.0175 (.0247)	-.1071 (.0275)***
Circuit 6	-.0558 (.0199)***	-.0038 (.0208)	.0595 (.0246)**
Circuit 7	-.0260 (.0200)	-.0136 (.0200)	.0397 (.0238)*
Circuit 8	-.0454 (.0246)*	.0318 (.0265)	.0137 (.0303)
Circuit 9	-.0367 (.0204)*	.0278 (.0215)	.0089 (.0246)
Circuit 10	.1131 (.0359)***	.0445 (.0335)	-.1576 (.0357)***

Marginal effects are calculated at the sample mean using parameter estimates from Table 4.7. For dummy variables, the partial effect on the probability of an outcome is the increase in that probability with a change in the dummy variable from 0 to 1. The partial effect of each era-interaction dummy is computed with prior era-interaction dummies set to 1 and future era-interaction dummies set to 0. Partial effects of each technology dummy are computed with other technology dummies set to 0. The base category is miscellaneous (low-tech). Partial effects for circuit dummies are computed similarly with the 4th Circuit as the base. Standard errors are shown in parentheses. * p<.10, ** p<.05, *** p<.01

Chapter 5

Conclusion

In the empirical work above, I make three important contributions to the study of patents and patent litigation. In Chapter 2, I show that the typical patent is of negligible value, but some patents are extremely valuable. I call on economists who study patent data to use any available signals of patent value to inform their research. Involvement in litigation is one useful signal that a patent is valuable. In Chapter 3, I use litigation to identify valuable patents and perform the first study of the geography of knowledge flows from valuable inventions. I find that knowledge flows from inventions represented by litigated patents have at least as strong a tendency to be localized as typical patents. This localization does not fade over time. This is the first evidence that for very valuable patents, the localization of knowledge spillovers is strong and persistent. For other applications, which may require the study of patents of great private value, I recognize the importance of identifying patents which not only are litigated but also do well in court. In Chapter 4, I study patent enforcement over the course of the 20th century and identify several significant relationships between patent characteristics and the risk, duration, and outcomes of litigation. I also test the response of these relationships to significant changes in patent policy and precedent. I review evidence of significant anti-corporate sentiment among judges and Supreme Court justices in the 1940's. I find that "flash of genius" era litigation is disproportionately difficult for corporate patentees in terms of duration but not in outcomes. The Patent Act of 1952 realigns the duration of litigation for corporate and individual patentees but invites a rash of submarine patenting behavior. The era between the Patent Act of 1952 and the establishment of the CAFC in 1982 was especially friendly towards patents issued from application continuations. This friendly environment for continuations is surely responsible in part for their proliferation in the second half of the 20th century.

There is much left to learn from litigated patents. This dissertation motivates the study of litigated patents, describes a comprehensive set of data on litigated patents, and presents one important example of how these data can be used to study technological change and innovation using patents that matter. As the data used for this work become publicly available, economists will surely benefit from using these data to test theories of economic growth, industrial organization, and law and economics. I look forward to further progress in these areas.

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Appendix A

Population Litigation Probabilities and Marginal Effects for Chapter 4

In the pooled sample of litigated and matched patents, the probability of litigation to a published validity or infringement decision is approximately 50% by construction. Below I describe how I convert the predicted probabilities from my estimation of selection into published adjudication to population probabilities of litigation to any court decision. This method is a refined version of that of Lanjouw and Schankerman (2001). The result is the predicted probability of litigation to a decision for a patent with given characteristics drawn from the population of patents rather than from the sample. I follow this method to estimate population probabilities for patents in each of the six technological categories. For convenience, I abbreviate "technological category" to "class" below.

For a given class, let L represent the number of patents in the population which are involved in litigation to a decision. Let αL represent the number of those patents for which I observe that litigation. $\alpha < 1$ because of truncation and underreporting of district court decisions. The aggregate probability of litigation that I observe in the pooled sample for a given class is:

$$Q = \alpha L / (\alpha L + U_s), \tag{A.1}$$

where U_s is the number of patents in that class in the pooled sample for which I do not observe litigation. The aggregate probability of litigation (observed and unobserved) in the population for a given class is:

$$P = L/(L + U_p), \tag{A.2}$$

where U_p is the total number of unlitigated patents in that class in the population. Combining (A1) and (A2) yields the following relationship between U_p and U_s:

$$U_p = \frac{Q(1-P)}{\alpha(1-Q)P} U_s \equiv K U_s. \tag{A.3}$$

The number of unlitigated patents in a given class in the population is greater than the number of patents in that class in the pooled sample for which I do not observe litigation by a factor of K. Within a class, the matched patents are random draws, so the distribution of characteristics among matched patents should be the same as among those in the population. Thus, the number of unlitigated patents with characteristics X in a given class in the population, $U_p(X)$, should be related to the analogous number from the sample, $U_s(X)$, by the same factor, K. This allows me to write down the following expression for the probability of litigation to a decision for a patent with characteristics X drawn from the population:

$$P(X) = \frac{L(X)}{L(X) + K U_s(X)}, \tag{A.4}$$

where $L(X)$ is the number of patents in the population with characteristics X litigated to a decision. For a patent in the pooled sample with characteristics X, the probability that I observe litigation to a decision is:

$$Q(X) = \frac{\alpha L(X)}{\alpha L(X) + U_s(X)}. \tag{A.5}$$

Solving (A5) for $U_s(X)$ and substituting into (A4) yields:

$$P(X) = \left(1 + \alpha K \frac{1 - Q(X)}{Q(X)}\right)^{-1}. \tag{A.6}$$

For a patent with characteristics X drawn from the population, I can infer the probability of litigation to a decision, $P(X)$, from the estimated probability for a patent with characteristics X drawn from the sample, $Q(X)$. Equation (A6) can also be used to derive population marginal effects. For a particular characteristic X_k, the population marginal effect is:

$$\frac{\partial P(X)}{\partial X_k} = \left[\frac{dP(X)}{dQ(X)}\right] \frac{\partial Q(X)}{\partial X_k}. \tag{A.7}$$

The last term in (A7) is the sample marginal effect computed from the probit estimation of litigation on patent characteristics. Using (A6), the conversion factor is:

$$\frac{dP(X)}{dQ(X)} = \frac{\alpha K}{\{Q(X) + \alpha K[1 - Q(X)]\}^2}. \tag{A.8}$$

Using the definition of K given in (A3) and measuring $Q(X)$ by the sample probability of litigation in the class, Q, the conversion factor reduces to:

$$\frac{dP(X)}{dQ(X)} = \frac{P(1-P)}{Q(1-Q)}. \tag{A.9}$$

I observe Q directly, and I estimate P by choosing a range of patent issue years and estimating the fraction of patents issued in those years which are litigated to a decision. For the denominator, I count all patents issued from 1929 to 1999 using the USPTO advanced search page. For the numerator, I need the number of patents issued from 1929 to 1999 involved in litigation that reaches a decision on validity or infringement. The data include virtually all appellate decisions for these patents but not all district court decisions. Thus, I must account for underreporting of cases which reach a decision in a district court but which are not appealed. To do so, I first restrict attention to district court decisions which are published ("reported") in the USPQ and for each patent issue year, I compute the percentage of litigated patents for which I also observe an appeal. I then divide the total number of patents involved in appellate decisions for that issue year by the corresponding percentage to produce an estimate of the total number involved in litigation to at least a district court decision. The result still must be corrected for truncation. I measure the truncation weight for patents issued in a given year by computing the percentage of litigated patents issued 20 years earlier for which I observe litigation by 1986. I then divide the estimated total count of litigated patents for each issue year by the corresponding truncation weight.

The result is an estimate of 9,813 patents involved in litigation to a decision on validity or infringement. The total number of patents issued from 1929 to 1999 is 4,671,437. Thus, I estimate the population probability of litigation, P, to be approximately .002102. The sample proportion, Q, after culling to a single observation per patent, is .506331. Substituting these into (A9) yields an aggregate conversion factor of .008392. I repeat this calculation for patents in each of the 6 technological categories and present population probabilities and conversion factors for each in Table 4.5.

These calculations of P and Q also allow me to calculate αK for use in equation (A6) to compute predicted probabilities of litigation for patents with characteristics X drawn from the population. Using αK, and (A6), I can infer the population probability, $P(X)$, from the estimated probability, $Q(X)$. Following this procedure after the estimation in Section 4.5.1, I estimate that a patent drawn from the population with the average characteristics of the litigated set has a 0.319-percent probability of litigation to a decision. The estimated probability for a patent drawn with the average characteristics of the controls is 0.201 percent.

Appendix B

Bivariate Probit Estimations for Chapter 4

To address the potential for endogeneity bias in the estimates in Section 5.1, I turn to bivariate probit estimation of litigation and issuance from a continuation. Greene (2003) describes the procedure for estimating a bivariate probit model in the case of a binary dependant variable with a binary endogenous explanatory variable. He shows that there is no need to treat the bivariate probit model with an endogenous binary variable differently from the case in which it is exogenous, except that in that case the bivariate probit need not be bivariate. I estimate a bivariate probit for each era because the model is not designed to account for interactions between the endogenous variable and other explanatory variables. This approach has the benefit of offering a likelihood-ratio test for each era to test whether the bivariate probit outperforms two independent univariate probit estimations. The test statistic is twice the difference between the log-likelihood from the bivariate estimation and the sum of log-likelihoods from the two univariate estimations. It is distributed $\chi^2(1)$. It is essentially a test of correlation between the outcomes after accounting for the included factors, equivalent to testing whether the univariate estimation of litigation suffers from endogeneity bias. The null hypothesis is that there is no additional correlation, and the outcome equations may be estimated independently, each as a univariate probit.

I present the results of the bivariate probit estimations by era in Tables B.1–B.5. There is little evidence of an endogeneity problem in the first three eras. The likelihood-ratio test statistics are $\chi^2(1) = 0.1157$ ($p = .734$) for the earliest era, $\chi^2(1) = 0.5235$ ($p = .469$) following the Declaratory Judgment Act, and $\chi^2(1) = 0.2267$ ($p = .634$) in the flash of genius era. The test statistic is slightly higher following the Patent Act of 1952 at $\chi^2(1) =$

1.031 ($p = .310$), but I still cannot reject the null hypothesis of no endogeneity bias at any reasonable significance level. For comparison, I also estimate a univariate probit of litigation for each era. I do not present the full results for brevity, but for each of these four eras, the estimates are generally indistinguishable from the bivariate probit results and substantially similar to those in Table 4.5. The notable exception is the estimated effect of a continuation on the probability of litigation. The bivariate probit estimates of this effect vary across eras and are statistically insignificant with large standard errors. However, for each of the first four eras, the 95-percent confidence interval for the estimated coefficient on Continuation includes the univariate estimate. Based on the imprecision of the bivariate estimates and the small likelihood-ratio test statistics, I conclude that the true effects of a continuation in these eras are unlikely to differ from the estimates of the univariate model, which are similar whether estimated separately for each era or at once using interaction terms as in Table 4.5.

In the CAFC era, the likelihood-ratio test statistic is $\chi^2(1) = 30.29$ ($p < .001$). Clearly, there is interdependence between the patentee's decision to file a continuation and his decision to litigate in this era. This is consistent with the idea that patent applicants in recent decades have begun to use continuations strategically as part of a plan to eventually litigate the continued patent. The univariate estimates, in which Continuation is treated as exogenous, indicate a positive, statistically significant relationship between continuations and litigation, but the bivariate estimates reveal that this result is due to endogeneity bias. The true direct effect of a continuation on litigation is negative and statistically significant at about -38 percentage points. I interpret these results as follows. In this era, when a patent applicant decides to file a continuation, he often does so with the intention to litigate the patent. This leads to the positive, statistically significant relationship in the univariate estimates. Alternatively, continuations may result from rejection of an original application by the patent examiner. Such continuations are exogenous in the sense that they are the result of the examiner's decision rather than a strategic plan on the part of the patentee, though the applicant can always choose to abandon a rejected application. To the extent that a continuation is exogenously determined, it may reflect rejection by the patent examiner and may represent a low quality patent. The inverse relationship estimated between litigation and the exogenous aspect of continuations may indicate that such patents are less likely to be the subject of litigation to a decision because of their low quality.

The magnitude of the bias from endogeneity is striking. The estimated marginal effect of a continuation on the probability of litigation is positive at about 12 percentage points in the unreported univariate probit estimation for the CAFC era. The estimate from Table 4.5 is similar.[1] Controlling for endogeneity with the bivariate probit, the estimate falls to -38 percentage points. The difference between these estimates indicates that, in practice, there is a significant interdependence in the CAFC era between the use of continuations and the decision to litigate. Though the direct effect of a continuation per se is to reduce the probability of litigation, there is an obvious correlation between continuation use and litigation in the data presented in Section 4.4. Taken together, this evidence suggests that patent applicants in recent decades have begun to take advantage of the continuation procedure as part of a plan to eventually litigate the patent.

[1]Note that computing the marginal effect of a continuation in the CAFC era from the estimates in Table 4.5 requires adding the effects of the era interactions to the direct effect. The sum is $.1936 + .0892 - .1212 - .1092 + .0720 = .1244$.

Table B.1
Bivariate Probit Estimation for Earliest Era

	Parameters	Standard Error	Sample Partial Effects
Litigation			
Assigned	.0987	.0633	.0393
Foreign	-.4405***	.1291	-.1728
Continuation	-.1866	2.899	-.0743
Division	.8208***	.1738	.2915
Application-to-Grant Lag	.0299*	.0162	.0119
Claims	.0343***	.0041	.0137
# of USPC Codes	-.1059***	.0309	-.0422
Constant	-.1960**	.0889	
Continuation			
Assigned	-.1419	.1581	-.0024
Foreign	-4.2268	786.2	-.0150
Number of Inventors	.3324**	.1443	.0065
Division	.5143*	.2995	.0172
Claims	.0144***	.0043	.0003
# of USPC Codes	-.0535	.0896	-.0010
Issue Year	.0158	.0152	.0003
Constant	-32.8324	29.29	
Number of observations		1,846	
% correctly predicted (Litigation)		62.68	
% correctly predicted (Continuation)		98.27	
Log-likelihood value		-1,328.4718	
Comparison log-likelihood		-1,328.5297	
Likelihood-ratio test		$\chi^2(1) = .1157, \quad p = .734$	

Dependent variables are involvement in litigation to a decision and issuance from a continuation. Observations include patents involved in validity or infringement decisions made prior to June, 1934, and published in the *United States Patents Quarterly* between 1929 and 2006 along with their controls. Comparison log-likelihood is the sum of log-likelihoods from two univariate probit estimations. Partial effects are calculated at the sample mean. For dummy variables, the partial effect on the probability of an outcome is the increase in that probability with a change in the dummy variable from 0 to 1. Standard errors are shown in parentheses. * p<.10, ** p<.05, *** p<.01

Table B.2
Bivariate Probit Estimation for Declaratory Judgement Act Era

	Parameters	Standard Error	Sample Partial Effects
Litigation			
Assigned	.0175	.0466	.0070
Foreign	-.3686***	.0923	-.1455
Continuation	-.1253	.9763	.0496
Division	.2176*	.1224	.0855
Application-to-Grant Lag	.0386***	.0107	.0154
Claims	.0295***	.0027	.0118
# of USPC Codes	-.1338***	.0213	-.0533
Constant	-.0703	.0565	
Continuation			
Assigned	.0039	.1087	.0002
Foreign	.1759	.1911	.0095
Number of Inventors	-.0221	.1499	-.0010
Division	.2853	.2103	.0173
Claims	.0081**	.0034	.0004
# of USPC Codes	-.0907**	.0376	.0042
Issue Year	.0243**	.0105	.0011
Constant	-49.1839**	20.22	
Number of observations		3,250	
% correctly predicted (Litigation)		61.91	
% correctly predicted (Continuation)		97.91	
Log-likelihood value		-2,426.2788	
Comparison log-likelihood		-2,426.5406	
Likelihood-ratio test		$\chi^2(1) = .5235, \quad p = .469$	

Dependent variables are involvement in litigation to a decision and issuance from a continuation. Observations include patents involved in validity or infringement decisions made during June, 1934–October, 1941, and published in the *United States Patents Quarterly* between 1929 and 2006 along with their controls. Comparison log-likelihood is the sum of log-likelihoods from two univariate probit estimations. Partial effects are calculated at the sample mean. For dummy variables, the partial effect on the probability of an outcome is the increase in that probability with a change in the dummy variable from 0 to 1. Standard errors are shown in parentheses. * p<.10, ** p<.05, *** p<.01

Table B.3
Bivariate Probit Estimation for Flash of Genius Era

	Parameters	Standard Error	Sample Partial Effects
Litigation			
Assigned	-.2146***	.0589	-.0851
Foreign	-.7165***	.1295	-.2724
Continuation	-.0493	.8545	-.0196
Division	.4801***	.1561	.1815
Application-to-Grant Lag	.0612***	.0141	.0243
Claims	.0333***	.0035	.0132
# of USPC Codes	-.1493***	.0238	-.0594
Backward References	.0002	.0247	.0001
Median Reference Age	-.0114	.0104	-.0045
Constant	.3102	.1982	
Continuation			
Assigned	.2184*	.1132	.0135
Foreign	-.5918	.3802	-.0232
Number of Inventors	-.0661	.1360	-.0042
Division	-.1900	.3095	-.0102
Claims	.0085***	.0032	.0005
# of USPC Codes	.0494	.0406	.0031
Backward References	.0817***	.0316	.0052
Median Reference Age	-.0290	.0269	-.0018
Issue Year	.0453***	.0123	.0029
Constant	-90.3656***	24.02	
Number of observations		2,214	
% correctly predicted (Litigation)		63.32	
% correctly predicted (Continuation)		96.48	
Log-likelihood value		-1,710.5523	
Comparison log-likelihood		-1,710.6656	
Likelihood-ratio test		$\chi^2(1) = .2267, \quad p = .634$	

Dependent variables are involvement in litigation to a decision and issuance from a continuation. Observations include patents involved in validity or infringement decisions made during November, 1941–June, 1952, and published in the *United States Patents Quarterly* between 1929 and 2006 along with their controls. For patents issued prior to 1947, references and median reference age are necessarily set to 0 and a pre-reference dummy is set to 1. Comparison log-likelihood is the sum of log-likelihoods from two univariate probit estimations. Partial effects are calculated at the sample mean. For dummy variables, the partial effect on the probability of an outcome is the increase in that probability with a change in the dummy variable from 0 to 1. Standard errors are shown in parentheses. * p<.10, ** p<.05, *** p<.01

Table B.4
Bivariate Probit Estimation for Patent Act Era

	Parameters	Standard Error	Sample Partial Effects
Litigation			
Assigned	-.1874***	.0367	-.0745
Foreign	-.6616***	.0652	-.2526
Continuation	.4324	.2652	.1669
Division	.3966***	.0954	.1533
Application-to-Grant Lag	.0091	.0101	.0036
Claims	.0313***	.0028	.0125
# of USPC Codes	-.1454***	.0135	-.0580
Backward References	.0318***	.0047	.0127
Median Reference Age	-.0038**	.0016	-.0015
Constant	.0662	.0593	
Continuation			
Assigned	-.0437	.0587	-.0049
Foreign	-.2700***	.1005	-.0251
Number of Inventors	-.0832*	.0430	-.0093
Division	.1408	.1174	.0174
Claims	.0153***	.0027	.0017
# of USPC Codes	.0295	.0202	.0033
Backward References	.0103*	.0060	.0011
Median Reference Age	-.0032	.0025	-.0004
Issue Year	.0520***	.0037	.0058
Constant	-103.504***	7.350	
Number of observations		5,564	
% correctly predicted (Litigation)		62.20	
% correctly predicted (Continuation)		92.52	
Log-likelihood value		-4,908.1257	
Comparison log-likelihood		-4,908.6412	
Likelihood-ratio test		$\chi^2(1) = 1.031, \quad p = .310$	

Dependent variables are involvement in litigation to a decision and issuance from a continuation. Observations include patents involved in validity or infringement decisions made during July, 1952–September, 1982, and published in the *United States Patents Quarterly* between 1929 and 2006 along with their controls. For patents issued prior to 1947, references and median reference age are necessarily set to 0 and a pre-reference dummy is set to 1. Comparison log-likelihood is the sum of log-likelihoods from two univariate probit estimations. Partial effects are calculated at the sample mean. For dummy variables, the partial effect on the probability of an outcome is the increase in that probability with a change in the dummy variable from 0 to 1. Standard errors are shown in parentheses. * p<.10, ** p<.05, *** p<.01

Table B.5
Bivariate Probit Estimation for CAFC Era

	Parameters	Standard Error	Sample Partial Effects
Litigation			
Assigned	-.0550	.0477	-.0219
Foreign	-.7151***	.0519	-.2751
Continuation	-1.0197***	.1248	-.3802
Division	.2559***	.0737	.1013
Application-to-Grant Lag	.0716***	.0104	.0286
Claims	.0154***	.0016	.0062
# of USPC Codes	-.1789***	.0192	-.0714
Backward References	.0116***	.0015	.0046
Median Reference Age	-.0020	.0018	-.0008
Constant	.2921***	.0658	
Continuation			
Assigned	.0570	.0538	.0183
Foreign	-.2570***	.0514	-.0797
Number of Inventors	.0324**	.0146	.0105
Division	.4274***	.0697	.1517
Claims	.0101***	.0015	.0033
# of USPC Codes	-.0035	.0184	-.0011
Backward References	.0101***	.0015	.0033
Median Reference Age	.0007	.0021	.0002
Issue Year	.0189***	.0024	.0061
Constant	-38.4681***	4.676	
Number of observations		4,236	
% correctly predicted (Litigation)		57.79	
% correctly predicted (Continuation)		74.69	
Log-likelihood value		-4,784.3135	
Comparison log-likelihood		-4,799.4606	
Likelihood-ratio test		$\chi^2(1) = 30.29, \quad p < .001$	

Dependent variables are involvement in litigation to a decision and issuance from a continuation. Observations include patents involved in validity or infringement decisions made after September, 1982, and published in the *United States Patents Quarterly* between 1929 and 2006 along with their controls. For patents issued prior to 1947, references and median reference age are necessarily set to 0 and a pre-reference dummy is set to 1. Comparison log-likelihood is the sum of log-likelihoods from two univariate probit estimations. Partial effects are calculated at the sample mean. For dummy variables, the partial effect on the probability of an outcome is the increase in that probability with a change in the dummy variable from 0 to 1. Standard errors are shown in parentheses. * p<.10, ** p<.05, *** p<.01