The Growing Complexity of the United States Patent System¹

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A great deal has been written of late on the growing importance of intellectual property rights to the economy. With this new focus has come increased attention to the patent system. It is well known that the number of patents is increasing rapidly.⁴ A variety of explanations have been offered for this increase. One explanation is economic: Writers talk of the “new” or “information” economy, in which ideas rather than capital investments are the mainstay of value.⁵ As intellectual property becomes more central to a company’s value, perhaps companies are willing to spend more to protect it. Another explanation is technological: we are in an era of astounding productivity attributable to

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⁴ Utility Patents Issued Per Year

<u>Year of Issue</u>	<u>Number of Patents Issued</u>
1999	153,493
1998	147,521
1997	111,983
1996	109,646
1995	101,419
1994	101,676

U.S. PATENT & TRADEMARK OFFICE, U.S. PATENT STATISTICS, CALENDAR YEARS 1963-1999 (2000), at <http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports.htm#PSR>.

⁵ See, e.g., Note, *Antitrust and the Information Age: Section 2 Monopolization Analyses in the New Economy*, 114 *Harv. L. Rev.* 1623, 1627 (2001).

technological innovation, and that innovation reflects itself in more patents.⁶ A third explanation is legal: the development of the Federal Circuit in 1982 led to stronger patent rights, which encouraged more patenting.⁷ There are even cultural explanations: the increasing attention paid to intellectual property in the media and popular press⁸ has led people to pay more attention to patents.

The focus on absolute numbers obscures a number of interesting facts about the trends in patenting over the past 25 years. To understand the significance of this broader trend, we should look not only at how many patents are being issued, but also at who is obtaining them and for what sorts of inventions. Further, we should try to understand how the process of prosecuting patents has changed over time.

In a recent study, we collected and analyzed a random sample of 1000 utility patents issued between 1996 and 1998.⁹ We then identified a large number of facts about each of these patents. In that article, we used data from this sample to predict the characteristics of patents being obtained in the entire population of patents issued during that period. We also tested for a large number of relationships in these patents, such as

⁶ For arguments along these lines, see Eric S. Maurer, Comment, *An Economic Justification for a Broad Interpretation of Patentable Subject Matter*, 95 **Nw. U. L. Rev.** 1057, 1073 (2001); F. Scott Kieff, *Property Rights and Property Rules for Commercializing Inventions*, 85 **Minn. L. Rev.** 697, n.4 (2001). The economic evidence is more ambiguous. See generally Edwin Mansfield, *Patents and Innovation: An Empirical Study*, 32 **Mgmt. Sci.** 173 (1986); **National Bureau of Economic Research, R & D, Patents, and Productivity** (Zvi Griliches ed., 1984); Richard C. Levin et al., *Appropriating the Returns from Industrial Research and Development*, 1987 **Brookings Papers on Econ. Activity** 783 (1987).

⁷ On these legal changes, see John R. Allison & Mark A. Lemley, *Empirical Evidence on the Validity of Litigated Patents*, 26 **AIPLA Q.J.** 185 (1998) (percentage of patents held valid rose from 35% in the 1970s to 54% in the early 1990s); Rochelle Dreyfuss, *The Federal Circuit: A Case Study in Specialized Courts*, 64 **N.Y.U. L. Rev.** 1, 25-26 (1989); Robert P. Merges, *Commercial Success and Patent Standards: Economic Perspectives on Innovation*, 76 **Calif. L. Rev.** 803, 820-21 (1988) (comparing pre- and post-Federal Circuit era statistics).

⁸ See, e.g., Kevin Rivette & David Kline, *Rembrandts in the Attic* (Harvard Bus. Sch. Press 2000).

⁹ John R. Allison & Mark A. Lemley, *Who's Patenting What? An Empirical Exploration of Patent Prosecution*, 53 **Vand. L. Rev.** 2099 (2000).

how nationality relates to area of technology and how the size of the patentee relates to the prosecution process. In this Article, we compare that data set of recent patents to a similarly random sample of 1000 patents issued twenty years earlier, between 1976 and 1978. By studying the differences between the groups, we can get a clear picture of how the patent system has changed over time.

The results are dramatic. By almost any measure – subject matter, time spent in prosecution, number of prior art references cited, number of claims, number of continuation applications filed, number of inventors – the patents issued in the late 1990s are more complex than those issued in the 1970s. While some of these effects are attributable to the patenting of new technologies like biotechnology and software, unknown in the early 1970s, the increase in complexity is robust even across areas of technology. Further, the patent system in the 1990s is more heterogeneous than it was in the 1970s. There are far greater differences by area of technology and by nationality in how patents are being prosecuted in the 1990s than there were in the 1970s.

We made a number of other interesting findings as well. Among our most important results are:

- ⌚ There are some radical differences in the nature of the technologies being patented. On the whole, the trend has been towards patenting in industries considered “high-tech,” such as software, semiconductors, computers, and biotechnology. Not all increases fit into this category, however; medical devices and automotive technologies also accounted for significantly more patents in the 1990s than in the 1970s. The big losers during this period were the traditional mainstay of patents – mechanical inventions – as well as the somewhat higher-tech electronics category.

- ⌚ U.S. patents are overwhelmingly obtained by the developed world. Nationality of origin has diversified slightly since the 1970s, but inventorship remains concentrated in North America, Europe, and a small number of Asian countries.
- ⌚ Patenting in the United States today is something that is largely done by corporations, not individuals. Further, the trend is clearly in that direction. But the development is not a new one; even in the 1970s sample more than three-quarters of all inventors assigned their patent rights to a corporation.
- ⌚ Patent prosecution time has increased rather substantially over the past twenty years. The increase has occurred across the board, but is particularly large in fields like pharmaceuticals and biotechnology. This is particularly significant given the change in patent term, which is now measured from the filing date. Increased delay in prosecution means that patentees receive less protection, a fact that was politically controversial throughout the 1990s. While part of this increase can be attributed to the greater use of continuation practice by patentees, even controlling for that practice patent applications take longer to get through the PTO than they did in the 1970s. There is much greater variation by area of technology and by nationality in the time spent in prosecution than there was in the 1970s.
- ⌚ Patents issued in the 1990s cited vastly more prior art than patents issued in the 1970s. Overall, patents in the 1990s sample cited almost three times as much total prior art, and more than ten times as much non-patent art, as patents in the earlier sample. Industries vary in the amount of prior art they cite much more than they did in the 1970s. Further, U.S. patentees cited the same number of references as their foreign counterparts in the 1970s, but nearly twice as many references in the 1990s.

- ⌚ Patents issued in the 1990s contained approximately 50% more claims than patents issued in the 1970s. This means that those patents were somewhat more expensive, and may also be an indication that the technology was more complex.

In Part I, we briefly review the existing empirical literature on trends in patent prosecution. In Part II, we outline the methodology of our study. In Part III, the heart of the article, we present our results. Finally, in Part IV, we speculate both on explanations for the dramatic increase in the complexity of patents and on its implications for patent policy. We reject a number of possible explanations, including both changes in the quality of PTO examination and changes in the nature of technology, as inconsistent with the data. The hypothesis that best fits the data is that patents are increasingly valuable to businesses, and that companies that expect to use patents in licensing or litigation are willing to spend more time and effort in the PTO to get a better patent. We discuss some of the implications of this idea for patent policy in Part IV as well.

I. Existing Literature

The lack of empirical evidence on the function and impact of the patent system has long been lamented.¹⁰ In recent years, a number of scholars have begun to address this deficiency in a variety of ways. This scholarship addresses three basic types of

¹⁰ George Priest complained years ago that there was virtually no useful economic evidence addressing the impact of intellectual property. George Priest, *What Economists Can Tell Lawyers About Intellectual Property*, 8 RES. L. & ECON. 19 (1986). Fritz Machlup told Congress that economists had essentially no useful conclusions to draw on the nature of the patent system. See SENATE SUBCOMM. ON PATENTS, TRADEMARKS, AND COPYRIGHTS, SENATE COMM. ON THE JUDICIARY, 85TH CONG., AN ECONOMIC REVIEW OF THE PATENT SYSTEM 55 (Comm. Print 1958) (prepared by Fritz Machlup). For some of the disagreements among historians over the impact of the patent system on innovation, see ROBERT P. MERGES ET AL., *INTELLECTUAL PROPERTY IN THE NEW TECHNOLOGICAL AGE* 126-27 (2d ed. 2000).

These complaints have less force today. As noted below, there is increasing attention in academic circles to the relationship between patents and innovation. Our study is one piece in this puzzle, albeit one focused on a portion of the problem that Priest might not consider the most important one.

questions: (1) why people patent, (2) what happens to patents after they are issued, and (3) what sorts of things are patented.¹¹

First, several researchers have focused attention on how patents are perceived and used by firms in various economic sectors. The 1987 study by Levin, Klevorick, Nelson and Winter is a prominent example.¹² There, the authors surveyed a large number of high-level R & D executives in over 100 industries to identify preferences among patents, secrecy, lead time, and other methods of protecting the competitive advantages of important new processes and products. Although the authors found significant inter-industry variations, patents generally were not viewed as the most effective means of encouraging innovation. Indeed, in some industries, patents were considered the least effective contributor to innovation.¹³

¹¹ A fourth sort of work not catalogued here concerns the relationship between patents and economic development. For work along these lines, see Josh Lerner, *150 Years of Patent Protection*, NBER working paper W7478 (2000); Zvi Griliches, *Patent Statistics as Economic Indicators: A Survey*, 28 **J. Econ. Lit.** 1661 (1990).

¹² Richard C. Levin et al, *Appropriating the Returns from Industrial Research and Development*, 1987 BROOKINGS PAPERS ON ECON. ACTIVITY 783.

¹³ *Id.* at 798. Not surprisingly, patents were viewed as much less effective for processes than for products. *Id.* at 794-95. Among the most important reasons found by the authors for the perceived limitations on the effectiveness of patents for were the ease of inventing around both process and product patents and doubts about patentability in the case of processes. *Id.* at 803. Given their findings, the authors were led to question why firms patent so much, and at an increasing rate. Their research did not explore this question. However, a recent study by Cohen, *et al.*, directly addresses this question. See Wesley M. Cohen *et al.*, *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)*, NBER Working Paper No. W7552 (Feb. 2000). Before seeking to answer this question, the Cohen study updates that of Levin and finds that, across many manufacturing sectors, patents are viewed as substantially less effective for appropriating the value of product innovations than all other alternatives, secrecy and lead time being the most preferred alternatives. The study finds a number of reasons why firms nonetheless seek patents. Unsurprisingly, the most important reason given by respondents was to prevent others from copying. The authors recognize, however, that the importance of this reason could have been exaggerated because many respondents may have viewed this as the most “socially desirable response.” The second most important reason was “blocking,” or preventing other firms from patenting related technology. Blocking and related defensive motives may help explain our finding that patent litigation commonly occurs long after the issuance of a patent. See John R. Allison & Mark A. Lemley, *Empirical Evidence on the Validity of Litigated Patents*, 26 **AIPLA Q.J.** 185, 237-38 (1998). For another test of possible explanations why firms increasingly seek patents, see Samuel Kortum & Josh Lerner, *Stronger Protection or Technological Revolution: What is Behind the Recent Surge in Patenting?*, 28 **Res. Pol.** 247 (1999). Kortum & Lerner reject the explanation that changes in patent law have prompted the surge in

Second, many studies have attempted to determine what people actually do with patents once they get them, and the related question of how valuable those patents are. This class of studies has several parts. A growing number of scholars have attempted to value patents, either in absolute or relative terms, by reference to the use that is made of them by the patentee or the citations made to them by others.¹⁴ Several other authors have evaluated patent acquisition and licensing strategies in various industries through case studies.¹⁵ One especially interesting study of licensing by Josh Lerner in 1995 empirically examined the patenting behavior of 419 new biotechnology firms with

patenting. For other views, see Arti Kaur Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 **Nw. U. L. Rev.** 77, 94-98 (1999) (patent law change has affected patenting in the biotechnology industry); Simone A. Rose, *Patent "Monopolyphobia": A Means of Extinguishing the Fountainhead?*, 49 **Case W. Res. L. Rev.** 509 (1999) (arguing that because patent filings are positively correlated with economic growth, patents must have caused growth, rather than the other way around). On the relationship between patent statistics and economic indicators generally, see Zvi Griliches, *Patent Statistics as Economic Indicators: A Survey*, 28 **J. Econ. Lit.** 1661 (1990). The manifold uses of patents beyond litigation and licensing are discussed in Mark A. Lemley, *Rational Ignorance at the Patent Office*, 95 **Nw. U. L. Rev.** — (forthcoming 2001) and Mark A. Lemley, *Reconceiving Patents in the Age of Venture Capital*, 4 **J. Sm. & Emerging Bus. L.** 137 (2000).

For other work along these lines, see, e.g., John Bound et al., *Who Does R&D and Who Patents?*, in **Patents, R&D and Productivity** (Zvi Griliches ed. 1984); Zvi Griliches, Bronwyn H. Hall, & A. Pakes, *R&D, Patents and Market Value Revisited: Is there a Second (Technological Opportunity) Factor?*, 1 **Econ. Innov. & New Tech.** 183 (1991).

Still other work explores trends in patenting in more detail on an industry-by-industry basis. See, e.g., John H. Barton, *The Impact of Contemporary Patent Law on Plant Biotechnology Research* (working paper 1998); Bronwyn Hall & Rosemarie Ham Ziedonis, *The Patent Paradox Revisited: Determinants of Patenting in the U.S. Semiconductor Industry, 1980-1994*, N.B.E.R. working paper W7062 (1999).

¹⁴ For an interesting approach to this question that accounts for the extent firms value patents by examining renewal data and multi-country filings, see Jean O. Lanjouw et al., *How to Count Patents and Value Intellectual Property: Uses of Patent Renewal and Application Data*, 46 **J. Indus. Econ.** 405 (1998). Cf. Mark Schankerman & Ariel Pakes, *Estimates of the Value of Patent Rights in European Countries During the Post-1950 Period*, 96 **ECON. J.** 1052 (1986) (attempting to value patents in Europe). For the patent citation approach, see, e.g., Adam B. Jaffe & Manuel Trajtenberg, *International Knowledge Flows: Evidence From Patent Citations*, 8 **Econ. Innov. & New Tech.** 105 (1999); Bronwyn H. Hall, Adam B. Jaffe & Manuel Trajtenberg, *Market Value and Patent Citations: A First Look*, N.B.E.R. working paper W7741 (2000).

¹⁵ Rebecca S. Eisenberg, *Public Research and Private Development: Patents and Technology Transfer in Government-Sponsored Research*, 82 **VA. L. REV.** 1663 (1996); Josh Lerner & Robert P. Merges, *The Control of Technology Alliances: An Empirical Analysis of the Biotechnology Industry*, 46 **J. Indus. Econ.** 125-156 (1998); Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope*, 90 **COLUM. L. REV.** 839 (1990); Robert P. Merges, *Contracting Into Liability Rules: Institutions Supporting Transactions in Intellectual Property Rights*, 86 **CAL. L. REV.** 1293 (1996); David J. Teece, *Profiting From*

varying litigation costs.¹⁶ One of Lerner's key findings was that firms with relatively higher litigation costs are less likely to seek patents in those subclasses¹⁷ in which there had been many patent damage awards to rivals, especially to those with lower litigation costs.¹⁸

A smaller number of empirical studies have been conducted on patent litigation. There are several comprehensive studies (including a recent one we conducted) on how patents fare in litigation.¹⁹ Other studies focus on a particular aspect of litigation. Of the

Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy, 15 RES. POL. 285 (1986).

¹⁶ Josh Lerner, *Patenting in the Shadow of Competition*, 38 J.L. & ECON. 463 (1995).

¹⁷ These subclasses exist within the patent classification system maintained by the United States Patent & Trademark Office (PTO). There are over 120,000 subclasses. Lerner's finding means that firms with relatively high litigation costs are more likely to use litigation-avoidance patenting strategies.

¹⁸ Lerner, *supra* note __, at 478-79. Using a number of ingenious data collection and testing methods, particularly in estimating relative litigation costs, Lerner contributes not only to the literature on patenting strategy but also to the literature on the various effects that litigation and other dispute resolution costs have on firms' behavior.

¹⁹ Two of these studies cover relatively early periods. The first, by P.J. Federico, provided validity and infringement data for litigated patents reported in the *United States Patent Quarterly (U.S.P.Q.)* during the years 1925-1954, with more in-depth study of patents litigated during the years 1948-1954. Although Federico did not attempt to examine a large number of variables, he did examine overall validity rates in a relatively thorough manner, and in the 1948-1954 portion of the study he explored the courts' treatment of uncited and cited prior art. P.J. Federico, *Adjudicated Patents, 1948-54*, 38 J. PAT. OFF. SOC'Y 233 (1956). Federico found that courts upheld the validity of patents in only about 30-40% of the cases in which validity was an issue. *Id.* at 236. He also concluded that the prior art before the courts was often better than used by the PTO in issuing the patent, based on his observation that accused infringers were generally more successful in convincing courts to invalidate patents on the basis of uncited prior art than on the basis of cited prior art. *Id.* at 249. Our data in a prior study confirm this observation, though the explanation Federico offers is by no means the only one. See John R. Allison & Mark A. Lemley, *Empirical Evidence on the Validity of Litigated Patents*, 26 AIPLA Q.J. 185, 231-34 (1998).

The other early study, first published by Koenig in 1974 and then updated through 1980, constitutes the most extensive set of data ever gathered on patent litigation. GLORIA K. KOENIG, PATENT INVALIDITY: A STATISTICAL AND SUBSTANTIVE ANALYSIS (rev. ed. 1980). Koenig also notes other early studies, but they appear to not add anything meaningful to the work of Federico and Koenig. KOENIG, *id.* at 3-4 to 3-10. Like Federico's data for 1925-1954, Koenig's data for 1953-1978 revealed that district and circuit courts found patents valid only about 35% of the time. Koenig collected all patent cases reported in the *U.S.P.Q.* in the years 1953-1978 to produce an array of descriptive statistics. She also selected a random sample of 150 patents from the years 1953-1967 for more in-depth study. In addition to finding that most courts held patents invalid, and noting the wide disparity of validity rates across regional circuits, she also found that obviousness (or "lack of invention") was the most frequently used basis for judicial invalidation of patents. *Id.* at 5-70 to 5-78. Koenig also studied the many kinds of prior art relied on by courts, and the ways in which uncited prior art played a role in the courts' decisions. *Id.* at 5-25 to 5-69.

relatively few recent contributions to the empirical literature on patent litigation, the work by Lanjouw and Lerner on injunctive relief in patent cases is notable.²⁰ They evaluate a sample of 252 patent suits, testing the hypothesis that preliminary injunctive relief in patent litigation is used to impose costs on rivals.²¹ Coolley has also produced a useful empirical study of a purely descriptive nature on patent infringement damages.²² Lanjouw and Schankerman evaluated data provided by the PTO about litigated patents to determine the ways in which litigated patents differ from the general patent pool.²³ At least two other studies²⁴ have attempted, with mixed success, to empirically analyze the decision-making behavior of the United States Court of Appeals for the Federal Circuit.²⁵

More recently, we conducted a study in 1998 covering all final written decisions on patent validity from 1989 through 1996. See John R. Allison & Mark A. Lemley, *Empirical Evidence on the Validity of Litigated Patents*, 26 **AIPLA Q.J.** 185 (1998). Finally, Kimberly Moore has a comprehensive study of judge and jury decisions in all cases that went to trial from 1983 to 1999. Kimberly A. Moore, *Judges, Juries and Patent Cases – An Empirical Peek Inside the Black Box*, 99 **Mich. L. Rev.** 365 (2000). Moore's study is notable for its completeness – it includes all jury verdicts, including those never reported in an opinion – and for its detailed investigation into issues of validity, infringement, enforceability and damages.

²⁰ Jean O. Lanjouw & Josh Lerner, *Tilting the Table? The Predatory Use of Preliminary Injunctions*, __ **J. L. & Econ.** __ (forthcoming 2001). Other good studies on particular issues include Kimberly A. Moore, *Forum Shopping in Patent Cases: Does Geographic Choice Affect Innovation?*, 79 **N.C. L. Rev.** 889 (2001); Kimberly A. Moore, *Are District Court Judges Equipped to Resolve Patent Cases?: "The Question is Which is to be Master – That's All"* (working paper 2001).

²¹ *Id.* Lanjouw and Lerner find that their data are consistent with the hypothesis that preliminary injunctive relief is a predatory weapon in patent cases.

²² Ronald B. Coolley, *Overview and Statistical Study of the Law on Patent Damages*, 75 **J. Pat. & Trademark Off. Soc'y** 515 (1993). This study analyzed several factors from 152 decisions between 1982-1992 in which the amount of damages was reported. Although unstated in the article, it appears that both district court and Federal Circuit decisions were included. The article also did not define the source of its data set, but apparently included decisions reported in West reporters, U.S.P.Q., and Lexis.

²³ Jean O. Lanjouw & Mark Schankerman, *Characteristics of Patent Litigation: A Window on Competition*, 32 **RAND J. Econ.** 129 (2001).

²⁴ Ronald B. Coolley, *What the Federal Circuit Has Done and How Often: Statistical Study of the CAFC Patent Decisions—1982-1988*, 71 **J. PAT. & TRADEMARK OFF. SOC'Y** 385 (1989); Donald R. Dunner, *et al.*, *A Statistical Look at the Federal Circuit's Patent Decisions: 1982-1994*, 5 **FED. CIR. B.J.** 151 (1995).

The Coolley study of Federal Circuit decision making is quite difficult to use as a basis for any type of statistical conclusion. It did not identify the source of its data or attempt any kind of precise definition of its data set, and it has a number of data comparability problems. Some of these problems stem from the inclusion of design patent decisions, decisions on appeal from all lower tribunals over which the

There is also a small body of empirical work on patent prosecution. This work attempts to define and explain the characteristics of patents themselves, rather than why they are obtained or how they are ultimately used. Some of these studies are industry specific. For example, Daniel Johnson has studied aspects of the prosecution process in the context of biotechnology patents, evaluating in one particular industry many of the characteristics we examine here across all industries.²⁶ Other studies cut across industries, but study only one particular aspect of the prosecution process.²⁷ Our 2000

Federal Circuit has appellate jurisdiction, and inclusion of all subjects of Federal Circuit decision and all types Federal Circuit judgments.

The study by Dunner, *et al.*, on the other hand, provides much more useful descriptive statistics. This research had the avowed objective of determining whether the Federal Circuit was “biased” in favor of patents. Specifically, Dunner examines whether the Federal Circuit is generally more pro-patent than its predecessor patent appeals courts, namely, the regional circuits and the Court of Customs and Patent Appeals (C.C.P.A.). Dunner’s study was based on 1302 Federal Circuit decisions of all kinds, many unreported; the source of the data set is not clear. Although the study was based on a very large data set that may present data comparability problems, one portion of it did segregate Federal Circuit decisions on patent validity. Like other studies of the Federal Circuit, the Dunner study found a much higher validity rate in the Federal Circuit than had been found in district court and regional court of appeals decisions prior to the Federal Circuit’s creation. This was found to be true both overall and with respect to the individual grounds of novelty/statutory bars, obviousness, and description and claim adequacy. *Id.* at 154.

Other work in the area that attempts to catalogue particular aspects of Federal Circuit decisions includes Rochelle Cooper Dreyfuss, *The Federal Circuit: A Case Study in Specialized Courts*, 64 **N.Y.U. L. Rev.** 1 (1989); John R. Allison & Mark A. Lemley, *How Federal Circuit Judges Vote in Patent Validity Cases*, 27 **Fl. St. U. L. Rev.** 745 (2000).

²⁵ Congress created the Federal Circuit in 1982 to serve, *inter alia*, as the only United States court of appeals to review district court patent cases. Although not relevant to our study, the same legislation also gave the newly created Federal Circuit appellate jurisdiction over appeals from decisions of the Patent and Trademark Office’s Board of Patent Appeals and Interferences in instances where the Board had affirmed the patent examiner’s rejection of a patent application. This latter form of appellate jurisdiction had previously been the province of the C.C.P.A., the existence of which was extinguished by the 1982 legislation. Federal Courts Improvement Act of 1982, P.L. 97-164, 96 Stat. 25, 37 (codified as amended at 28 U.S.C. § 1295 (1994)).

²⁶ See Daniel K.N. Johnson, *Biotechnology Inventions: What Can We Learn From Patents?* (working paper 2000).

²⁷ See, e.g., Mark A. Lemley, *An Empirical Study of the Twenty-Year Patent Term*, 22 **AIPLA Q.J.** 369 (1994); Chris L. Holm, *Patent Prosecution Comparison Between the United States Patent and Trademark Office and the European Patent Office*, 25 **AIPLA Q.J.** 233 (1997) (both studying time spent in prosecution).

article was a comprehensive study of the relationship between multiple characteristics of patents across all major areas of technology.²⁸

Finally, there has been a fair amount of work done on the history of the patent system, though very little of it is empirical.²⁹ One empirical work of note is Josh Lerner's catalogue of multiple patent systems over time.³⁰ But Lerner's work is broad-brush, while our aim in this study is to make detailed comparisons over a fairly short time-frame.

II. Description of the Study

We collected two random samples, each of 1,000 utility patents issued in the United States during a two-year period. Starting with the patent having the first number issued in the first week of June, 1996, and ending with the patent having the last number issued in the last week of May, 1998, we then used a random-number generator to select a random sample of 1,000 patent numbers from this population.³¹ The earlier data were collected in the same way, starting with the patent having the first number issued in the

²⁸ Allison & Lemley, *Who's Patenting What*, *supra* note ____.

²⁹ Among the better non-empirical sources are **H. Dutton, *The Patent System and Inventive Activity During the Industrial Revolution 1750-1852*** 103-48 (1984); Fritz Machlup & Edith Penrose, *The Patent Controversy in The Nineteenth Century*, 10 **J. Econ. Hist.** 1 (1950); Catherine L. Fisk, *Removing the 'Fuel of Interest' from the Fire of Genius: Law and the Employee-Inventor, 1830-1930*, 65 **U. Chi. L. Rev.** 1127 (1998), Robert P. Merges, *One Hundred Years of Solicitude: Intellectual Property Law, 1900-2000*, 88 **Calif. L. Rev.** 2187 (2000); Edward C. Walterscheid, *To Promote the Progress of Useful Arts: American Patent Law and Administration, 1787-1836*, 80 **J. Pat. & Trademark Off. Soc'y** 11 (1998).

³⁰ See Lerner, *150 Years*, *supra* note ____.

³¹ When a sample is truly random, the larger the sample, the more likely it will include duplicate numbers. Knowing that this would be the case with a sample of 1,000, we actually selected an initial sample of 1,050. Fourteen of the numbers were duplicates, and were discarded. We then substituted the next 14, i.e., randomly generated numbers 1,001-1,014. The remainder of the 1,050 were discarded. Not only was this method a matter of necessity, but it also does not affect the randomness of the sample.

first week of June, 1976, and ending with the patent having the last number issued in the last week of May, 1978.

For each patent in the sample, we obtained a wide variety of information including the following: (1) PTO classification number and PTO technology group (mechanical, chemical, or electrical); (2) area of technology, among the 14 technology groups we defined, and number of technology areas into which each patent fell;³² (3) the invention's country of origin;³³ (4) filing date, U.S. and foreign priority dates, issue date, and time spent in prosecution;³⁴ (5) the number and type of filings to which each patent claimed priority, if any; (6) the number of inventors; (7) whether the patent had been assigned; (8) whether the patent had a foreign assignee, and whether it had at least one foreign inventor; (9) the number and type of prior art references cited on the face of the patent; and (10) the number and type of claims contained in the patent.³⁵

Most of these data were available in the patent itself or easily derived from information in the patent. There was one major exception. Because we found the PTO's subject matter classification scheme inadequate for our purposes, we classify the patents in our sample into areas of technology that we have defined ourselves.³⁶ The act of defining areas of technology in today's world is as much art as it is science. Some might reasonably disagree with some of our definitions; although almost all of our fourteen

³² For more information on how we defined these groups, see *infra* notes ___-___ and accompanying text.

³³ For more information on how we defined country of origin, see *infra* notes ___-___ and accompanying text.

³⁴ Time spent in prosecution was determined by subtracting the first U.S. priority date from the issue date.

³⁵ In the study of 1990s patents, we also obtained information from the PTO on small entity status. The PTO did not keep similar records before 1980, however, so we cannot compare small entity status between the two samples.

areas are susceptible to more than one definitional approach, we believe ours is at least as reasonable as other possible alternatives. While it is possible to devise an almost endless list of categories and subcategories, we chose the fourteen categories in this study because they reflect the areas of technology into which inventions in the sample generally fell. In many cases the categories also have significance in larger policy debates. For example, while we could have decided not to separate out software patents from the computer-related category, there is enough debate about software patents that we thought it worth analyzing them separately.³⁷ Following are the definitions of technology areas employed in this study, listed in the order in which they appeared in our spreadsheet columns.

(1) Pharmaceutical: Any process or substance to be used in the diagnosis or treatment of diseases or other medical conditions in humans or animals including processes or substances used in medical research. In this data set, a technology classified as Pharmaceutical will also be within either the Chemistry or Biotechnology areas.³⁸

(2) Medical device: An apparatus to be used for the diagnosis or treatment of diseases in humans or animals including apparatuses used in medical research. An invention classified as a medical device will necessarily fall within at least one other classification, such as computer-related, electronics, mechanics, acoustics, or optics.

³⁶ Similarly, we did not use the “Canadian Concordance” between PTO classifications and industries, because we believe the PTO classifications themselves are sometimes suspect.

³⁷ The patents collected in our study issued before the Federal Circuit’s 1998 decision in *State Street Bank & Trust v. Signature Fin. Servs.*, 149 F.3d 1368 (Fed. Cir. 1998), which permitted the patenting of “business methods.” We therefore did not attempt to break out business methods into a separate technology area. In any event, we did not encounter any patents in our sample that fit the business methods category.

³⁸ All of the patents in the 1970s sample classified as Pharmaceutical were also classified as Chemistry, but none was also classified as Biotechnology, presumably because the science was still in its infancy at that point.

(3) Biotechnology: Any process or product involving advanced genetic techniques intended to construct new microbial, plant or animal strains.³⁹

(4) Computer-Related: (a) Any process or product for improving computer hardware (except for advances in semiconductor technology, which are in a separate, mutually exclusive classification). (b) An invention solely embodied in software. (c) Any invention in which a microprocessor or other integrated logic circuit is expressed in the patent as being a critical part of the invention (again excluding advances in semiconductor technology itself). Any invention in part (c) of the Computer-Related classification will necessarily also be classified in one or more other categories.

(5) Software: An invention that is completely embodied in software, even if the claims of the patent refer to a system or article of manufacture. A pure software invention is also placed in the Computer-Related classification. The instructions embodied in software code can often be embodied in semiconductor chips in a device; this is done in the obvious instances of modern consumer electronic devices, automobiles, and other devices in which the instructions are very specific to a particular function of the device and the use of software for logic instructions simply is not practically feasible. Another researcher might include within the Software classification those inventions in which the algorithms are embodied in chips, but we have chosen to include within our definition of Software only those inventions that consist purely of software that is not embodied in hardware.⁴⁰

³⁹ No patents in the 1970s sample fell within the Biotechnology category.

⁴⁰ No patents in the 1970s sample fell within the Software category.

(6) Semiconductor: A process or product intended to advance the state of the art in researching, designing, or fabricating semiconductor computer chips.

(7) Electronics: A process or product in which the sole or a critical part of the invention makes use of traditional electronic circuitry or involves electric energy storage. An invention in this classification may also be included in other classifications, including chemistry, mechanics, or optics.

(8) Chemistry: A process that consists solely of chemical reactions, a product resulting from such a process, or an invention of which a chemical process or product is a critical part. An invention in the field of chemistry may be included in one or more other classifications, such as electronics or optics.

(9) Mechanics: A process or product that consists solely of the use of mechanical parts, sometimes combined with heat, hydraulics, pneumatics, or other power sources; or an invention in which the above is a critical part. Some inventions classified as mechanical also will be in one or more other classifications, such as electronics. While many different types of inventions fit into this category, it should not be confused with a catchall “other” category.

(10) Acoustics: A process or product that consists solely or as a critical part of an invention using sound waves. Such an invention may also be included in another classification, such as medical device or computer-related.

(11) Optics: A process or product intended to advance the state of the art in the use of light waves or imaging. This may be its sole purpose or it may be a critical part of an invention also having other purposes. Optics technology often will also be classified in one or more other areas, such as medical devices, semiconductors, electronics, or chemistry.

(12) Automotive-related: As expressed in the patent, an invention that is intended for use with automobiles or trucks. An invention in this classification necessarily will also be included within another classification, such as mechanics, electronics, or even computer-related.

(13) Energy-related: As expressed in the patent, an invention that intends to advance the state of the art in the production, processing, or transmission of energy. An invention is also included in this classification if its intended use is research into some aspect of the production, processing, or transmission of energy. The definition of “energy” includes that *produced by any means from any source*, including fossil fuels, nuclear power, electricity produced, and the many forms of radiation. An invention in this classification necessarily will also be included within another classification, such as mechanics, electronics, acoustics (for example, seismological inventions for detection of oil and gas), optics, chemistry, and even computer-related.

(14) Communications-related: As expressed in the patent, any invention intended to improve the state of the art in communications. As in the other broad classifications, an invention placed in this classification necessarily will also be included within another classification, such as optics, electronics, or computer-related.

We separate our results into two parts. In the first part, we use our samples as a tool to describe the approximate characteristics of the larger population of issued patents.⁴¹ Because our study covers only a sample, it cannot predict with perfect accuracy the characteristics of the population as a whole. However, because the sample

⁴¹ More precisely, we are predicting the characteristics of the populations we have defined, which are utility patents issued in the United States during the mid-1976 to mid-1978 and mid-1996 to mid-1998 time periods. These results will not necessarily be predictive of patents issued outside that time period.

size is random and so large, the “confidence intervals,” the range within which we can be 95% (or 99%) confident the actual number will fall, are quite small. In describing our results in this first part, we have chosen to omit reference to the exact confidence intervals unless they are important to the conclusions we identify.⁴² For this study, the critical facts are the differences between the two samples. It is those disparities that permit us to identify trends in patent prosecution over time. We present the differences between the mean numbers in the samples. We also ran statistical tests to estimate the significance of these differences in the relevant populations as a whole. To do this, we used two-tailed t-tests for comparison of the means of the two samples.

A second set of results involves the evaluation of relationships between different aspects of the data within each time period. For both samples, we have taken most of the characteristics identified in the first part and related them to each other.⁴³ We then compare the relationships across samples. For example, we study the relationships between an invention’s country of origin and the mean time spent in prosecution in both the 1970s data and the 1990s data. We then compare the two, looking for differences in the relationships between the two samples. Again, we use two-tailed t-tests to compare the means.

⁴² We do of course have the confidence intervals in our data set and will make them available to scholars along with the larger data set. In Tables where we do report confidence intervals, they are reported as margins of error in each direction from the reported mean, and are calculated at a 95% confidence level.

⁴³ These relationship tests are all bivariate, not multivariate. In other words, we test only the relationship between two elements of the data we have collected, not the relationship among three or more of those elements. Thus, we can predict with confidence that two characteristics are related to each other – for example, the invention’s country of origin and mean time spent in prosecution. However, it is likely that other factors, such as area of technology or number of applications filed, contribute to explaining this relationship. Thus, we wish to emphasize that we are *not* predicting cause and effect, merely correlation.

III. Results

A. Characteristics of the Patents

As noted above, we collected a variety of facts about each issued patent in the sample. These facts include the area of technology, country of origin, the presence or absence of foreign priority, the number of prior U.S. filings, the time spent in prosecution, the number of inventors, whether or not the invention was assigned, whether the inventor or the assignee were foreign, the number and type of references cited in the patent, and the number and type of claims in the patent. In this section, we use this data to predict the descriptive characteristics of the larger population of patents issued during 1976-1978. We then compare these descriptive characteristics with the results we obtained in our parallel study of patents from the 1990s. We conduct statistical tests on the significance of the differences between the two samples. We describe the results of this analysis in the sections that follow.

1. Area of Technology

We used two different measures of area of technology. First, we used the PTO's classification system, which divides each patent into the categories "Mechanical, Chemical, and Electrical." Second, we also constructed our own set of fourteen technology categories by examining each patent in detail.

The PTO classification system provides a very rough measure of technological field. Even by this coarse measure, however, technology has changed in the last 20 years. In the 1976-1978 sample, the PTO classified 476 patents as "mechanical," 307 as "chemical", and 217 as "electrical." By contrast, of the patents in the 1996-1998 study,

the PTO classified 374 as “mechanical,” 292 as “chemical,” and 334 as “electrical.”⁴⁴ These numbers reflect a rather striking trend towards patenting in certain fields the PTO generally classifies as electrical, such as computer software. The share of electrical patents jumped from roughly one in five to one in three over this period.⁴⁵ Virtually all of this increase has come at the expense of patents classified as mechanical; chemical patents remained roughly constant in percentage terms throughout the years studied.⁴⁶

We were not content to rely on the PTO classification system, however, for two reasons. First, we did not find it particularly reliable. In the course of this study, we came upon numerous instances of what appear to us to be wrong or arbitrary classification decisions.⁴⁷ Second, the PTO system groups together technologies that may have very different characteristics. For example, pharmaceutical, petroleum, and biotechnology inventions would all be classed as “chemical” under the PTO system, even though the industries in question are very different. This problem is exacerbated by the

⁴⁴ Allison & Lemley, who’s patenting what, *supra* note ___, at 2113-14.

⁴⁵ This is roughly consistent with prior data. A study of 2,081 patents issued in 1994 found that 874 were classified by the PTO as mechanical, 604 as chemical, and 603 as electrical. See Mark A. Lemley, *An Empirical Study of the Twenty-Year Patent Term*, 22 *AIPLA Q.J.* 369, 388 Table 2 (1994). The 1994 data show significantly more electrical patents than the 1976-78 data, but not as many as in 1996-98. This is consistent with the hypothesis that the number of electrical patents is increasing. 29.0% of the patents in that study were classified by the PTO as electrical, and 29.0% as chemical. In our current study, by contrast, using patents issued from 1996 through 1998, a virtually identical 29.2% of the patents are chemical, but 33.4% are electrical.

⁴⁶ Because the PTO issued so many more patents in the 1990s than it did in the 1970s, the declining share of mechanical patents does not necessarily reflect an absolute decline in the number of mechanical patents being issued. It may simply be that the rate of electrical patenting is increasing faster than the rate of mechanical patenting.

⁴⁷ Two of the many examples follow: (1) Pat. No. 5,525,451, “Photoreceptor Fabrication Method,” issued June 11, 1996. The PTO placed the patent within its Mechanical category, but a reading of the patent reveals that it does not intend to advance the state of art in Mechanics; instead, the patent clearly reveals that the inventors sought to advance the Optics and Computer-Related arts. (2) Pat. No. 5,539,844, “Ball Bearing Cages and Ball Bearings,” issued July 23, 1996. The PTO placed the patent within its Electrical category, when even a casual reading of the patent reveals that it had nothing at all to do with electronics, but instead was purely mechanical.

problem of inventions that cross over between industries, such as bioinformatics or computer-controlled mechanical devices.

To deal with these problems, we designed a classification system that is more finely graded than the PTOs “mechanical-electrical-chemical” division, but more industry-based than the PTO’s detailed classification scheme. Further, we were willing to class a particular patent in more than one category where necessary.⁴⁸ The results of this classification system, sorted by 1990s frequency, are presented in Table 1.

Table 1
Technology Areas Sorted by 1990s Frequency

Technology Area	1970s Frequency	1990s Frequency
Mechanics	520	329
Computer-Related	74	242
Chemistry	254	207
Optics	100	128
Semiconductors	23	93
Pharmaceuticals	51	78
Electronics	183	77
Software	0	76
Automobile-Related	39	72
Medical Devices	29	64
Communications-Related	33	41
Biotechnology	0	37
Energy-Related	46	24
Acoustics	22	22
Total Technology Areas	1374	1489

The most notable differences between the two samples are also the least surprising: the complete absence of software and biotechnology patents in the 1970s data. Both

⁴⁸ Indeed, this was quite common. The 1,000 patents we studied in the 1990s sample produced 1,489 total technology areas, or an average of nearly 1.5 areas per patent. Some patents were classed in as many as four different areas. *See* Table 1 for the total number of technology areas in both samples.

technologies were in their infancy in the early 1970s, when applications resulting in patents during the period of our study would have been filed. Further, software was not considered patentable by the courts during this period,⁴⁹ meaning that even those software patent applications that were filed did not result in issued patents.

There are other differences as well. The percentage of mechanical and electronics patents dropped precipitously from the 1970s to the 1990s. Mechanical patents accounted for more than half of all patents issued in the 1976-1978 period, but less than a third of those issued twenty years later. Similarly, electronics patents accounted for 18% of all patents in the 1970s, but less than 8% in the 1990s.⁵⁰ Other, less precipitous, drops can also be observed in the share of chemistry and energy-related patents. By contrast, computer-related inventions, semiconductors, and medical devices all increased significantly during this period. Indeed, the number of semiconductor patents *quadrupled* in this period, from 23 to 93; the number of computer-related inventions more than tripled, from 74 to 242; and the number of medical device patents doubled, from 29 to 64. Less dramatic but still significant increases (over 50%) occurred in pharmaceutical and automotive patents.

It is also worth noting that these numbers may actually understate the significance of the changes in subject matter over this period. Our “chemistry” category, for example, includes biotechnology inventions as well as more traditional sorts of chemistry. Since biotechnology patents increased from 0 in the 1970s study to 37 in the 1990s study, the

⁴⁹ This was a result of the Supreme Court’s decision in *Gottschalk v. Benson*, 409 U.S. 63 (1972). For discussion of the history of software patents during this period, see Pamela Samuelson, *Benson Revisited: The Case Against Patent Protection for Algorithms and Other Computer Program-Related Inventions*, 39 *Emory L.J.* 1025, 1033 n.24 (1990).

⁵⁰ N.B. As discussed in Part II, our definition of “mechanical” and “electronics” patents are different and generally more restrictive than the PTO’s classification categories of the same name.

fact that the total number of chemistry patents declined over that period means that the number of traditional (non-biotechnology) chemistry patents declined even more.

Clearly, there has been a sea change in patenting during this period. On the whole, the trend has been towards patenting in industries considered “high-tech,” such as software, semiconductors, computers, and biotechnology. Not all increases fit into this category, however; medical devices and automotive technologies also accounted for significantly more patents in the 1990s than in the 1970s. The big losers during this period were the traditional mainstay of patents – mechanical inventions – as well as the somewhat higher-tech electronics category.

2. Country of Origin

We also classed each patent by country of origin. In defining “country of origin,” we were concerned with identifying the nation in which the invention itself originated. Thus, we generally looked at inventor domicile, with assignee location used as a sort of “tie-breaker.”⁵¹

In both the 1976-78 and 1996-98 samples, only 12 countries had five or more patents issued. They were not the same twelve countries in both samples, however. Summary results for the 15 countries having five or more U.S. patents in one or both samples are presented in Table 2, organized by number of patents granted in the 1990s study.

⁵¹ We did not use the PTO’s definition of “country of origin.” The PTO determines country of origin merely by looking at the residence of the first listed inventor, which can be misleading. We looked at the residence of a plurality of inventors. If there were an equal number of inventors from two or more countries, we looked to the domicile of the assignee as a “tie-breaker.”

Table 2
Patents Granted By Country of Origin

Country	1970s Patents	1990s Patents
United States	635	540
Japan	126	212
Germany	82	66
France	30	31
South Korea	0	25
Taiwan	1	24
United Kingdom	29	19
Canada	14	17
Italy	10	13
Netherlands	14	12
Switzerland	13	8
Australia	3	6
Sweden	11	4
Denmark	5	2
U.S.S.R./Russia	5	0

These numbers are consistent with those identified by the PTO for the population of patents issued during this period.⁵² Notably few countries are represented on either list. The predominance of domestic inventors in the U.S. patent system was more evident in the 1970s than in the 1990s. Nonetheless, even in the 1990s domestic inventors account for more than half of all the U.S. patents issued. Further, there were almost no patents issued on behalf of inventors in countries outside of North America, Europe, and the Pacific Rim, as is demonstrated in Table 3.

⁵² See U.S. PTO, *supra* note __, at Table A1-2. Slight discrepancies result from the imperfection of predicting population characteristics from even a large sample, see *supra* note __ and accompanying text,

Table 3
Patents Granted By Region

Region	1970s Patents	1990s Patents
North America ⁵³	649	557
Pacific Rim ⁵⁴	131	271
Europe ⁵⁵	217	167
TOTAL	997	995

In the 1970s the patents were strikingly Eurocentric; Japan was the only country outside of North American and Europe that obtained more than five patents in our 1976-78 sample. In the 1990s, the fast-growing Asian economies of Korea and Taiwan did engage in significant patenting activity. Nonetheless, in both periods there were virtually no patents issued to inventors in the developing world. At least in the United States, patenting is done by the developed world.

3. Nature of Inventors and Owners

We also studied a number of characteristics about inventors and patent ownership, including the number of inventors and whether the invention was assigned. These characteristics give us insight into how innovation is practiced in the modern world. The

and from the slightly different definitions of “country of origin” used by the PTO. On the differences between our test and the PTO’s, *see supra* note ____.

⁵³ Includes the U.S. and Canada.

⁵⁴ Includes Japan, Korea, Australia, Taiwan, Hong Kong, and Singapore in the 1990s, and Japan, the Philippines, Australia, and Taiwan in the 1970s.

⁵⁵ Includes the U.K., Ireland, Germany, Austria, France, Italy, Switzerland, the Netherlands, Belgium, Sweden, Norway, Finland, Denmark, and the Czech Republic in the 1990s, and the U.K., Germany, France,

data belie the traditional and once-accurate notion of the typical inventor as an individual working alone in his garage. In both of our samples, but particularly in the 1990s, large corporations obtained the overwhelming majority of patents.⁵⁶

Many inventions are not developed by a single individual, but by two or more inventors collaborating. While inventive collaboration is certainly possible between individuals, it is one of the hallmarks of “big science” at major corporations. The data show significant changes between the 1970s and the 1990s in this regard. In the 1976-78 sample, each patent listed an average of 1.7 inventors, and the median patent listed only one inventor. By the time of the 1996-98 sample, each patent listed 2.26 inventors on average, and the median patent listed two inventors.⁵⁷ Further, the data show an increase in assignment of patents from inventors to corporations.⁵⁸ Inventors assigned their patent rights to a corporate entity, typically but not necessarily an employer, in 788 out of 1,000 cases in the 1970s sample. In the 1990s sample, the number of assignments rose to 851 out of 1,000 cases.

Italy, Switzerland, the Netherlands, Sweden, Denmark, Austria, Spain, Greece, Belgium, Luxembourg, Norway, Finland, Czechoslovakia, Hungary and the U.S.S.R. in the 1970s.

⁵⁶ This supposition is borne out by the PTO statistics, which identify the entities – mostly large companies -- that own the most patents. *See* U.S. PTO, *supra* note __, at Table B.

While some patents are owned by small corporations, our analysis of the PTO’s small entity data for the 1990s sample demonstrated that the majority are owned by large corporations. *See* Allison & Lemley, *Who’s Patenting What*, *supra* note __, at 2117 (only 10.7% of patents owned by small corporations).

⁵⁷ These differences are statistically significant, with a t-Test p value < .001. We should note the possibility – which we have not tested empirically – that the 1984 changes to 35 U.S.C. § 116 encouraged more inventors to be listed on some patents, and that this is at least a partial explanation for the increase in the number of inventors per patent. On the increased role of joint inventorship in patent law, see Rochelle Cooper Dreyfuss, *Collaborative Research: Conflicts on Authorship, Ownership, and Accountability*, 53 *Vand. L. Rev.* 1161 (2000).

⁵⁸ In the U.S., patents are always issued in the name of the individual inventor or inventors. *See* 35 U.S.C. § 115, 116. Thus, a large entity that owns a patent must have received it by assignment from the inventor, or by some comparable mechanism of implied assignment. *See, e.g.*, 35 U.S.C. § 118, 261. Because we collect data from the face of the patent, our data necessarily reflects only assignments to entities as of the time the patent issued.

Patenting in the United States today is something that is largely done by corporations, not individuals. Further, the trend is clearly in that direction. But the development is not a new one; even in the 1970s sample more than three-quarters of all inventors assigned their patent rights to a corporation. Disputes between corporations and individual inventors about reform of the patent system have been among the most contentious issues in intellectual property law of late; we do not intend to enter into that dispute here. But the debate should be informed by a recognition that corporations, not individuals, own the overwhelming majority of patents in the U.S. today.⁵⁹

4. The Prosecution Process

Finally, we collected a variety of data about the prosecution process of the patents in the sample. Specifically, we studied the time spent in prosecution, the total number of continuations, continuations-in-part (CIPs) and divisionals filed by the applicant,⁶⁰ whether they claimed priority to a foreign application, the number and type of prior art references cited in each patent, and the number of claims in each patent.

a. *Time in Prosecution*

⁵⁹ While this may reflect a trend towards employee inventorship, it is also possible that independent inventors are simply more likely to create and assign patent rights to their own corporations than they were in the past. But as noted above, small corporations as a whole own no more than 10.7% of the patents issued, so this is a relatively minor effect.

⁶⁰ In this paper, we refer to the use of these three instruments collectively as “continuation practice” or “refilings.”

We studied the time spent in prosecution, which we define as the time from the filing of the *first* U.S. application to the issue date.⁶¹ The question of how long patents spend in prosecution is particularly important now, because the patent term was changed in 1994 to run 20 years from the first filing date.⁶² Thus, the longer a patent spends in prosecution, the less term it will have.

Prosecution times increased significantly between the 1970s and 1990s samples. On average, the patents issued in our 1970s sample spent 815 days, or 2.23 years, in prosecution. By contrast, in the 1990s sample those numbers increased to 1,011 days, or 2.77 years, in prosecution on average. In both samples, the median prosecution time was less than the mean, indicating that the average time in prosecution in both samples was skewed upward by a few patents that spent a very long time in prosecution. Nonetheless, there also was a significant increase in the median from the 1976-78 period (648 days, or 1.78 years) to the 1996-98 period (811 days, or 2.22 years). The range of prosecution times varied widely in both cases. In the 1970s it ranged from a low of 0.59 years to a high of 13.85 years, while in the 1990s the range ran from a low of 1.16 years to a high of 18.15 years.⁶³

It seems clear, therefore, that patent prosecution time has increased rather substantially over the past twenty years. This is particularly significant given the change in patent term, which is now measured from the filing date. Increased delay in prosecution means that patentees get less term, though it is worth noting that on average

⁶¹ Thus, where a patent application claims priority to one or more prior applications, the date we report is the earliest priority date claimed. This is important, because focusing only on the most recently filed application would understate the total time a patent application spent at the PTO. See Lemley, *supra* note ___, at 383 (explaining this methodology).

⁶² 35 U.S.C. § 154.

⁶³ All these differences were statistically significant.

they still benefit from the change to the 20-year patent term. It remains to be seen whether the increase in pendency time will be reversed once the 20-year term is fully in effect.⁶⁴ If the trend is not reversed, however, it will doubtless spur further calls for term extensions.⁶⁵

Closely related to time spent in prosecution is the extent to which patent applications claim priority to previously filed applications, called parent or grandparent applications, for priority in the patents that ultimately issued. In both samples, a significant minority of the patentees based their priority on a prior U.S. application. But the numbers were significantly greater in the 1990s sample than in the 1970s sample. Thus, 49 of the 1970s patents and 159 of the 1990s patents claimed priority via at least one continuation application, 68 of the 1970s patents and 111 of the 1990s patents via a CIP application, and 56 of the 1970s patents and 99 of the 1990s patents via a divisional application.⁶⁶ On average, the total number of U.S. applications in a priority chain, including the one that ultimately resulted in a patent, was 1.32 in the 1970s sample and 1.50 in the 1990s sample. While the median patent did not claim priority from a parent application in either sample, some patents claimed priority based on as many as eight (1976-78) or nine (1996-98) different U.S. applications. On the other hand, a majority of

⁶⁴ See Lemley, *supra* note __, at 385-87 (predicting a 20% drop in pendency times once 1995 patent term reforms are fully in effect). Since many of the patents in our 1996-98 sample issued on applications originally filed before 1995, however, Lemley's arguments may still be valid, and may simply not have had time to take effect. In our prior study, we speculated at some length on possible reasons for the increase in pendency time in the late 1990s. See Allison & Lemley, *Who's Patenting What*, *supra* note __, at 2118-19. One of the reasons we offered was that the 96-98 sample includes a disproportionate number of applications filed in 1995 in order to take advantage of the old 17-year term, and those applications may be expected to spend longer in prosecution.

⁶⁵ Congress has already passed a labyrinthine set of term extensions designed to account for various delays in the prosecution process. See 35 U.S.C. § 154(b).

⁶⁶ Because some but not all of the patents used more than one type of priority mechanism, we cannot merely sum these numbers to determine the number of patents relying on prior U.S. applications.

the 1976-78 patents (518 out of 1000) and a plurality of the 1996-98 patents (410 out of 1000), did not claim priority either to any previously filed application or to a foreign application.

The growth in the use of continuation practice is important, because the data not surprisingly demonstrate that patents based on multiple applications spend longer in prosecution than those based only on a single application. The results are presented in Tables 4A and 4B.

Table 4A
Time in Prosecution by Nature of Prior Application Filed, 1976-1978 Data

	Priority Based on Instant Application	Priority Based on Continuation	Priority Based on Divisional	Priority Based on CIP	Priority Based on Foreign Filing
Avg Yrs In PTO	1.70	3.72	3.35	4.25	2.22
Median	1.53	3.34	2.92	3.57	1.79
Mode	1.44	3.34	2.92	2.91	1.42
Std.Dev	0.98	1.33	1.81	2.49	1.41
Max	13.70	7.72	12.56	13.85	11.30
Min	0.59	1.70	1.43	0.96	0.76

Table 4B
Time in Prosecution by Nature of Prior Application Filed, 1996-1998 Data

	Priority Based on Instant Application	Priority Based on Continuation	Priority Based on Divisional	Priority Based on CIP	Priority Based on Foreign Filing
Avg yrs in PTO	1.99	5.23	4.78	5.06	2.66
Median	1.84	4.72	4.18	4.31	2.23
Mode	1.70	4.10	3.49	3.23	2.85
Std. Dev.	0.76	2.55	2.61	2.73	1.55
Max	7.88	18.15	18.15	18.15	12.79
Min	0.67	1.36	1.28	1.53	0.82

In both samples, patents claiming priority to another U.S.-filed application spent significantly longer in prosecution than patents claiming priority only to the instant application. This is not surprising; it naturally takes the PTO longer to examine applications multiple times than to do so once. Still, it is important to note that the growth in the use of continuation and related applications does not explain all the variation in prosecution time. Even applications that do not claim priority to any outside source spent longer in prosecution in the 1990s (1.99 years on average) than in the 1970s (1.70 years on average). Further, across each type of priority claim, it took the PTO longer to resolve that claim in the 1996-98 timeframe than it had twenty years before.

b. *Prior Art References*

Citations to prior art are an important proxy for the rigor of the examination process. Generally speaking, the more prior art the PTO considers, the stronger the patent is in litigation.⁶⁷

The numbers in our samples are quite dramatic. In the 1970s, the patents in our sample made reference to an average of 5.72 total pieces of prior art. The median patent cited 4 prior art references; patents cited anywhere from a low of zero prior art references to a high of 33 references. By contrast, patents in the 1990s sample cited almost three times as much art. The patents in that sample cited an average of 15.16 total references. The median patent cited 10 prior art references; patents cited anywhere from a low of

⁶⁷ Another study we conducted found that patents are most likely to be held invalid in litigation on the basis of prior art not cited before the PTO. See John R. Allison & Mark A. Lemley, *Empirical Evidence on the Validity of Litigated Patents*, 26 *AIPLA Q.J.* 185 (1998).

zero prior art references to a high of 163 references.⁶⁸ The data are presented in Tables 5A and 5B.

Table 5A

Prior Art References, 1976-1978

Prior Art	U.S. Patent Refs	Foreign Patent Refs	Non-Patent Refs	Total Refs
Mean	5.04	0.47	0.21	5.72
Median	4	0	0	4
Minimum	0	0	0	0
Maximum	19	8	6	33

Table 5B

Prior Art References, 1996-1998

Prior Art	U.S. Patent Refs	Foreign Patent Refs	Non-Patent Refs	Total Refs
Mean	10.34	2.44	2.37	15.16
Median	7	1	0	10
Minimum	0	0	0	0
Maximum	137	43	68	163

We divided those references into three categories of prior art, also noted in Table 5: prior U.S. patents, prior patents from outside the U.S., and non-patent prior art.⁶⁹ Citations in both samples were overwhelmingly made to U.S. patents. On average, each patent in the 1996-98 sample cited 10.34 prior U.S. patents, compared with only 2.44 foreign patents and 2.37 non-patent references. The numbers are even more striking in the 1970s sample, where patents cited an average of only 0.47 foreign patents and 0.21 non-patent

⁶⁸ These differences are statistically significant, with a t-Test p value < .001.

⁶⁹ The latter category includes all prior art references other than issued patents or published patent applications. For example, scientific journal articles, catalogues, and evidence of public use all fall into the non-patent art category.

references.⁷⁰ Indeed, the median patent in both samples cited *no* non-patent prior art at all.⁷¹

The absence of non-patent prior art is particularly striking, given that in many areas of technology, other patents may not be the best source of prior art.⁷² The predominance of U.S. patents may also reflect the limitations of the PTO systems for searching: the PTO is much more likely to find documents that it itself has generated.⁷³ Given that in many fields the most relevant prior art is non-patent prior art, the predominance of patents in the art actually cited by the PTO suggests serious shortcomings in the PTO's validity investigation.⁷⁴

Notwithstanding these shortcomings, it is striking how much more art is cited in the 1990s sample than was cited twenty years before. It is not clear what explains this difference. Indeed, it is not even possible to tell for sure whether the patent applicant or the PTO has found the art in question.⁷⁵ One possibility is that the growth of the Internet and private computer databases has made prior art searches much easier and more fruitful than they were in the 1970s. Another possible explanation is that the PTO simply does a

⁷⁰ All these differences are statistically significant, with t-test p-values < .001 for total references, .000 for U.S. patent references, .000 for foreign patent references, and .000 for non-patent references.

⁷¹ Further, these data may if anything overstate the number of non-patent prior art references actually cited, since some apparently non-patent sources may in fact be reported abstracts of published European Patent Office applications.

⁷² See Julie E. Cohen, *Reverse Engineering and the Rise of Electronic Vigilantism: Intellectual Property Implications of "Lock-Out" Programs*, 68 **S. Cal. L. Rev.** 1091, 1177-80 (1995); Greg Aharonian, Internet Patent News Service, <http://www.bustpatents.com> (arguing that software patents are of doubtful validity because they cite very little non-patent prior art).

⁷³ One possible explanation for the low citation rate of foreign patents is that many foreign patents also issued in the U.S., and it is easier to cite the U.S. counterpart.

⁷⁴ It does not necessarily follow that the PTO should beef up searching and prosecution, however. See Mark A. Lemley, *Rational Ignorance at the Patent Office*, 95 **Nw. U. L. Rev.** ____ (forthcoming October 2001). But the reader should be aware of the limitations of the examination the PTO does conduct.

⁷⁵ We cite some indirect evidence suggesting that it is the applicant, not the examiner, *infra* note ____.

more thorough job of examining applications than it did in the 1970s, though the minimal time examiners spend per patent seems to belie that theory.⁷⁶ A third possibility is that the 1990s patents are more complex, or at least tend to be in fields which are richer sources of prior art than the technologies that dominated the patents in the 1970s sample. Whatever the explanation, the dramatic increase in prior art cited per patent – and particularly the ten-fold increase in citations to non-patent prior art – should be taken as a positive sign by those who argue for increased rigor in the PTO examination process.⁷⁷

c. *Claims*

Finally, we also investigated the number of claims filed in each patent. The number of claims filed has increased significantly between the 1970s and the 1990s, though not as dramatically as prior art citations. On average, patents in the 1970s sample had 9.94 claims, compared with 14.87 claims in the 1990s sample. The median patent had 8 claims in the 1970s and 12 claims in the 1990s. The vast majority of these claims were dependent in both samples; the median patent had only one independent claim in the 1970s and two independent claims in the 1990s. The increase in the number of claims between the two sample periods is primarily attributable to the growth of dependent claims, from an average of 7.85 in 1976-78 to 12.12 in 1996-98.⁷⁸ These data are summarized in Tables 6A and 6B.

⁷⁶ See *id.* at __ (examiners spend 18 hours per patent on average).

⁷⁷ See, e.g., Robert P. Merges, *As Many as Six Impossible Patents Before Breakfast: Property Rights for Business Concepts and Patent System Reform*, 14 **Berkeley Tech. L.J.** 577 (1999).

⁷⁸ All these differences are statistically significant, with t-test p-values < .001 for total claims, .000 for independent claims, and .000 for dependent claims.

Table 6A
Number and Type of Claims, 1976-1978

Claims	Independent	Dependent	Total
Mean	2.09	7.85	9.94
Median	1	6	8
Minimum	1	1	1
Maximum	31	125	127

Table 6B
Number and Type of Claims, 1996-1998

Claims	Independent	Dependent	Total
Mean	2.75	12.12	14.87
Median	2	10	12
Min	1	0	1
Max	24	115	120

By itself, the number of claims in a patent does not tell us much. But some have suggested that the number of claims is a proxy for the size, complexity or value of an invention.⁷⁹ We're not entirely persuaded that this is true; the number of claims could reflect resource constraints, drafting style, uncertainty about the law or how significant an invention the patent represents, or a host of other things. At a minimum, the increase in the number of claims over time suggests that applicants may be putting more care into drafting their applications, since more claims means both higher filing fees and higher attorney's fees.

⁷⁹ Lanjouw and Schankerman treat the number of claims as one indicator of the value of patents, demonstrating that the more claims a patent has, the more likely it will be involved in infringement litigation. See Jean. O. Lanjouw & Mark Schankerman, *Characteristics of Patent Litigation: A Window on Competition*, 32 **RAND J. Econ.** 129 (2001). This proposition seems modestly intuitive, as well, in that the more claims a patent has, the more likely it is that related activities by others will infringe; the greater likelihood of infringement by others seems to translate into greater value for the patent.

B. Relationships Among the Data

In our prior study, we conducted statistical tests on a number of relationships between the individual characteristics we identified for each patent. In this study, we have conducted the same tests on the patents in the 1976-78 sample. We compare the results of the two samples to illuminate differences in the relationships over time.

1. Relationships Between Technology and Country of Origin

We found significant differences between the technologies patented by inventors in different countries in both the 1976-78 and 1996-98 samples. We tested these relationships in a number of ways. First, we examined the breakdown of inventions into the PTO categories of mechanical, chemical, and electrical for each country with five or more patents. The results are presented in Tables 7A and 7B.

Table 7A
Technology Divisions by Country of Origin, 1976-78⁸⁰

	U.S.	Canada	Japan	U.K.	Germ.	France	Italy	Switz.	Neth.	Sweden	Denmark	U.S.S.R.	Total
Mech.	313	8	49	9	35	11	5	8	10	7	5	1	461
Chem.	178	1	45	16	34	12	3	3	2	3	0	3	300
Elec.	144	5	32	4	13	7	2	2	2	1	0	1	213
Total	635	14	126	29	82	30	10	13	14	11	5	5	974

%	U.S.	Canada	Japan	U.K.	Germ.	France	Italy	Switz.	Neth.	Sweden	Denmark	U.S.S.R.
Mech.	49.29%	57.14%	38.89%	31.03%	42.68%	36.67%	50.00%	61.54%	71.43%	63.64%	100.00%	20.00%
Chem.	28.03%	7.14%	35.71%	55.17%	41.46%	40.00%	30.00%	23.08%	14.29%	27.27%	0.00%	60.00%
Elec.	22.68%	35.71%	25.40%	13.79%	15.85%	23.33%	20.00%	15.38%	14.29%	9.09%	0.00%	20.00%

Table 7B
Technology Divisions by Country of Origin, 1996-98

	US	Canada	Japan	Korea	Australia	Taiwan	UK	Germ.	France	Italy	Switz.	Neth.	Total
Mech	223	10	45	7	3	17	8	26	10	5	5	5	356
Chem	162	4	55	3	1	2	7	26	11	4	1	2	273
Elec	155	3	112	15	2	5	4	14	10	4	2	5	327
Total	540	17	212	25	6	24	19	66	31	13	8	12	959

%	US	Canada	Japan	Korea	Australia	Taiwan	UK	Germ.	France	Italy	Switz.	Neth.
Mech	41.30%	58.82%	21.23%	28.00%	50.00%	70.83%	42.11%	39.39%	32.26%	38.46%	62.50%	41.67%
Chem	30.00%	23.53%	25.94%	12.00%	16.67%	8.33%	36.84%	39.39%	35.48%	30.77%	12.50%	16.67%
Elec	28.70%	17.65%	52.83%	60.00%	33.33%	20.83%	21.05%	21.21%	32.26%	30.77%	25.00%	41.67%

⁸⁰ The totals in the last column do not add to 1000 because we have omitted from Tables 7A and 7B countries that had fewer than 5 U.S. patents in our sample.

Some differences are evident from this data. We caution, however, that it is impossible to draw detailed inferences from changes in many of these countries because of the small sample size. In the 1970s sample, the U.S., Canada, Italy, Switzerland, the Netherlands, Sweden and Denmark had a disproportionately high share of mechanical patents. By contrast, the U.K., Germany, France and the U.S.S.R. were over-represented in chemical patents in the 1970s, and only Canada had more than 30% electrical patents during this period. By the time of the 1990s sample, these numbers had changed somewhat. United States' inventors continued to patent somewhat more mechanical inventions, and somewhat fewer electrical inventions, than the world average. Other countries patenting more mechanical inventions than average, and fewer electrical inventions, include Canada, Taiwan, and the U.K. By contrast, Japan and Korea both patented far more electrical inventions than average, and fewer mechanical and chemical inventions. The percentage of U.S. inventions that were electrical actually rose during this period, from 22.7% to 28.7%. However, the percentage of electrical inventions in other countries rose faster, with the result that the U.S. share of electronics inventions actually fell somewhat. We tested both of these relationships for statistical significance and determined that there is a strong, statistically significant relationship between PTO subject matter classification and country of origin in both the 1970s and 1990s samples.⁸¹

Because, as noted above, the PTO's subject matter classifications are unreliable, we also tested the relationships between country of origin and each of the fourteen areas of technology we have defined for these studies. The results are presented in Tables 8A and 8B.

⁸¹ We conducted a Chi-square test in both cases, which found significant differences in PTO subject matter class both between foreign and U.S. patents, and country by country. In the 1976-78 study, Chi-square p-values = .037 for foreign vs. US and .018 for country-by-country. In the 1996-98 data, Chi-square p-values = .002 for foreign vs. US and .001 for country-by-country. On the Chi-square test, see, e.g., **Michael O. Finkelstein & Bruce Levin, *Statistics for Lawyers* 159-165 (1990).**

Table 8A
Areas of Technology by Country of Origin, 1976-78

	U.S.	Canada	Japan	U.K.	Germ.	France	Italy	Switz.	Neth.	Sweden	Denmark	U.S.S.R.	Total
Pharm	24	1	9	2	8	2	0	2	1	0	0	0	49
Med.Dev.	22	0	2	0	1	1	1	0	0	0	0	0	27
BioTech.	0	0	0	0	0	0	0	0	0	0	0	0	0
Comp-Rel.	51	1	12	1	2	7	0	0	0	0	0	0	74
Software	0	0	0	0	0	0	0	0	0	0	0	0	0
SemiCond.	12	1	8	1	1	0	0	0	0	0	0	0	23
Electronics	113	2	32	3	18	1	2	1	3	3	0	2	180
Chemistry	148	3	42	7	30	8	2	3	1	1	1	2	248
Mechanics	341	7	44	18	42	13	5	10	11	8	4	3	506
Acoustics	16	0	1	0	0	2	0	0	1	0	0	0	20
Optics	63	0	19	4	4	3	1	0	2	0	0	0	96
Auto-Rel	19	0	9	1	7	1	2	0	0	0	0	0	39
Energy-Rel	40	0	1	1	1	2	0	0	1	0	0	0	46
Commun-Rel	20	2	4	1	0	6	0	0	0	0	0	0	33
Total	869	17	183	39	114	46	13	16	20	12	5	7	
%	U.S.	Canada	Japan	U.K.	Germ.	France	Italy	Switz.	Neth.	Sweden	Denmark	U.S.S.R.	
Pharm	2.76%	5.88%	4.92%	5.13%	7.02%	4.35%	0.00%	12.50%	5.00%	0.00%	0.00%	0.00%	
Med.Dev.	2.53%	0.00%	1.09%	0.00%	0.88%	2.17%	7.69%	0.00%	0.00%	0.00%	0.00%	0.00%	
BioTech.	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Comp-Rel.	5.87%	5.88%	6.56%	2.56%	1.75%	15.22%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Software	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
SemiCond.	1.38%	5.88%	4.37%	2.56%	0.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Electronics	13.00%	11.76%	17.49%	7.69%	15.79%	2.17%	15.38%	6.25%	15.00%	25.00%	0.00%	28.57%	
Chemistry	17.03%	17.65%	22.95%	17.95%	26.32%	17.39%	15.38%	18.75%	5.00%	8.33%	20.00%	28.57%	
Mechanics	39.24%	41.18%	24.04%	46.15%	36.84%	28.26%	38.46%	62.50%	55.00%	66.67%	80.00%	42.86%	
Acoustics	1.84%	0.00%	0.55%	0.00%	0.00%	4.35%	0.00%	0.00%	5.00%	0.00%	0.00%	0.00%	
Optics	7.25%	0.00%	10.38%	10.26%	3.51%	6.52%	7.69%	0.00%	10.00%	0.00%	0.00%	0.00%	
Auto-Rel	2.19%	0.00%	4.92%	2.56%	6.14%	2.17%	15.38%	0.00%	0.00%	0.00%	0.00%	0.00%	
Energy-Rel	4.60%	0.00%	0.55%	2.56%	0.88%	4.35%	0.00%	0.00%	5.00%	0.00%	0.00%	0.00%	
Commun-Rel	2.30%	11.76%	2.19%	2.56%	0.00%	13.04%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	

Table 8B
Areas of Technology by Country of Origin, 1996-98

	US	Canada	Japan	Korea	Aust	Taiwan	UK	Germ	France	Italy	Switz	Neth.	Total
Pharm	48	2	7	0	2	0	4	3	3	2	0	1	72
Med.Dev.	48	0	5	1	0	0	1	1	4	0	1	1	62
BioTech.	31	0	3	0	0	0	1	0	1	1	0	0	37
Comp-Rel.	121	3	83	9	1	2	3	10	4	2	0	2	240
Software	40	1	23	1	1	1	2	1	4	0	0	2	76
SemiCond.	46	0	31	6	0	1	0	2	1	2	0	1	90
Electronics	35	3	21	2	1	2	2	7	2	1	0	0	76
Chem.	105	4	40	1	2	2	5	20	11	3	1	4	198
Mechanics	194	7	31	7	2	17	8	27	11	4	6	4	318
Acoustics	11	0	7	1	0	0	1	1	1	0	0	0	22
Optics	51	3	53	6	1	1	3	3	0	1	1	4	127
Auto-Rel	31	1	24	1	1	0	2	9	2	0	1	0	72
Energy-Rel	14	1	4	0	0	0	1	0	2	0	0	0	22
Commun-Rel	25	0	11	1	0	0	0	1	3	0	0	0	41
Total	800	25	343	6	11	26	33	85	49	16	10	19	1453

%	US	Canada	Japan	Korea	Aust	Taiwan	UK	Germ	France	Italy	Switz	Neth.	Total
Pharm	61.54%	2.56%	8.97%	0.00%	2.56%	0.00%	5.13%	3.85%	3.85%	2.56%	0.00%	1.28%	92.31%
Med.Dev.	75.00%	0.00%	7.81%	1.56%	0.00%	0.00%	1.56%	1.56%	6.25%	0.00%	1.56%	1.56%	96.88%
BioTech.	83.78%	0.00%	8.11%	0.00%	0.00%	0.00%	2.70%	0.00%	2.70%	2.70%	0.00%	0.00%	100.00%
Comp-Rel.	50.00%	1.24%	34.30%	3.72%	0.41%	0.83%	1.24%	4.13%	1.65%	0.83%	0.00%	0.83%	99.17%
Software	52.63%	1.32%	30.26%	1.32%	1.32%	1.32%	2.63%	1.32%	5.26%	0.00%	0.00%	2.63%	100.00%
SemiCond.	49.46%	0.00%	33.33%	6.45%	0.00%	1.08%	0.00%	2.15%	1.08%	2.15%	0.00%	1.08%	96.77%
Electronics	45.45%	3.90%	27.27%	2.60%	1.30%	2.60%	2.60%	9.09%	2.60%	1.30%	0.00%	0.00%	98.70%
Chem.	50.72%	1.93%	19.32%	0.48%	0.97%	0.97%	2.42%	9.66%	5.31%	1.45%	0.48%	1.93%	95.65%
Mechanics	58.97%	2.13%	9.42%	2.13%	0.61%	5.17%	2.43%	8.21%	3.34%	1.22%	1.82%	1.22%	96.66%
Acoustics	50.00%	0.00%	31.82%	4.55%	0.00%	0.00%	4.55%	4.55%	4.55%	0.00%	0.00%	0.00%	100.00%
Optics	39.84%	2.34%	41.41%	4.69%	0.78%	0.78%	2.34%	2.34%	0.00%	0.78%	0.78%	3.13%	99.22%
Auto-Rel	43.06%	1.39%	33.33%	1.39%	1.39%	0.00%	2.78%	12.50%	2.78%	0.00%	1.39%	0.00%	100.00%
Energy-Rel	58.33%	4.17%	16.67%	0.00%	0.00%	0.00%	4.17%	0.00%	8.33%	0.00%	0.00%	0.00%	91.67%
Commun-Rel	60.98%	0.00%	26.83%	2.44%	0.00%	0.00%	0.00%	2.44%	7.32%	0.00%	0.00%	0.00%	100.00%

Again, we caution against reading too much into these results, particularly where the sample sizes are small (because the country, the technology category, or both had relatively few patents in them). In both samples there is clearly a significant variation between countries with respect to the areas of technology in which they obtain patents. What is more surprising is that this variation does not appear to be consistent between the two samples. This can best be seen by comparing the percentages of any given country for any given technology with the percentage of patents that involve that technology in the population as a whole.

Thus, Germany and Switzerland had more than their share of pharmaceutical patents in the 1970s, but in the 1990s it was the U.S., the U.K., and Italy who were over-represented. Similarly, the U.S. and France had more computer-related patents in the 1970s sample, while Japan and Korea were over-represented in this field in the 1990s sample. Japan, Sweden and the USSR were over-represented in electronics patents in the 1970s, while Canada was over-represented in the 1990s; Germany, Japan and the USSR had more chemistry patents in the 1970s, Germany and France in the 1990s; the U.S., Canada, the U.K., Sweden and Switzerland had more mechanical patents in the 1970s, while Taiwan was over-represented in the 1990s; France had more communications-related patents in both samples.

The data for the U.S. are surprising both with respect to fields of technology and with respect to their change over time. The U.S. was underrepresented in the 1970s in pharmaceuticals, semiconductors, chemistry, and automotive patents, but was over-represented in medical devices, acoustics, and energy. In the 1990s, by contrast, the U.S. has less than its share of semiconductor, optics, automotive and electronics patents, but is

over-represented in the fields of pharmaceuticals, medical devices, and biotechnology.

This is demonstrated more clearly in Tables 9A and 9B.

Table 9A
Areas of Technology by U.S. Origin, 1976-78

	U.S-origin	non-US origin	%	U.S-origin	non-US origin
Pharm	24	27	Pharm	47.06%	52.94%
Med.Dev.	22	7	Med.Dev.	75.86%	24.14%
BioTech.	0	0	BioTech.	N/A	N/A
Comp-Rel.	51	23	Comp-Rel.	68.92%	31.08%
Software	0	0	Software	N/A	N/A
SemiCond.	12	11	SemiCond.	52.17%	47.83%
Electronics	113	70	Electronics	61.75%	38.25%
Chemistry	148	106	Chemistry	58.27%	41.73%
Mechanics	341	179	Mechanics	65.58%	34.42%
Acoustics	16	6	Acoustics	72.73%	27.27%
Optics	63	37	Optics	63.00%	37.00%
Auto-Rel	19	20	Auto-Rel	48.72%	51.28%
Energy-Rel	40	6	Energy-Rel	86.96%	13.04%
Commun-Rel	20	13	Commun-Rel	60.61%	39.39%
Total	869	505	Share of Total	63.50%	35.50%

Table 9B
Areas of Technology by U.S. Origin, 1996-98

	US origin	non-US	Total	%	US origin	non-US
Pharm	48	30	78	Pharm	61.54%	38.46%
Med.Dev.	48	16	64	Med.Dev.	75.00%	25.00%
BioTech.	31	6	37	BioTech.	83.78%	16.22%
Comp-Rel.	121	121	242	Comp-Rel.	50.00%	50.00%
Software	40	36	76	Software	52.63%	47.37%
SemiCond.	46	47	93	SemiCond.	49.46%	50.54%
Electronics	35	42	77	Electronics	45.45%	54.55%
Chemistry	105	102	207	Chemistry	50.72%	49.28%
Mechanics	194	135	329	Mechanics	58.97%	41.03%
Acoustics	11	11	22	Acoustics	50.00%	50.00%
Optics	51	77	128	Optics	39.84%	60.16%
Auto-Rel	31	41	72	Auto-Rel	43.06%	56.94%
Energy-Rel	14	10	24	Energy-Rel	58.33%	41.67%
Commun-Rel	25	16	41	Commun-Rel	60.98%	39.02%
Total	800	690	1490	Share of Total	54.00%	46.00%

These relationships show very high statistical significance.⁸²

We have not attempted here to read any social significance into these numbers. It is certainly possible to speculate about why some countries patented disproportionately in the technologies they did. Are those countries preeminent in those fields? That is one possible explanation, though casual inspection suggests some surprises along those lines. Japan might be thought to excel in semiconductors and optics, for instance, but its overrepresentation in software and underrepresentation in electronics are harder to explain. Similarly, it seems implausible that the U.S. is behind the innovation curve in and semiconductor inventions.

An alternative explanation might focus on the relative economic value of patents in different industries. Here the question is not so much one of a country's prominence in a particular field as the economic incentives to file patents abroad. Foreign inventors might not file in the U.S. applications for inventions they considered less valuable, or inventions for which the U.S. was unlikely to be a large market. By contrast, owners of valuable inventions are more likely to seek worldwide protection, and owners of inventions in certain fields like software may want protection in the U.S. even if they do not seek it elsewhere. This may explain why inventors in other countries disproportionately patent inventions in the pharmaceutical, semiconductor, computer-related and software fields. The market-based theory also explains otherwise surprising results about the patents prosecuted by U.S. inventors. Because U.S. inventors are likely to file here if they file anywhere, these "less valuable" inventions have not been filtered

⁸² We conducted a Chi-square test in both samples. We found significant differences in areas of technology both between foreign and U.S. patents, and country by country. In the 1976-78 data, Chi-square p-values = .037 for foreign vs. US and .018 for country-by-country. In the 1996-98 data, Chi-square p-values = .008 for foreign vs. US and .014 for country-by-country.

out by the decision to file abroad. Thus, the prevalence of mechanical inventions and medical devices among U.S. inventors may not say anything at all about the relative prominence of the U.S. in these fields. It may merely mean that mechanical inventors are less likely to file worldwide.

This market-based theory cannot be a full explanation for the differences we observe, however. For example, some areas of technology that seem especially valuable, like biotechnology, are dominated by U.S. patentees. Further, while there is some overlap between overrepresentation in the 1970s sample and in the 1990s sample, there is far more variation. The market-based theory would predict a rough consistency between results in both samples, except to the extent the economics of a particular industry changed radically during that time. This prediction is not borne out by the data.

2. Relationships Between Technology and the Prosecution Process

We evaluated a number of relationships between areas of technology and various aspects of the patent prosecution process. For areas of technology, we again used two different measures, including the PTO classifications into mechanical, electrical and chemical patents, and our more detailed classification into 14 more specific areas. However, we have focused our study on the latter, more detailed system. We then tested those classifications for relationships to the number of U.S. applications filed per issued patent, total years the application spent in the PTO, the number of inventors, the number and type of references cited, and number and type of claims filed. We do not report on all these studies in detail here, however. In the number of applications filed, the number of inventors, and the number and type of claims, the relationship among areas of

technology remained largely unchanged from the 1970s to the 1990s.⁸³ Thus, those issues are fully discussed in our prior study.⁸⁴ Rather, we focus on the relationship between area of technology, on the one hand, and time in prosecution and prior art references on the other.

a. Technology and Time in Prosecution

First, we compared the time patents spent in prosecution to the area of technology. This is a highly contested and politically divisive issue because of the change in patent term beginning in 1995.⁸⁵ Since patent terms are generally now measured from the date of first U.S. filing, spending longer in the PTO reduces the amount of protection afforded an invention. Thus, industries whose patents spend longer in prosecution than average may feel unfairly disadvantaged by the 20-year patent term.⁸⁶

We studied the relationships between area of technology and time in prosecution in both the 1976-78 and 1996-98 data. The results of this analysis are presented in Tables 10A and 10B.

⁸³ The absolute numbers changed, as reported *supra*. But the variation by area of technology did not change.

⁸⁴ See Allison & Lemley, *Who's Patenting What?*, *supra* note __, at 2125-26 (applications), 2129-30 (inventors), 2132 (claims).

⁸⁵ For discussion of some of this controversy, as well as an earlier study of the phenomenon, see Lemley, *supra* note __, at 369.

⁸⁶ In response to these criticisms, Congress in 1999 passed the American Invention Protection Act, which includes a labyrinthine series of patent term extensions to compensate inventors for various sorts of delay in the PTO. See 35 U.S.C. § 154(b).

Table 10A
Time in Prosecution by Area of Technology, 1976-1978

	Pharm	Med.Dev.	BioTech.	Comp-Rel.	Software	SemiCond.	Electronics	Chemistry	Mechanics	Acoustics	Optics	Auto-Rel	Energy-Rel	Commun-Rel
Mean # Yrs. In PTO	2.63	2.22	0.00	2.04	0.00	2.37	2.11	2.85	1.94	1.88	2.40	1.85	2.40	1.93
Median	2.18	1.97	0.00	1.75	0.00	2.05	1.71	2.21	1.66	1.72	2.07	1.46	1.97	1.43
Mode	2.03	1.97	0.00	2.11	0.00	1.15	1.07	5.52	1.13	1.04	1.70	1.40	#N/A	1.38
Std.Dev	1.70	0.92	0.00	1.07	0.00	1.39	1.51	2.04	1.11	0.89	1.44	1.00	1.55	1.09
Max	9.78	4.41	0.00	5.98	0.00	6.61	12.56	13.85	9.82	4.12	10.43	6.39	8.07	5.98
Min	0.98	0.94	0.00	0.79	0.00	1.15	0.61	0.78	0.59	0.65	0.87	1.01	0.74	0.95
Margin of Error +/-	0.24	0.17	0.00	0.12	0.00	0.30	0.11	0.12	0.05	0.20	0.15	0.16	0.23	0.19

Table 10B
Time in Prosecution by Area of Technology, 1996-1998

	Pharm	Med.Dev.	BioTech.	Comp-Rel.	Software	SemiCond.	Electronics	Chemistry	Mechanics	Acoustics	Optics	Auto-Rel	Energy-Rel	Commun-Rel
Mean # yrs in PTO	4.46	2.76	4.72	2.82	3.15	2.73	2.12	3.52	2.27	2.66	2.81	2.20	2.74	2.64
Median	3.24	2.33	3.91	2.42	2.78	2.33	1.86	2.59	1.97	2.11	2.39	2.08	1.87	2.52
Mode	#N/A	1.35	#N/A	1.82	1.82	1.35	1.57	1.70	1.53	2.84	2.45	2.16	3.09	2.85
Std. Dev.	2.95	1.41	2.71	1.56	1.58	1.48	0.94	2.59	1.13	1.51	1.61	0.82	1.62	1.01
Max	12.79	7.68	10.38	10.22	10.22	8.81	5.42	18.15	8.52	6.21	8.81	4.89	8.11	6.11
Min	1.02	1.01	0.71	0.82	1.07	1.10	0.67	0.93	0.73	1.04	0.82	0.76	0.94	0.94
Margin of Error +/-	0.33	0.18	0.45	0.10	0.18	0.15	0.11	0.18	0.06	0.33	0.14	0.10	0.34	0.16

These data demonstrate a substantial change between the 1970s and the 1990s. First, as discussed above, the absolute magnitude of the numbers is higher across the board in the 1996-98 sample: patents took longer to make it through the PTO than they did in 1976-78.⁸⁷ But the variation in the time spent in prosecution across areas of technology also increased significantly during that time. The 1970s sample shows a reasonable amount of variation. Average times in prosecution ranged from a low of 1.85 years in automotive technology, 1.88 years in acoustics, 1.93 years in communications, and 1.94 years in mechanical inventions to a high of 2.85 years in chemistry and 2.63 years in pharmaceuticals. By contrast, the variation in the 1990s sample was much higher. Average times in prosecution in the 1990s sample ranged from a low of 2.12 years for electronics patents to a high of 4.72 years for biotechnology, 4.46 years in pharmaceuticals, and 3.52 years in chemistry. Put another way, the ratio of highest to lowest average (a measure of variation) was 1.54 in the 1970s study, but had risen to 2.23 in the 1990s study. These results are statistically significant.⁸⁸

While the variation increased between the two studies, areas of technology generally remained stable in their relative time in prosecution. Pharmaceuticals and chemistry spent the longest time in prosecution in both studies,⁸⁹ while automotive, electronics, and mechanical inventions spent relatively little time in prosecution in both

⁸⁷ See *supra* notes ___-___ and accompanying text.

⁸⁸ We used an ANOVA F test in the 1976-78 study and a Poisson regression in the 1996-98 study. On the use of the ANOVA F test in this situation, see **William Mendenhall, Mathematical Statistics With Applications** (4th ed. 1990). The ANOVA F statistic = 7.86 and the p-value < .001. For the Poisson regression, the results are reported in detail in our prior study, *supra* note ___, at 2127 n.88. The variance from the mean in that study was statistically significant for pharmaceuticals, medical devices, biotechnology, software, and chemical inventions. We used different tests because, when analyzing the 1976-78 data, we determined that while use of Generalized Linear Models (GLM) such as Poisson and Gamma worked well and yielded accurate results for the 1996-98 data analyzed earlier, the use of GLM was not necessary in this case and simpler methods such as ANOVA F would work just as well.

studies. Given that the same sorts of inventions appear at the top (and bottom) of both lists, it is not clear why the variation has increased over this period. One possible explanation is that the industries most affected – pharmaceuticals and biotechnology – obtained statutory term extensions in the period between the two studies.⁹⁰ A company's ability to extend its patent term may make it willing to spend more time in prosecution and refile its application more times in hopes of getting a better patent.

The policy implications of these findings are unclear. On the one hand, it might seem unfair to give less protection to some types of technology than to others. Thus, these data might be used to support an argument for differential protection for certain types of technology.⁹¹ On the other hand, to the extent that the longer prosecution periods are within the control of patent applicants because they result from voluntary filing of multiple “continuation” applications,⁹² the result seems much less unfair.

⁸⁹ Biotechnology did not exist as a category in the 1970s study.

⁹⁰ See 35 U.S.C. §§155-156.

⁹¹ Some economists have suggested that the duration of patent protection should vary by industry to account for different economic factors in different fields. Cf. Ian Ayres & Paul Klemperer, *Limiting Patentees' Market Power Without Reducing Innovation Incentives: The Perverse Benefits of Uncertainty and Non-Injunctive Remedies*, 97 **Mich. L. Rev.** 985 (1999); Richard Gilbert & Carl Shapiro, *Optimal Patent Length and Breadth*, 21 **RAND J. Econ.** 106 (1990) (discussing optimal patent length). For a skeptical discussion of this idea, see Louis Kaplow, *The Patent-Antitrust Intersection: A Reappraisal*, 97 **Harv. L. Rev.** 1813 (1984). The law does in fact permit such variation in the specific context of pharmaceuticals. See 35 U.S.C. §§155, 155A, 156.

For a detailed discussion of differential patent protection by industry, see Burk & Lemley, *supra* note ____.

⁹² On the relationship between years in the PTO and the number of applications filed in both samples, see *supra* notes ____ and accompanying text. It is clear from our prior study that pharmaceuticals and biotechnology, two of the areas with the longest pendency times, also have a disproportionately high number of refilings. See Allison & Lemley, *supra* note ___, at 2154 Table 9.

Two types of refilings – continuations and continuations in part – are within the control of the applicant. Divisionals, however, are required by the PTO to prevent an applicant from claiming more than one invention in a single patent (the so-called “restriction” requirement). It is conceivable, therefore, that the growth in the number of refilings in certain industries results in part from a PTO practice of requiring strict adherence to this rule only in certain industries.

We tested this hypothesis in the pharmaceutical industry and found it unpersuasive. In the 1970s sample just over 10% of all pharmaceutical applications, compared with 5.6% of total applications, filed divisionals. The discrepancy was smaller in the 1990s sample: 14% of pharmaceutical applications,

Further, at least with respect to pharmaceutical and biotechnology inventions, it seems likely that patent protection is less important in the early stages of a product (particularly before FDA approval), and more important at the end of the patent term.⁹³ If so, the actual harm to owners of these patents seems less important. By contrast, the harm to owners of software patents should be correspondingly greater because of the fast-changing nature of the software field.⁹⁴

b. Technology and Prior Art References

We also tested the relationship between areas of technology and the number and type of prior art references cited in the patent. Citation of prior art is the best proxy we have in these data for the quality and thoroughness of a patent examination, so variation in the prior art cited by area may be indicative of variation in the quality of the patents that issue. The results are presented in Tables 11A and 11B.

compared with 10% of total applications. Thus, it is true that pharmaceutical patents were subject to more restriction requirements. This does not explain the total increase in filings, however. While pharmaceutical patent applicants in the 1970s filed fewer continuations and CIP applications than other technologies, in the 1990s sample pharmaceutical patent applicants accounted for a disproportionate number of continuations and CIPs. In the 1990s sample, pharmaceutical patents accounted for 7.8% of the patents, but fully 22% of the continuations and CIPs filed.

⁹³ This results from the significant time such inventions normally spend in the FDA approval process.

⁹⁴ The law changed in 1999 to require that most patent applications be published after 18 months, and to give the owners of published patent applications a right to recover royalties from anyone who begins infringing after a patent application is published but before the patent issues. 35 U.S.C. § 122. It is possible that these new provisions will somewhat ease the pressure to get a patent issued early in industries like software.

Table 11A
Prior Art References By Area of Technology, 1976-78

U.S. Patent References

	Pharm	Med.Dev.	BioTech.	Comp-Rel.	Software	SemiCond.	Electronics	Chemistry	Mechanics	Acoustics	Optics	Auto-Rel	Energy-Rel	Commun-Rel
Mean # US pat ref	2.24	5.76	0.00	4.53	0.00	4.22	5.16	4.37	5.47	4.32	4.17	5.64	5.52	4.52
Median	2.00	5.00	0.00	4.00	0.00	3.00	4.00	4.00	5.00	4.00	4.00	5.00	5.00	4.00
Mode	1.00	4.00	0.00	3.00	0.00	3.00	4.00	4.00	4.00	5.00	2.00	4.00	5.00	3.00
Std.Dev	2.29	2.80	0.00	2.81	0.00	2.75	2.96	3.32	2.95	2.08	2.55	2.97	3.47	2.77
Max	12.00	11.00	0.00	16.00	0.00	13.00	16.00	19.00	17.00	10.00	14.00	15.00	15.00	14.00
Min	0.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	2.00	0.00	1.00	1.00	1.00

Foreign Patent References

	Pharm	Med.Dev.	BioTech.	Comp-Rel.	Software	SemiCond.	Electronics	Chemistry	Mechanics	Acoustics	Optics	Auto-Rel	Energy-Rel	Commun-Rel
Mean # Foreign pat ref	0.35	0.48	0.00	0.09	0.00	0.00	0.31	0.38	0.64	0.23	0.20	0.46	0.35	0.21
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Std.Dev	1.16	1.06	0.00	0.29	0.00	0.00	0.80	0.81	1.12	0.43	0.64	0.76	0.67	0.74
Max	8.00	5.00	0.00	1.00	0.00	0.00	6.00	8.00	7.00	1.00	5.00	2.00	3.00	4.00
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Non-Patent References

	Pharm	Med.Dev.	BioTech.	Comp-Rel.	Software	SemiCond.	Electronics	Chemistry	Mechanics	Acoustics	Optics	Auto-Rel	Energy-Rel	Commun-Rel
Mean # non-pat ref	0.78	0.10	0.00	0.26	0.00	0.26	0.26	0.50	0.05	0.27	0.39	0.00	0.24	0.36
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mode	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Std.Dev	1.24	0.56	0.00	0.68	0.00	0.69	0.73	1.01	0.28	1.08	0.91	0.00	0.60	1.06
Max	6.00	3.00	0.00	3.00	0.00	3.00	5.00	6.00	3.00	5.00	5.00	0.00	2.00	5.00
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Total References

	Pharm	Med.Dev.	BioTech.	Comp-Rel.	Software	SemiCond.	Electronics	Chemistry	Mechanics	Acoustics	Optics	Auto-Rel	Energy-Rel	Commun-Rel
Mean # total pat ref	3.37	6.34	0.00	4.88	0.00	4.48	5.73	5.26	6.15	4.82	4.76	6.10	6.11	5.09
Median	3.00	6.00	0.00	4.00	0.00	3.00	5.00	5.00	5.00	5.00	4.00	6.00	5.00	4.00
Mode	3.00	4.00	0.00	3.00	0.00	3.00	4.00	5.00	4.00	5.00	2.00	6.00	4.00	3.00
Std.Dev	3.13	3.06	0.00	3.02	0.00	2.87	3.36	3.57	3.42	2.04	2.81	3.28	3.65	2.93
Max	20.00	13.00	0.00	19.00	0.00	13.00	19.00	20.00	25.00	10.00	16.00	17.00	17.00	14.00
Min	0.00	2.00	0.00	1.00	0.00	1.00	1.00	0.00	0.00	2.00	1.00	1.00	1.00	2.00

Table 11B
Prior Art References By Area of Technology, 1996-98

U.S. Patent References

	Pharm	Med.Dev.	BioTech.	Comp-Rel.	Software	SemiCond.	Electronics	Chemistry	Mechanics	Acoustics	Optics	Auto-Rel	Energy-Rel	Commun-Rel
Avg # US pat ref	6.06	19.44	4.59	10.21	9.59	6.49	9.35	9.94	12.70	8.95	10.16	12.36	14.63	10.56
Median	3	12	2	7	7	5	7	6	8	7	7	8	10	6
Mode	0	5	0	6	5	2	4	3	6	4	5	7	10	6
Std. Dev.	10.14	22.60	7.40	11.43	12.90	5.20	11.32	12.44	14.33	5.98	14.19	13.88	16.94	14.50
Max	76	137	38	112	112	25	87	82	137	19	137	68	82	87
Min	0	0	0	0	1	0	0	0	0	1	0	0	1	1

Foreign Patent References

	Pharm	Med.Dev.	BioTech.	Comp-Rel.	Software	SemiCond.	Electronics	Chemistry	Mechanics	Acoustics	Optics	Auto-Rel	Energy-Rel	Commun-Rel
Avg # For pat ref	2.60	2.84	2.97	1.77	1.26	1.57	1.66	3.63	2.60	1.82	2.14	3.83	1.79	1.66
Median	1	1	1	0	0	1	0	2	1	0	1	2	2	0
Mode	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Std. Dev.	3.84	5.80	7.36	2.72	2.39	2.17	2.93	4.62	4.21	3.53	3.09	4.83	1.98	3.40
Max	24	36	43	16	12	10	18	24	36	15	17	19	6	18
Min	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Non-patent References

	Pharm	Med.Dev.	BioTech.	Comp-Rel.	Software	SemiCond.	Electronics	Chemistry	Mechanics	Acoustics	Optics	Auto-Rel	Energy-Rel	Commun-Rel
Avg # non-pat ref	9.88	3.56	16.30	2.75	3.54	1.34	0.83	3.43	0.53	2.45	2.72	0.63	0.75	2.41
Median	5	0	15	0	1	0	0	1	0	0	0	0	0	0
Mode	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Std. Dev.	12.60	10.55	12.68	7.56	7.33	3.03	2.32	6.92	1.83	6.35	7.43	1.64	1.15	9.84
Max	68	67	68	63	36	19	14	55	19	30	67	8	3	63
Min	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Total Prior Art References

	Pharm	Med.Dev.	BioTech.	Comp-Rel.	Software	SemiCond.	Electronics	Chemistry	Mechanics	Acoustics	Optics	Auto-Rel	Energy-Rel	Commun-Rel
Avg # total art ref	18.55	25.84	23.86	14.74	14.39	9.41	11.84	17.00	15.84	13.23	15.02	16.82	17.17	14.63
Median	12	15	17	10	10	8	9	11	11	10	10	10	14	8
Mode	1	11	8	7	7	5	4	8	5	19	7	7	25	6
Std. Dev.	18.34	29.86	20.19	17.14	17.15	6.59	13.75	17.11	16.75	11.72	18.53	16.50	17.76	23.05
Max	83	163	93	137	137	30	105	101	163	58	163	84	87	118
Min	1	1	1	1	1	1	0	1	0	1	1	1	1	1

There are a number of interesting facts in these data. We have already noted the striking increase in prior art citations of all types between the 1970s sample and the 1990s sample.⁹⁵ These data help bring that change into focus. One way of understanding the magnitude of the change is that the industry with the highest average number of references cited in the 1970s sample (medical devices, with 6.34 total references) is well below the industry with the *lowest* average number of references in the 1990s sample (semiconductors, with 9.41 total references). Clearly, then, the increase in prior art citations has occurred across the board.

Interestingly, though, the variation has also changed dramatically between the two samples. In the 1976-78 study, there was remarkably little variation among technology areas in the number and type of prior art references they cited. The average total reference citations ranged from a low of 3.37 (pharmaceuticals) to a high of 6.34 (medical devices). By contrast, the range is much wider in the 1996-98 study. There, the average total references ranged from a low of 9.41 (semiconductors) to a high of 25.84 (medical devices). This means that the variation index (the ratio of highest average to lowest average) rose from 1.88 in the 1970s to 2.75 in the 1990s. Further, the pharmaceutical industry, which cited the least references in the 1970s, cited more than average by the 1990s. Clearly, then, there is not only a general trend towards citing more prior art, but a particular inclination to do so in certain industries.

The same pattern replicates itself when we consider different types of prior art. In the 1970s study, there was no major variation in the citation of different types of art across technology areas. By contrast, the variation was much more substantial in the 1990s study. In the 1990s sample, citation of U.S. patents as prior art references ranged

⁹⁵ See *supra* notes ___-___ and accompanying text.

from a low of 4.59 on average for biotechnology patents to a high of 19.44 for medical device patents.⁹⁶ Compare this to the range of U.S. patents cited in the 1970s sample: a low of 2.24 on average for pharmaceutical patents to a high of 5.76 for medical devices. Similarly, there is almost no variation in the 1970s sample with respect to foreign patents: a low of 0 in the semiconductor industry to a high of 0.64 on average for mechanical inventions. By contrast, in the 1990s sample, software inventions cite the fewest foreign patents, 1.26 on average, while automotive patents cite the most foreign patents, 3.83.⁹⁷

The same pattern – with even more dramatic numbers – is evident in the non-patent references cited in each area of technology. Virtually no non-patent prior art was cited in the 1970s sample: a low of 0 citations in the automotive industry to a high of 0.78 in the pharmaceutical industry. By contrast, in the 1990s sample citations to non-patent prior art ranged from a low of 0.53 citations on average for mechanical inventions to a high of 16.30 references on average for biotechnology inventions. These variations are statistically significant in both samples.⁹⁸

3. Relationships Between Nationality and the Prosecution Process

⁹⁶ These differences were also reflected in the median numbers: the median biotechnology patent cited 2 U.S. patent references, the median pharmaceutical patent cited 3 U.S. patent references, while the median medical device patent cited 12 U.S. patent references.

⁹⁷ As noted above, the absolute growth in the citation of foreign patents is striking. *See supra* notes ___-___ and accompanying text.

⁹⁸ We used an ANOVA F test in the 1976-78 study and a Poisson regression in the 1996-98 study. For total references, the ANOVA F statistic = 3.35 and the p-value = .035. For U.S. patent references, the ANOVA F statistic = 7.10 and the p-value = .001. For foreign patent references, the ANOVA F statistic = 9.32 and the p-value < .001. For nonpatent references, the ANOVA F statistic = 22.06 and the p-value < .001. For the Poisson regression, the results are reported in detail in our prior study, *supra* note ___, at 2130 n.98. See *supra* note --, for an explanation of why we used different tests for these relationships in the two data sets.

In the previous section we compared the relationships between area of technology and a number of specific facts about the prosecution process over time. In this section we test the relationship between the same prosecution process metrics and the invention's country of origin. Thus, we tested the relationship between country of origin and the following factors in both the 1976-78 and 1996-98 samples: number of applications filed, time spent in prosecution, number of inventors, number and type of references cited, and number and type of claims filed. We do not report on all these studies in detail here, however. In the number of inventors and the number and type of claims, the relationship among areas of technology remained largely unchanged from the 1970s to the 1990s.⁹⁹ Thus, those issues are fully discussed in our prior study.¹⁰⁰ Rather, we focus on the relationship between area of technology, on the one hand, and the number of applications filed, time in prosecution and prior art references on the other.

a. Country of Origin and Number of Applications Filed

First, we tested the relationship between country of origin and the total number of U.S. applications filed leading up to the issuance of each patent. As noted elsewhere, continuation practice is a legal but controversial process because it has been associated with so-called "submarine patents."¹⁰¹ Here we evaluate whether use of this practice

⁹⁹ The absolute numbers changed, as reported *supra*. But the variation by area of technology did not change.

¹⁰⁰ See Allison & Lemley, *Who's Patenting What?*, *supra* note __, at 2136-37 (inventors), 2138-39 (claims).

¹⁰¹ See, e.g., Steve Blount & Louis Zarfas, *The Use of Delaying Tactics to Obtain Submarine Patents and Amend Around a Patent That a Competitor Has Designed Around*, 81 **J. Pat. & Trademark Off. Soc'y** 11 (1999); Timothy R. DeWitt, *Does Supreme Court Precedent Sink Submarine Patents*, 38 **Idea** 601 (1998); Lemley, *supra* note __, at 369; David L. Marcus, *Is the Submarine Patent Torpedoed? Ford Motor Co. v. Lemelson and the Revival of Continuation Application Laches*, 70 **Temple L. Rev.** 521 (1997); James W. Morando & Christian H. Nadan, *Silent Enemies*, **Recorder**, May 4, 1994, at 10.

differs by nationality over time. We conducted a country-by-country analysis for each of the countries with five or more patents in at least one of our samples. The results are presented in Tables 12A and 12B.

Table 12A
Number of Applications Filed by Country of Origin, 1976-1978

	U.S.	Canada	Japan	U.K.	Germ.	France	Italy	Switz.	Neth.	Sweden	Denmark
Total # US apps filed	846	16	169	36	113	39	12	16	17	13	5
Median	1	1	1	1	1	1	1	1	1	1	1
Mode	1	1	1	1	1	1	1	1	1	1	1
Std.Dev	0.67	0.53	0.74	0.51	1.10	0.53	0.63	0.44	0.43	0.40	0.00
Max	6	3	6	3	8	3	3	2	2	2	1
Min	1	1	1	1	1	1	1	1	1	1	1
Average	1.33	1.14	1.34	1.24	1.38	1.30	1.20	1.23	1.21	1.18	1.00

Table 12B
Number of Applications Filed by Country of Origin, 1996-1998

	US	Canada	Japan	Korea	Australia	Taiwan	UK	Germ.	France	Italy	Switz.	Neth.
Total # US apps. Filed	865	27	317	32	7	24	29	76	47	18	8	16
Median	1	1	1	1	1	1	1	1	1	1	1	1
Mode	1	1	1	1	1	1	1	1	1	1	1	1
Std. Dev.	1.12	1.18	0.95	0.54	0.41	0	1.02	0.53	1.03	0.96	0	0.89
Max	9	5	8	3	2	1	5	4	5	4	1	4
Min	1	1	1	1	1	1	1	0	1	1	1	1
Mean	1.60	1.59	1.50	1.28	1.17	1.00	1.53	1.15	1.52	1.38	1.00	1.33

The 1970s data show no statistically significant variation by country of origin in the use of the continuation practice.¹⁰² By contrast, the 1990s data show substantially greater variation by country in the use of the continuation practice. That variation is statistically significant.¹⁰³ In the 1990s, patents of U.S. origin had more refilings on average than any other country of origin represented in the sample (1.60 total applications per issued patent). Other countries' patentees with refiling rates nearly as high included those from Canada, Japan, the U.K. and France. By contrast, other countries had significantly lower refiling rates. Indeed, patentees from two countries, Taiwan and Switzerland, never engaged in refiling in the sampled patents.

While in both samples only a minority of patentees from every country tested used this procedure, the use of continuation practice clearly rose between the 1976-78 study and the 1996-98 study. Further, the increase was clearly concentrated in inventions originating in only a few countries, especially the U.S., Canada, Japan, the U.K. and France. By contrast, patentees from other countries rarely if ever used the procedure in the 1990s study. These findings may also affect our observations in the next section, relating to time spent in prosecution.

b. Country of Origin and Time Spent in Prosecution

¹⁰² We used the ANOVA F test. For foreign vs. US, the F statistic = 0.44 and the p-value = 0.509. For country-by-country, the F statistic = 0.49 and the p-value = 0.911. In neither case can we reject the null hypothesis that there is no relationship between nationality and the number of applications filed.

¹⁰³ We used a Poisson regression. The differences are statistically significant when comparing U.S.-origin patents with foreign-origin patents as a whole (p = .004). When comparing U.S.-origin patents with those originating in each foreign country individually, the differences are statistically significant only with respect to two countries (Taiwan, p = .014; Germany, p = .004).

Next, we related country of origin to the time spent in prosecution in both the 1976-78 and 1996-98 samples. We tested both U.S.-origin versus foreign-origin patents and country-by-country results. The results are presented in Tables 13A and 13B.

Table 13A
Time Spent in Prosecution by Country of Origin, 1976-1978

	U.S.	Canada	Japan	U.K.	Germ.	France	Italy	Switz.	Neth.	Sweden	Denmark	U.S.S.R.
Mean # Yrs. In PTO	2.24	1.81	2.27	2.24	2.41	2.19	2.41	1.71	1.93	1.95	2.24	1.66
Median	1.77	1.59	1.78	2.06	1.87	1.79	1.73	1.59	1.78	1.67	1.78	1.42
Mode	1.44	#N/A	1.54	1.61	1.40	1.42	1.73	#N/A	#N/A	#N/A	#N/A	#N/A
Std.Dev	1.61	0.64	1.45	0.94	1.99	1.27	1.68	0.67	0.90	0.97	1.70	0.98
Max	13.85	3.64	7.57	4.77	11.30	7.71	6.39	2.97	4.54	4.52	5.23	3.30
Min	0.59	1.15	0.76	1.18	0.94	0.97	1.19	0.77	0.87	1.13	1.01	0.81
Margin of Error +/-	0.06	0.19	0.13	0.18	0.22	0.24	0.60	0.20	0.26	0.32	1.06	0.60

	US	Non-US
Mean # Yrs. In PTO	2.24	2.21
Median	1.77	1.78
Mode	1.44	1.42
Std.Dev	1.61	1.45
Max	13.85	11.30
Min	0.59	0.76
Confidence	0.06	0.12

Table 13B
Time Spent in Prosecution by Country of Origin, 1996-1998

	US	Canada	Japan	Korea	Australia	Taiwan	UK	Germ.	France	Italy	Switz.	Neth.
Avg yrs in PTO	2.92	2.98	2.76	2.29	3.57	1.32	3.50	2.37	2.65	2.71	1.83	2.40
Median	2.33	2.10	2.37	2.13	1.95	1.30	2.37	2.15	2.32	2.12	1.94	1.86
Mode	1.35	#N/A	1.46	#N/A	#N/A	1.27	#N/A	1.63	2.85	#N/A	1.95	#N/A
Std. Dev.	1.99	2.16	1.45	0.93	4.00	0.35	2.82	1.36	1.32	1.54	0.53	1.74
Max	18.15	9.70	8.96	4.77	11.67	2.19	12.79	10.22	6.20	6.45	2.54	7.34
Min	0.69	1.51	0.94	1.13	1.47	0.67	1.28	0.82	1.01	1.22	1.18	1.03
Margin of Error +/-	0.08	0.55	0.10	0.19	2.10	0.07	0.68	0.17	0.24	0.46	0.22	0.55

	US	Non-US
Avg yrs in PTO	2.92	2.60
Median	2.33	2.17
Mode	1.35	1.82
Std. Dev.	1.99	1.56
Max	18.15	12.79
Min	0.69	0.67
Margin of Error +/-	0.08	0.07

The results are quite interesting. In the 1970s sample, U.S.-origin and foreign-origin patents were statistically indistinguishable in the time they spent in prosecution.¹⁰⁴ More generally, the variation among countries of origin was modest, ranging from a low of 1.66 years on average for the U.S.S.R. and 1.71 for Switzerland to a high of 2.41 years on average for Germany and Italy. The 1990s sample tells a different story. In the 1996-98 study, U.S.-origin patents spent significantly longer in prosecution than foreign-origin patents: 2.92 years for U.S.-origin patents, compared with 2.60 years for foreign-origin patents. The variation among individual countries of origin is even greater, ranging from a low of 1.32 years on average for Taiwanese patentees to a high of 3.57 years for Australian patentees.¹⁰⁵ And while the time in prosecution for patents as a whole increased during this period, the time spent in prosecution by the German-origin patents in our samples actually fell slightly, though the drop was well within the margin of error.

The fact that U.S.-origin patents spend longer in prosecution than their foreign-origin counterparts today may seem to support the complaints of those who allege that the U.S. patent system is somehow stacked against U.S. patent applicants. We encourage

¹⁰⁴ While the numbers differ slightly, the difference is well within the margin of error. We used the ANOVA F test. For foreign vs. US, the F statistic = 0.14 and the p-value = .705. For country-by-country, the F statistic = 0.42 and the p-value = .946. Thus, we cannot reject the null hypothesis that there was no relationship in 1976-78 between country of origin and time spent in prosecution.

¹⁰⁵ These results are statistically significant for Foreign vs. U.S. We used a Gamma regression because one of the variables is continuous rather than discrete. The terms Poisson regression and Gamma regression are shorthand phrases for particular types of Generalized Linear Models. One builds the model and then uses regression (here, logistic regression) to produce a result. *See generally* JAMES K. LINDSEY, *APPLYING GENERALIZED LINEAR MODELS* 18-25, 132-33 (1997); PETER McCULLAGH & JOHN A. NELDER, *GENERALIZED LINEAR MODELS* 287-322 (2nd ed. 1989). The differences are statistically significant when comparing U.S.-origin patents with foreign-origin patents as a whole ($p < .001$). When comparing U.S.-origin patents with those originating in each foreign country individually, the differences are statistically significant only with respect to two countries (Korea, $p = .028$; Taiwan, $p < .001$; Germany, $p = .004$; Switzerland, $p = .019$).

Thus, the results of the country-by-country analysis are less certain because with some countries the size of the sample was so small. Thus Australia, the outlier in this test, had only six patents in the sample, reducing the predictive power of the results for that country. Indeed, the median patent for Australia spent less than two years in prosecution, well below the median for many other countries with lower means.

caution in attempting to explain these results, however. As noted in the previous section, time spent in prosecution may be dependent on other factors like the total number of applications filed. Thus, the fact that U.S. patentees refiled patent applications more often than those from any other country likely contributes to the longer time in prosecution experienced by U.S. patentees, and Taiwanese reluctance to engage in this practice may explain their quicker prosecution times. This is particularly likely since U.S. patentees' use of the refiling procedure increased substantially during the same period that its time in prosecution increased. Further, because different patentees from different countries obtain patents in different areas of technology, the national variation may be related to the variation by area of technology observed earlier.¹⁰⁶ Thus, the fact that U.S. patentees have disproportionately more biotechnology and pharmaceutical patents, coupled with the fact that those patents tend to spend longer in prosecution, may help to explain why U.S.-origin patents spend longer in prosecution on average. It may also be an artifact of the data set, particularly for countries with relatively few patents in the sample.¹⁰⁷ Again, however, settling on an explanation is not possible from this data alone.

c. Country of Origin and Prior Art References

We tested the relationship between country of origin and the number and type of prior art references cited. While we analyzed data for each country with five or more

¹⁰⁶ See *supra* notes ___-___ and accompanying text.

¹⁰⁷ Thus, the country whose patents were prosecuted the most quickly in the 1976-78 sample was the U.S.S.R. We rather doubt, however, that this proves that the U.S. PTO was biased in favor of patentees from the U.S.S.R. during the 1970s.

patents, in the interest of simplicity we discuss here only the aggregate results for U.S. and foreign inventors. The results are presented in Tables 14A and 14B.

Table 14A
Number and Type of Prior Art References by Country of Origin, 1976-1978

	U.S.	Non-US
Avg # US pat ref	5.34	4.48
Median	5.00	4.00
Mode	5.00	3.00
Std.Dev	3.16	2.84
Max	19.00	14.00
Min	0.00	0.00

	U.S.	Non-US
Avg # Foreign pat ref	0.42	
Median	0.00	
Mode	0.00	
Std.Dev	0.90	
Max	6.00	
Min	0.00	

	U.S.	Non-US
Avg # non-pat ref	0.22	0.23
Median	0.00	0.00
Mode	0.00	0.00
Std.Dev	0.69	0.79
Max	5.00	6.00
Min	0.00	0.00

	U.S.	Non-US
Avg # total pat ref	5.98	5.14
Median	5.00	5.00
Mode	5.00	2.00
Std.Dev	3.51	3.05
Max	25.00	16.00
Min	0.00	1.00

Table 14B
Number and Type of Prior Art References by Country of Origin, 1996-1998

	US	Non-US
Avg # US pat ref	13.85	6.23
Median	9	5
Mode	7	5
Std. Dev.	15.21	4.86
Max	137	37
Min	0	0

	US	Non-US
Avg # For pat ref	2.03	2.93
Median	0	2
Mode	0	0
Std. Dev.	4.24	3.58
Max	43	26
Min	0	0

	US	Non-US
Avg # non-pat ref	3.41	1.16
Median	0	0
Mode	0	0
Std. Dev.	8.19	3.49
Max	68	55
Min	0	0

	US	Non-US
Avg # total pat ref	19.29	10.31
Median	13	9
Mode	7	7
Std. Dev.	20.07	7.82
Max	163	70
Min	0	1

There are a number of interesting relationships among these data. In the 1976-78 sample, there was not much variation between U.S. and foreign patentees in the number and type of prior art references cited. U.S. patentees cited slightly more total references on average (5.98 U.S. vs. 5.14 foreign), but the median patent in each group cited a total of five pieces of prior art. U.S. and foreign patentees cited virtually identical numbers of foreign patent and non-patent references.¹⁰⁸

The 1996-98 data tell a different story. The most dramatic change – the growth in prior art citations from the 1970s to the 1990s across all categories – has already been remarked upon.¹⁰⁹ But this change disproportionately affected U.S. patentees. In the 1996-98 sample, U.S.-origin patents included significantly more prior art references than their foreign-origin counterparts, both on average, with 19.29 per U.S.-origin patent compared to 10.31 per foreign-origin patent, and at the median, with 13 in the median U.S.-origin patent compared to 9 in the median foreign-origin patent. The breakdown of this prior art reflects national origin to some extent; foreign patentees are more likely to cite foreign patents as prior art, and much less likely to cite U.S. patents. This last fact gives us some inferential evidence that much of the prior art cited in patents is in fact art submitted by the applicant, not art found by the examiner. Applicants are more likely to have access to prior art from their home country. However, there is no reason to

¹⁰⁸ Nonetheless, most of these differences are statistically significant. We used the ANOVA F test for both foreign vs. US and country-by-country analysis. For foreign vs. US and total references, the ANOVA F statistic = 12.38 and the p-value < .001; for U.S. patent references, the ANOVA F statistic = 18.07 and the p-value < .001; for foreign patent references, the ANOVA F statistic = 3.54 and the p-value = .006; for nonpatent references, the ANOVA F statistic = 0.47 and the p-value = .491. For country-by-country and total references, the ANOVA F statistic = 2.04 and the p-value = .022; for U.S. patent references, the ANOVA F statistic = 2.26 and the p-value = .010; for foreign patent references, the ANOVA F statistic = 2.67 and the p-value = .002; for nonpatent references, the ANOVA F statistic = 0.58 and the p-value = .444. Thus, for both types of tests the results are statistically significant for every type of reference except non-patent references.

¹⁰⁹ See *supra* notes ___-___ and accompanying text.

believe that examiners would be more likely to find art from the applicant's home country.¹¹⁰ Thus, if the art cited tends disproportionately to be from the applicant's country of origin, it is most likely because the applicants themselves have found and cited that art. We have not examined the prosecution files, however, and so have no concrete evidence on who finds the cited prior art.¹¹¹

To the extent that citation of a great deal of prior art is evidence of a more rigorous prosecution process, something the last paragraph calls into question, it appears that U.S.-origin patents were subject to somewhat more searching inquiry than foreign-origin patents.¹¹² Again, however, we urge caution in interpreting this data. There is likely a connection between the types of technology patented in the U.S. and the prior art citation counts. Because U.S. patentees are disproportionately represented in pharmaceutical and biotechnological inventions, and because those inventions cite more prior art than average, it may make sense that U.S.-origin inventions cite more art than their foreign-origin counterparts. The change over time is harder to explain, however.

¹¹⁰ It is possible that since foreign applicants are more likely to file *first* outside the U.S., the foreign art cited actually represents art found by a non-U.S. patent office and then submitted by the applicant to the U.S. PTO.

¹¹¹ We did take an unsystematic look at several randomly selected patents, and in each case found at least some art that examiners were unlikely to have access to. *See, e.g.*, U.S. Patent No. 6,006,227. For a more systematic approach to this question in one industry – the Internet – see John R. Allison & Emerson H. Tiller, *Report on Internet-Related Software Patents to the National Academy of Sciences STEP Board* (working paper 2001).

¹¹² The fact that U.S. patentees have much more art cited than their foreign counterparts is difficult to reconcile with the commonly held belief that foreign patent offices are better than the U.S. PTO at searching prior art. Were that true, we would expect to see foreign applicants (who file abroad more than U.S. applicants do) citing more, not less, prior art to the U.S. PTO, especially since most foreign patentees file outside the U.S. before filing in the U.S.

IV. Implications of Our Results

A. Explaining the Results

We have analyzed a great deal of data. Neither the complexity of the relationships we found nor the nature of our methodology lend themselves to easy predictions about causation. The reader is cautioned, therefore, that we now leave the hard world of data for the rather more speculative world of theorizing.

There are at least two themes that stand out from the data. First, obtaining a patent was a more complex process in the late 1990s than it was twenty years earlier. Across the board, patent applicants put more claims in their patents, cited more prior art of all types, spent longer in prosecution, and refiled their applications more times. Patented inventions tended to be for more complex, “high technology” inventions, and they had more inventors than twenty years before.¹¹³

Second, patents in the 1990s were much more heterogeneous than their 1970s counterparts. In our companion study, we observed that “the U.S. patent prosecution system is not unitary. Rather, different entities experience very different sorts of patent prosecution. For example, chemical, pharmaceutical, and biotechnological patents spend much longer in prosecution than other types of patents. Chemical, medical, and biotechnological patents cite much more prior art than other patents, and use continuation practice much more frequently.”¹¹⁴ Our current study demonstrates that this heterogeneity is a product of the last twenty years. None of the factors that today vary so

¹¹³ This is broadly consistent with Kimberly Moore’s finding that patent *litigation* is increasingly complex as well, at least as measured by trial length. See Moore, *Forum Shopping*, *supra* note __, at 932-34.

¹¹⁴ Allison & Lemley, *Who’s Patenting What?*, *supra* note __, at 2146.

much by nationality or area of technology were so divided in the 1970s sample. Something has happened in the past three decades to cause different pieces of the patent system to move in such different directions.

We can think of several possible explanations for these changes, particularly the increasing complexity of patents, but none is entirely satisfactory. First, it is certainly true that the nature of the technology being patented has changed significantly over this period. Two of the fourteen subject matter categories we used in our 1990s study – software and biotechnology – are not represented at all in the 1970s study. 1970s patents were more likely to be mechanical inventions, and mechanical inventions tend to be simpler than many others. This is doubtless a partial explanation for the increased time in prosecution and the increase in prior art citations. Those two factors in turn may influence both the number of applications filed (because applications are more likely to be rejected as more prior art is considered, necessitating more bites at the apple by patent applicants) and the number of claims (since patent attorneys may have to draft claims more carefully to avoid the prior art). Technological changes may also explain the increase in heterogeneity; inventions simply come in more different fields than they used to.

But changes in technology cannot explain all the results of our study. In particular, we find that the relationship between area of technology and such factors as time spent in prosecution and prior art references cited has itself changed over time. If the overall numbers were simply an artifact of shifts in technology – more patents in the semiconductor category, say, and fewer in mechanics – we would expect to see the

characteristics of patents *within* those categories remain stable. But they have changed dramatically, as Part III.B.2 shows.¹¹⁵

A second hypothesis is that the U.S. PTO conducted much more thorough examinations of patents in the 1990s than it did in the 1970s. Were this true, it would provide an explanation for many of the complexity-related changes. A more thorough examination would cite more prior art, would lead to more rejections and thus more refilings, which would in turn cause patents to spend more time in prosecution, and may also cause patentees to write more claims as a safeguard.¹¹⁶ The problem with the heightened examination process theory is that it does not appear to be borne out by the facts. PTO Examiners spend startlingly little time on a patent – an average total of only 18 hours over three years.¹¹⁷ Further, Quillen and Webster have found that once continuation, CIP and divisional applications are accounted for, the PTO in the 1990s ultimately granted patents on 97% of the applications that were filed.¹¹⁸ It is hard to imagine that this is a significantly more rigorous examination than the PTO conducted in the 1970s.

¹¹⁵ See *supra* notes ___-___ and accompanying text.

¹¹⁶ It would not necessarily follow that the PTO would *allow* more claims, however, which is what our data show.

¹¹⁷ See, e.g., Brenda Sandburg, *Speed Over Substance?*, **Intell. Prop. Mag.** (March 1999) (18 hours on average; Examiners may spend more time on complex technologies); Thomas, *Collusion*, *supra* note ___, at [draft at 10] (16 to 17 hours); author’s conversation with Q. Todd Dickinson, Director of the U.S. PTO, April 2000. Cf. *Patent Nonsense: The Knowledge Monopolies*, **The Economist**, April 8, 2000 (“patent Examiners spend only eight hours on a patent, on average.”).

I should make it clear that this is an average across all industries, and that there may be substantial variation in the hours spent from one industry to another. See Dickinson, *supra* (hours spent range from 8 per patent in some art units to 32 in other art units).

¹¹⁸ See Cecil D. Quillen, Jr. & Ogden H. Webster, *Continuing Patent Applications and Performance of the U.S. Patent Office* (working paper 2000).

Examination quality might also provide an explanation for heterogeneity, but only if the quality of the PTO examination were thought to vary significantly by subject matter. There is certainly anecdotal evidence to support this proposition; biotech attorneys regularly complain that the examiners in their art units are too tough on them,¹¹⁹ while others complain about the laxity of examination in fields like software.¹²⁰ There is also evidence that the law itself varies somewhat by subject matter, with biotechnology patents being read more narrowly than software patents.¹²¹ The evidence would have to be significantly stronger to explain our results, however. The variation occurs across many different fields. Further, it changes over time. Evidence regarding software and biotechnology patents is largely irrelevant to our results, since neither field had any patents in our 1970s sample. We know of no evidence – anecdotal or otherwise – to suggest that examination quality has changed radically in different directions in other fields.

Third, it may be that the increase in patenting during the last quarter-century reflects a greater willingness to patent incremental or marginal improvements over the prior art. If this is true in general, it may explain the greater complexity of the patent system; if it is true only in certain industries, it may also explain heterogeneity. The theory is that innovations that represent only a slight improvement over the prior art are harder to obtain patents for. They require the applicant to distinguish more and closer

¹¹⁹ See, e.g., Janice M. Mueller, *The Evolving Application of the Written Description Requirement to Biotechnological Inventions*, 13 **Berkeley Tech. L.J.** 615 (1998); Margaret Sampson, *The Evolution of the Enablement and Written Description Requirements Under 35 U.S.C. § 112 in the Area of Biotechnology*, 15 **Berkeley Tech. L.J.** 1233 (2000).

¹²⁰ For a detailed discussion, see Julie E. Cohen & Mark A. Lemley, *Patent Scope and Innovation in the Software Industry*, 89 **Calif. L. Rev.** 1, 42-45 (2001) and sources cited therein.

¹²¹ See Dan L. Burk & Mark A. Lemley, *Is Patent Law Technology-Specific?* (working paper 2001).

prior art, and probably to write more claims to ensure that some of those claims survive. Further, examiners may be less willing to grant patents on such marginal technologies. This in turn means a tougher prosecution process, which may take longer and require the filing of more continuations. We will call this theory incrementalism.¹²²

While incrementalism may explain the growing complexity of the patent prosecution process, it has a harder time explaining industry-specific variation in that process. In particular, the line of reasoning set out above would lead one to conclude that patents were most marginal in the biotechnology and pharmaceutical industries, and most pioneering in the semiconductor industry. This goes against the received wisdom in these fields, as well as what sector-specific empirical evidence we have. That evidence suggests just the opposite: that semiconductor patents are rarely litigated and generally for incremental improvements,¹²³ while biotechnology and pharmaceutical patents are frequently for entirely new products and tend to be litigated or licensed more often than patents in other industries.¹²⁴ Thus, incrementalism seems troubling as an explanation for modern changes in patenting.

¹²² Interestingly some reviewers suggested the opposite theory to us – that broader claims implicated more prior art, and therefore required more detailed prosecution. That theory, which has implications diametrically opposed to incrementalism, strikes us as an offshoot of the patent value theory we discuss below.

¹²³ See, e.g., Lemley, *Rational Ignorance*, *supra* note __, at [draft at 11] (most semiconductor patents cross-licensed without litigation); Bronwyn Hall & Rosemarie Ham Ziedonis, *The Patent Paradox Revisited: Determinants of Patenting in the U.S. Semiconductor Industry*, NBER Working Paper 7062 (1999) (discussing cross-license patterns as a substitute for litigation in the semiconductor industry); Thomas et al., *supra* note __, at 659-660 (patent litigation infrequent in the semiconductor and computer industries).

¹²⁴ Lanjouw and Schankerman measure the percentage of patents in various industries that are litigated. While their definition of industries does not match ours precisely, they do isolate “drugs” as an industry. They find that drug patents are somewhat more likely to be litigated than other sorts of patents. Lanjouw & Schankerman, *supra* note __, at __. Others have claimed that the biotechnology industry is particularly likely to engage in patent litigation. See, e.g., John M. Golden, *Biotechnology, Technology Policy, and Patentability: Natural Products and Invention in the American System*, 50 **Emory L.J.** 101, 172 (2001) (“Biotechnology patent litigation is generally recognized to be peculiarly frequent”); Martin Enserink, *Patent Office May Raise the Bar on Gene Claims*, 287 **Science** 1196, 1197 (2000) (“[v]irtually every major

A fourth possible explanation has to do with search techniques. It is much easier for the PTO and patent applicants to find relevant prior art today than it was in the 1970s. Computer searching in particular may enable examiners to find more non-prior art, thus helping to explain the ten-fold increase in non-patent prior art citations. It may also enable examiners to find prior art patents that aren't classified in the same category as the application, but which have search terms in common. And on the chain of reasoning used above, citing more prior art may help explain the other results we found. We do think that the ease of searching is a partial explanation for the dramatic increase in prior art citations, and therefore perhaps indirectly for some of the other findings. But it does not seem to us to be the whole explanation. U.S. patent applicants now cite far more art than foreign patent applicants, but did not do so in the 1970s. The ease of PTO searching doesn't explain why prior art citations tend to show up disproportionately in applications filed by U.S. nationals.¹²⁵ Similarly, the search technology theory has difficulty

therapeutic product to emerge from the biotech field has been the subject of intense and often bitter litigation."); Sandra M. Thomas et al., *Patenting of Recombinant Proteins: An Analysis of Tissue Plasminogen Activator (t-PA) in Europe, the United States and Japan*, 24 **Res. Pol'y** 645, 660 (1995) (biotechnology companies "spend proportionally more time and money for patent protection" than companies in other industries).

Interestingly, our prior study of patent validity litigation casts some doubt on this received wisdom. We found that of the patents litigated to final judgment on validity grounds during the period 1989 through 1996, only 3.0% were biotechnology patents and another 3.7% pharmaceutical patents. *See Allison & Lemley, Empirical Evidence, supra* note __, at 217 Table 5. By contrast, in the 1970s sample biotechnology patents were 0% and pharmaceutical patents 5.1% of the total; in the 1990s sample biotechnology patents were 3.7% and pharmaceutical patents 7.8% of the total. While the data are not strictly comparable – the patents litigated in the Allison/Lemley population mostly issued during the early 1980s – they seem to belie the suggestion that biotechnology and pharmaceutical patents are disproportionately likely to be litigated to judgment. One possible explanation is that more suits are filed in these industries, but that the cases are more likely to settle. *See Allison & Lemley, Empirical Evidence, supra* note __, at 218 n.68 (suggesting this possibility).

¹²⁵ One possible explanation is that the searches are being conducted by patentees, not examiners, and that U.S. inventors had better access to computer search tools than their counterparts in Europe and Asia.

explaining the variation in prior art citations across areas of technology.¹²⁶ It is possible to construct explanations for these differences – U.S. nationals may have better access to technology, and computer searching may work better in some industries than others because of the nature of prior art.¹²⁷ As a result, we don’t want to rule this explanation out altogether.

A final hypothesis has to do with the increasing importance of patents to the economy. On this theory, companies have started to pay greater attention to their patent portfolios, and make greater use of the patents they have. Certainly there is anecdotal evidence that patents have a higher profile in companies now than they did in the 1970s.¹²⁸ And patent litigation is increasing;¹²⁹ it may be that licensing is increasing too. An increase in the importance of patents may in turn mean that patentees are willing to expend more effort to “get it right” – to increase the post-issuance value of their patents. Filing more claims is one way to do that, as it makes it more likely that a patent will read on an accused infringer’s device. Citing more prior art¹³⁰ will also make a patent more

¹²⁶ It is possible that non-patent prior art is more likely to be computer-indexed in some fields than in others. Even if this is true, however, it provides no explanation for the increased citation to U.S. patent references, which make up the bulk of the increase in prior art citations.

¹²⁷ Cf. Julie E. Cohen, *Reverse Engineering and the Rise of Electronic Vigilantism: Intellectual Property Implications of “Lock-Out” Programs*, 68 **S. Cal. L. Rev.** 1091, 1179 (1995) (arguing that software prior art is particularly difficult to find). Cohen argues that software prior art is hard to find even with computer search tools, which may explain why software patents cite less prior art than biotechnology and pharmaceutical patents, despite the fact that computer programmers are presumably the most familiar with online search tools.

¹²⁸ See generally Rivette & Kline, *supra* note __; Samson Vermont, *The Economics of Patent Litigation* 3 (working paper 2001) (“Patents are more important than they used to be”). But see Levin et al., *supra* note __; Cohen et al., *supra* note __ (both conducting studies of technical managers and finding that patents were not considered particularly important in many manufacturing sectors).

¹²⁹ See Moore, *Judges, Juries*, *supra* note __, at 384 Table 1 (patent suits increased from 940 in 1983 to 2191 in 1999). Of course, the number of patents issued went up sharply during this time as well.

¹³⁰ On this theory, unlike prior ones, the increase in prior art citations results from the applicant rather than the examiner citing more art. Unfortunately, we know of no feasible way to determine empirically who first cites a piece of prior art short of collecting and reading thousands of prosecution histories.

valuable in litigation, as it is much harder to prove a patent is invalid if the PTO has already considered and rejected the relevant prior art.¹³¹ More claims and more prior art may mean a longer prosecution process, particularly if the patentee is willing to fight harder to get patent claims with significant scope. Fighting for a broad patent may necessitate refile, further delaying the issuance of a patent.

The patent value theory may also explain at least some of the heterogeneity we found in the data. First, we found in a prior study that U.S. patentees are far more likely than foreign patentees to enforce their patents in court. Indeed, U.S. patentees accounted for only about half of the total patents issued, but more than 5/6 of the patents litigated to judgment.¹³² Thus, it is plausible that U.S. patentees consider their patents more valuable, at least as litigation or licensing tools, and are more willing to spend time and money to improve their quality.¹³³ This may help explain our findings that U.S. patents cite far more prior art than their foreign counterparts, that they are more likely to be refiled, and that they spend longer in prosecution.

Second, patents are clearly more likely to be used offensively in some industries than in others. In particular, patent litigation is especially likely to occur in the biotechnology and pharmaceutical industries, the two industries that spent the most time

¹³¹ For empirical proof of this point, as well as a discussion of the intuition behind it, see Allison & Lemley, *Validity*, *supra* note __, at 231-34. For an argument that patentees are doing exactly this – citing lots of prior art in an effort to “bullet-proof” their patents – see Jay Kesan, *Getting It Right at the Outset: Granting Patent Rights Commensurate With Innovation* (working paper 2001).

¹³² *See id.* at 224-27.

¹³³ Logically, foreign patents should be somewhat more valuable on average than U.S. patents, for the simple Bayesian reason that foreign patentees have decided their patent is valuable enough to file abroad, while not all U.S. patentees will make the same decision. Again, however, this perceived value may be due to something other than litigation value.

in prosecution and which were the second and third highest citers of prior art.¹³⁴ By contrast, in the semiconductor and electronics industries litigation is uncommon, and patent owners frequently engage in royalty-free cross-licensing.¹³⁵ Patents in those two industries cited the least prior art in the 1990s, and they were among the quickest patents to issue. While litigation and licensing aren't the only measures of patent value – there are lots of other uses for patents¹³⁶ – they are certainly an indicator of how valuable the patentee considers the invention to be.

A related virtue of this theory is that it can help explain the change in heterogeneity over time. Patents issued in the 1970s arrived at a low point for the patent system. The Federal Circuit did not yet exist. Two-thirds of all patents litigated during that period were held invalid,¹³⁷ and relatively few patent lawsuits were filed.¹³⁸ By common consensus, patents simply weren't very important to business strategy during that period. By contrast, the patent boom of the 1980s and 1990s has led to dramatic changes in the patent system as a whole. But it has been particularly important for U.S. patentees, and for patents in certain industries.¹³⁹

¹³⁴ See *supra* note __ (collecting sources).

¹³⁵ See *supra* note __ (collecting sources).

¹³⁶ See, e.g., Lemley, *Reconceiving Patents*, *supra* note __.

¹³⁷ See, e.g., Karen G. Bender et al., *Patent Decisions of the United States Court of Appeals for the Federal Circuit: The Year 1985 in Review*, 35 **Am. U. L. Rev.** 995, 997 (1986); Donald R. Dunner, *The United States Court of Appeals for the Federal Circuit: Its First Three Years*, 13 **AIPLA Q.J.** 185, 186 (1985) (before the creation of the Federal Circuit in 1982, the regional courts of appeals found only about 35% of patents valid).

¹³⁸ See Moore, *Judges, Juries*, *supra* note __, at 384 Table 1 (showing the increase in patent litigation over time).

¹³⁹ One industry-specific explanation may be that pharmaceutical companies have concentrated their efforts in the U.S. because of the difficulty of enforcing pharmaceutical patents abroad.

If our patent value theory is correct, it implies that litigated patents will on average cite more prior art, have more claims, and spend longer in prosecution than ordinary patents. There is some indirect evidence to support this supposition;¹⁴⁰ we plan to test it more fully in a later study.

We do not believe that the increasing salience of patents to U.S. business offers a full explanation for our findings. Changes in technology and new search techniques doubtless played a role as well, and there are almost certainly other factors at work. But the patent value theory strikes us as the most plausible explanation for many of the dramatic changes we have seen over the last quarter-century.

B. Policy and Research Implications

The scholarly effort to explain what drives innovation has been a long and complex one.¹⁴¹ We hope the data in our study will be a useful contribution to this search. By focusing on changes in the U.S. patent system over time, and how the system differs from industry to industry, our study paves the way for sector-specific analyses of the patent system as a driver of innovation. Future research may focus on how particular industries differ in the various countries we have studied, how those industries changed over time, and how patents once issued are used in those industries.

¹⁴⁰ Lemley found in 1994 that patents litigated between 1989 and 1994, and which issued before that time, spent longer in prosecution than a random sample of patents issued in 1994. *See* Lemley, *20-Year*, *supra* note __, at 421-22. Since overall time in prosecution was increasing rather than decreasing during this period, the most plausible explanation is that litigated patents weren't a random cross-section of issued patents, but had spent longer in prosecution. But the 1994 study did not test that proposition statistically. In addition, Lanjouw and Schankerman found that the number of claims in a patent was positively correlated with the likelihood of litigation, which they interpret to be a measure of patent value. Lanjouw & Schankerman, *supra* note __, at __. And Harhoff et al. found that citations to prior art were positively correlated with patent value. *See* Dietmar Harhoff et al., *Citations, Family Size, Opposition and the Value of Patent Rights* (working paper 1999).

¹⁴¹ We discussed some of the voluminous literature in part I.

Whether or not we are able to explain why the U.S. patent system has changed so much over time, it is important for policy-makers to take these changes into account. In particular, we believe our findings have at least three implications for policy-makers:

⌚ If our patent value theory is correct, the patents that applicants consider most important are also the ones that get the most attention in the PTO. If so, this is a useful allocation of scarce PTO resources. It does not follow that courts should give more deference to patents in litigation; indeed, one of the authors has argued for less deference.¹⁴² But it does suggest that the patent system has a useful equilibrating tendency, passing less valuable patents through the system more quickly and cheaply and spending more time on the patents that are likely to matter most in the courts.¹⁴³

⌚ The changes we observe in patent prosecution today will affect litigation in the future. In our patent validity study, we found that it took an average of 8.6 years from the time a patent was issued until it was litigated to final judgment.¹⁴⁴ This means that the changes we have been describing have yet to make their full effect felt. Only over the next decade, as the patents in our 1996-98 sample make it to court, will we see how the increase in prior art citations and the changes in area of technology will change the face

¹⁴² See Lemley, *Rational Ignorance*, *supra* note __, at [draft at 33-35]. Lemley argues that even if the PTO pays a disproportionate amount of attention to patents that are more likely to end up in litigation, it cannot possibly duplicate the validity analysis that litigants and a court will ultimately perform. Thus, while our hypothesis may strengthen the case for the status quo, it does not necessarily justify the presumption of validity.

¹⁴³ Because a patent is not litigated or licensed doesn't mean it doesn't matter, of course. Indeed, there are many other valuable uses for patents. See *id.* at [draft at 9-13]; Mark A. Lemley, *Reconceiving Patents in the Age of Venture Capital*, 4 **J. Sm. & Emerging Bus. L.** 137 (2000).

¹⁴⁴ Allison & Lemley, *Empirical Evidence*, *supra* note __, at 236 Table 12.

of litigation. In general, the increasing complexity of technology, of patents and of the prosecution process may signal trouble ahead for the jury system in patent cases.¹⁴⁵

⌚ Finally, our findings here reconfirm our conclusions in the companion study that different industries experience the patent system very differently. Further, it is clear that this heterogeneity developed in the last 25 years. Heterogeneity has significant implications for patent system reform. One solution might be to try to restore homogeneity, perhaps by allocating more examiners to certain industries or conducting more uniform prior art searches. In the absence of such an effort, though, it may be unwise to set patent policy based on prosecution as a whole. Objections and proposals for reform that are tailored to the needs of one industry may not fit another well at all. Thus, those who would make generalizations about patent prosecution should take care to ensure that they do not merely project the experience of one type of client or industry onto the prosecution process as a whole. We are not prepared to go to the opposite extreme, and suggest that the patent system should be divided up and tailored to each industry.¹⁴⁶ We simply don't know enough about the costs and benefits of such an approach.¹⁴⁷ But it is surely true that the simple, homogeneous patent system that we have grown accustomed to is not the system that we will face in the future.

¹⁴⁵ Cf. Moore, *Forum Shopping*, *supra* note ___, at 932-34 (noting calls for a specialized patent trial court).

¹⁴⁶ To some extent this has already been done in the pharmaceutical industry, where special provisions permit the extension of patent term. See 35 U.S.C. §§ 155-156. There are periodic proposals to extend the term of particular patents. See Robert Patrick Merges & Glenn Harlan Reynolds, *The Proper Scope of the Copyright and Patent Power*, 37 **Harv. J. Legis.** 45 (2000) (discussing efforts to extend the term of particular patents). And it is relatively common for scholars to suggest tailoring the patent system to take account of the peculiarities of the software industry. See, e.g., Peter S. Menell, *Tailoring Legal Protection for Computer Software*, 39 **Stan. L. Rev.** 1329 (1987); Leo Raskind, *The Uncertain Case for Special Legislative Protection for Computer Software*, 47 **U. Pitt. L. Rev.** 1131 (1986); Pamela Samuelson et al., *A Manifesto Concerning the Legal Protection of Computer Programs*, 94 **Colum. L. Rev.** 2308 (1994); Richard Stern, *The Bundle of Rights Suited to New Technology*, 47 **U. Pitt. L. Rev.** 1229, 1262-67 (1986).

¹⁴⁷ Cf. Louis Kaplow, *The Patent-Antitrust Intersection: A Reappraisal*, 97 **Harv. L. Rev.** 1815 (1984) (cautioning against the automatic use of individually tailored patent terms).

One of the real problems with such industry-specific tailoring is that it gives rise to enormous opportunities for rent-seeking. Industries will seek special treatment for their inventions. Further, as our prosecution studies have demonstrated, patents do not fit cleanly into technology categories. Many patents fall into more than one category, *see* Allison & Lemley, *Who's Patenting What*, *supra* note __, at 2114 & n.45, and the categorization of patents into technology areas is far more art than science. Tailoring the patent system to fit different industries would require a reliable means for classifying patents into industry categories.