The Federal Circuit Enriched Patent Owners Without Eliciting Better Inventions

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Abstract

How do changes in patent law affect the exchange by which society awards an exclusive right of limited duration and the inventor discloses technology that others may freely use after the period of exclusivity? Between 1983-1985, the U.S. Court of Appeals for the Federal Circuit shifted the law in favor of patent owners, to degrees varying geographically by judicial circuit. We find that the Federal Circuit was associated with an increase in the commercial value of patents by 11.7 percent, but no significant increase in the technological quality of the patented inventions followed. Apparently, the value of the patent monopoly increased substantially without a commensurate increase in inventors' contributions of knowledge to society.

Keywords: Patents, law, commercial value, technological quality

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I. Introduction

Patents embody an exchange: society awards an exclusive right of limited duration, and the inventor discloses technology on which others build their own technologies during the exclusivity period, where others may freely market it after the period of exclusivity. "Judicial decisions characterize the enabling disclosure in the patent as the quid pro quo of the patent monopoly. In order to obtain a patent, the applicant must first contribute "a measure of worthwhile knowledge to the public storehouse," subject to the knowledge contributed in the patent being "worthwhile."[2] Yet, relatively little is known about the worth of the technology disclosed to society vis- à-vis the commercial value of the exclusive right.[3] An empirical challenge in studying this issue is that patent law is national, and therefore, research might be confounded by concurrent changes in national economic and scientific conditions.[4] Here, we identify an institutional development which changed patent law to different degrees within a country, which so enables a quasi-experimental study of the balance in the patent exchange.

In the United States, patent disputes are tried in federal district court. Until 1982, appeals were heard by the regional appeallate courts, which varied considerably in their interpretation of the same federal law. Then, Congress established the Court of Appeals for the Federal Circuit to unify patent appeals. While harmonizing the interpretation of the law, the Federal Circuit shifted important aspects markedly in favor of patent owners.[5] Notably, the degree of shift varied geographically by judicial circuit.[6] Based on historical patent decisions,[7] we construct an index to represent the pro-patentee shift in the law by circuit. On average, the Federal Circuit shifted rulings in favor of patent owners by 107%, ranging from a slight 2% decrease in Colorado (Tenth Circuit) to a 400% increase in Massachusetts (First Circuit).

We use the index to investigate the effect of the Federal Circuit on the patent

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[2] Rebecca S. Eisenberg, *Patents and the Progress of Science: Exclusive Rights and Experimental Use*, 56 U. CHI. L. REV. 1017, 1022 (1989).

[3] Michele Boldrin & David K. Levine, *The Case Against Patents*, 27 J. ECON. PERSPS. 3, 6 (2013).

[4] *See generally* Josh Lerner, *The Empirical Impact of Intellectual Property Rights on Innovation: Puzzles and Clues,* 99 AM. ECON. REV. 343 (2009); Deepak Somaya, *Patent Strategy and Management: An Integrative Review and Research Agenda*, 38 J. MGMT. 1084 (2012); Kenneth Guang-Lih Huang, Xuesong Geng, & Heli Wang, *Instiutional Regime Shift in Intellectual Property Rights and Innovation Strategies of Firms in China*, 28 ORG. SCI. 355 (2017).

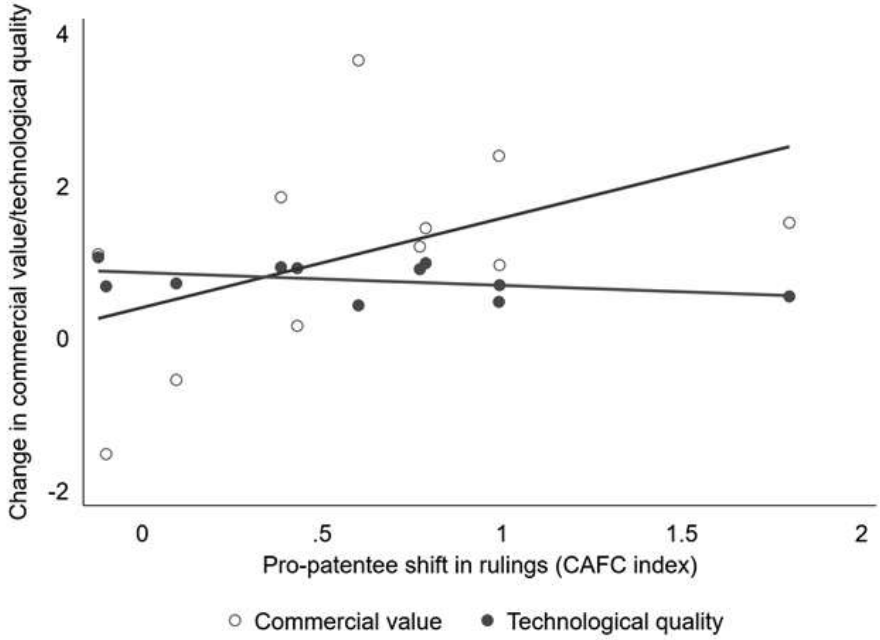
[5] Rochelle C. Dreyfuss, *The Federal Circuit: A Case Study in Specialized Courts*, 64 N.Y.U. L. REV. 1, 26 (1989). *See also* Cecil D. Quillen, Jr., *Proposal for the Simplification and Reform of the United States Patent System*, AM. INTELL. PROP. L. ASS'N Q. J. 189, 192 n.10 (1993) (discussing changes that have caused the "standards for patentability" to be lowered).

[6] Matthew D. Henry & John L. Turner, *The Court of Appeals for the Federal Circuit's Impact on Patent Litigation*, 35 J. L. STUD. 85, 86 (2017); Scott E. Atkinson et al., *The Economics of a Centralized Judiciary: Uniformity, Forum Shopping, and the Federal Circuit*, 53 J. L. & ECON. 411 (2013) ("We also find that the CAFC mitigates but does not eliminate nonuniformity across circuits.").

[7] *See generally* Matthew D. Henry et al., *Dynamics of Patent Precedent and Enforcement: An Introduction to the UGA Patent Litigation Datafile* (University of Ga., Working Paper, 2013) [hereinafter *UGA Patent Litigation Datafile*], https://ssrn.com/abstract=2228103.

exchange. Figure 1 graphs the average changes in the commercial value and technological quality of patents against the index. Shifts in the law favoring patent owners were associated with larger economic rents for patent owners but without any commensurate effect on the technological quality of the patented inventions.

Figure 1. Federal Circuit: Change in commercial value and technological quality of patents.



Note: Figure 1 presents a binned scatter plot of the relationship between the CAFC index (representing the pro-patentee shift in law due to the CAFC) and change in the average commercial value or technological quality of patents.

Consistent with the figure, multiple regression analyses suggest that the Federal Circuit was associated with the commercial value of patents rising by an average of 11.7% (confidence interval [-2.8, 48.4]), with a more pronounced effect in industries where patents were reportedly less effective in appropriability.[8] By contrast, the Federal Circuit was associated with the technological quality of the patented inventions (as measured by forward citations)[9] falling by 3.6% [confidence interval

[8] Wesley M. Cohen et al., *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)* 3–5 (Nat'l Bureau of Econ. Rsch., Working Paper No. 7552, 2000); Ashish Arora et al., *R&D and the Patent Premium*, 26 INT'L J. INDUS. ORG. 1153, 1173 (2008).

[9] Manuel Trajtenberg, *A Penny for your Quotes: Patent Citations and the Value of Innovations*, 21

[-15.0, 3.9]. Importantly, the point estimate of the change in technological quality is less than the lower confidence limit of the increase in the commercial value.

Our interpretation—that the increase in commercial value is due to the Federal Circuit shifting the law in favor of patent owners—is more robust than alternative explanations including concurrent increase in the technological quality of the patented inventions, changes in the law that increased the scope of patents, and changes in scientific discoveries. Our findings and explanations are also more robust than possible forum shopping in patent litigation.

The present work makes three contributions. Ours is the first (to our knowledge) empirical study of the effect of changes in the legal protection of patents on the patent exchange. We find that, to the degree that the Federal Circuit shifted the law in favor of patent owners (differently by judicial circuit), the commercial value of patents increased significantly, but the technological quality of the patented inventions did not. Apparently, the Federal Circuit tilted the patent exchange towards patent owners. The welfare calculation is even less favorable when considering the effects on pre-Federal Circuit patents as the Federal Circuit could not have affected their underlying inventions.

Second, we quantify the private, commercial value of marginal changes in the strength of exclusivity provided by patents. Prior research mostly estimated the value of patents from renewals[10] and changes in stock market prices.[11] Yet, the current policy debate is mostly not about whether to abolish patents but rather how to adjust the strength and scope of patent exclusivity.[12] It was well known that the Federal Circuit shifted the law in favor of patent owners.[13] Here, we quantify the impact of this strengthening of the exclusive rights on the private value of patents, which was previously an open question.

RAND J. ECON. 172, 172 (1990).

[10] Mark Schankerman & Ariel Pakes, *Valeur et Obsolescence des Brevets: Une Analyse des Statistiques de Renouvellement des Brevets Europeens [Patent Value and Obsolescence: An Analysis of European Patent Renewal Statistics]*, 36 REVUE ECONOMIQUE 917, 918 (1985); Mark Schankerman, *How Valuable is Patent Protection? Estimates by Technology Field*, 29 RAND J. ECON. 77, 78 (1998); Jean O. Lanjouw, *Patent Protection in the Shadow of Infringement: Simulation Estimations of Patent Value*, 65 REV. ECON. STUD. 671, 671–73 (1998).

[11] Leonid Kogan et al., *Technological Innovation, Resource Allocation, and Growth*, 132 Q. J. ECON. 665, 665–66 (2017).

[12] MICHAEL D. FRAKES & MELISSA F. WASSERMAN, DECREASING THE PATENT OFFICE'S INCENTIVES TO GRANT INVALID PATENTS 4, 7 (Brookings Institution 2017) (2017); Donald Zuhn, *Senators Tillis and Cotton Propose Sequenced Examination Approach*, PATENT DOCS (Mar. 29, 2021), https://www.patentdocs.org/2021/03/senators-tillis-and-cotton-propose-sequenced-examination-approach.html; The New York Times Editorial Board, *Opinion: Save America's Patent System*, N.Y. TIMES (April 16, 2022), https://www.nytimes.com/2022/04/16/opinion/patents-reform-drug-prices.html. *Contra* Boldrin & Levine, *supra* note 3, at 4, 14 (concluding that "the ultimate goal should be the abolition of patents").

[13] Dreyfuss, *supra* note 5, at 26–27; Quillen, Jr., *supra* note 5, at 195–97; Henry & Lerner, *supra* note 6, at 86–87; Atkinson et al., *supra* note 6, at 415–16 (2009).

Third, we contribute a more nuanced understanding of patent value. Previous research has shown that the commercial value of patents, as measured by the stock market, was positively correlated with the technological quality of the patented inventions, as measured by forward citations.[14] We exploit an exogenous shock in the interpretation of patent law to reveal that changing the legal protection of patents could affect the commercial value of patents and the technological quality of the patented inventions differently. In line with previous research showing disparities between commercial value and technological quality,[15] we suggest that the commercial value of patents be used to measure technological quality with caution.

Below, Section 2 reviews the legal background to the Federal Circuit. Section 3 presents the index, while Section 4 reports estimates of the commercial value and technological quality of patents. Section 5 concludes with a discussion of policy implications and directions for further research.

II. Patent Law

In the United States, patent law is a federal matter.[16] An inventor applies to the U.S. Patent and Trademark Office (USPTO), which reviews the application and then decides whether to grant the patent.[17] Once a patent is granted, disputes over the validity of the patent are adjudicated in federal district court, International Trade Commission, or the Patent Trial and Appeals Board.[18] Each state comprises one or more federal judicial districts with a U.S. District Court in each.[19] The districts are organized into twelve regional circuits, with one Court of Appeals in each regional circuit.[20]

Historically, appeals of both International Trade Commission and Board of Patent Appeals and Interferences (the predecessor to Patent Trial and Appeals Board) decisions were tried by the U.S. Court of Customs and Patent Appeals (CCPA), while appeals of patent decisions by district courts were tried by the respective regional circuit court.[21] Although supposedly administering the same federal law, the appeal

[14] Kogan et al., *supra* note 11, at 706.

[15] David S. Abrams et al., *Patent Value and Citations: Creative Destruction or Strategic Disruption?* 2 (University of Pennsylvania, Inst. for L. & Econ., Working Paper No. 19647, 2013); Maria Veihl, *Strategic Patenting: The Dark Side of Patents* (2022), https://www.mariaveihl.com/uploads/1/4/2/0/142056153/strategic_patenting_11012022.pdf.

[16] 28 U.S.C. § 1338.

[17] 35 U.S.C. § 2.

[18] 28 U.S.C. § 1338; *see generally* Colleen Chien, Christian Helmers, & Alfred Spigarelli, *Inter Partes Review and the Design of Post-Grant Patent Reviews*, 33 BERKELEY TECH. L.J. 817 (2018).

[19] 28 U.S.C. § 132.

[20] 28 U.S.C. § 41.

[21] Joseph R. Re, *Brief Overview of the Jurisdiction of the U.S. Court of Appeals for the Federal Circuit Under § 1295(a)(1)*, 11 FED. CIR. BAR J. 651, 653–54 (2001).

courts varied considerably in their interpretations and even conflicted.[22]

Then, in 1972, the U.S. Congress appointed the Hruska Commission to review the mounting caseload in the federal appeals courts.[23] The Commission recommended two major reforms: split the Fifth and Ninth Circuits to create two additional circuit courts and establish a new national court of appeals to resolve conflicts among the circuit courts.[24] The Commission also noted particular issues with appeals in tax and patent matters.[25]

Side-stepping the Hruska Commission's two major recommendations, Congress passed the Federal Courts Improvement Act (96 Statutes 25) to establish the Court of Appeals for the Federal Circuit in April 1982.[26] The Federal Circuit assumed jurisdiction over all appeals against the USPTO and district courts on patent matters as well as appeals against decisions of several other federal agencies.[27] On patent matters, the Federal Circuit adopted the decisions of the CCPA as binding precedent and thereby nullified precedents set by the circuit courts.[28]

While ostensibly harmonizing the interpretation of patent law, the Federal Circuit shifted important aspects markedly in favor of patent owners.[29] In a series of decisions between 1982 and 1985, the Federal Circuit (1) elevated nonstatutory factors to primary importance in determining nonobviousness, (2) narrowed the scope of prior art regarded as relevant to determining nonobviousness, particularly in relation to patents that combined old elements, and (3) strengthened the presumption of validity to require clear and convincing evidence of invalidity.[30]

Consequently, the probability that a district court would rule a patent as invalid fell by half, the probability that a patent owner would appeal against a judgment of invalidity rose by a quarter, and the probability that an appeals court would over-rule a judgment of invalidity rose by nearly three times.[31]

To the extent that a patent was more likely to be held valid, then courts would be more likely to find that the patent was infringed given the same facts and circumstances. However, the Federal Circuit did restrict the interpretation of the doctrine of equivalents and give attention to the "reverse doctrine of equivalents" so as to make findings of infringement less likely.[32]

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[22] Dreyfuss, *supra* note 5, at 6–7.
[23] Charles W. Adams, *The Court of Appeals for the Federal Circuit: More Than a National Patent Court*, 49 MISSOURI L. REV. 43, 48 (1984).
[24] *Id.*
[25] *Id.* at 50.
[26] Dreyfuss, *supra* note 5, at 3, 6.
[27] Re, *supra* note 21.
[28] *See generally* South Corp. v. U.S., 690 F.2d 1368 (Fed. Cir. 1982).
[29] Dreyfuss, *supra* note 5, at 26.
[30] Quillen, Jr., *supra* note 5, at 192–95 (1993).
[31] Henry & Lerner, *supra* note 6, at 90.
[32] Dreyfuss, *supra* note 5, at 28.

Our main objective is to compare the commercial value and technological quality of patented inventions exploiting differences by circuit in the shifting interpretation of patent law due to the Federal Circuit. A key methodological issue is whether the timing and direction of Federal Circuit rulings were not anticipated.

The legal background suggests that it would have been difficult to foresee the timing and direction of the Federal Circuit rulings. Congress did not enact the two main recommendations of the Hruska Commission, but some years later, it set up the Federal Circuit focusing on patents, trademarks, and administrative law. Still, we check whether the Federal Circuit was anticipated by studying the effect of the Federal Circuit on appeals. If the timing and direction of the Federal Circuit rulings had been anticipated, the Federal Circuit's assumption of jurisdiction should not have affected the rate of appeals. In the UGA Patent Litigation Datafile, a dataset of patent litigation in the U.S. from 1929 to 2006, the rate of appeals remained consistent between 1953 and 2006.[33]

More formally, we use the UGA Patent Litigation Datafile to estimate the following logistic model of whether a case was decided by an appeal court:

$$Appeal_{\,p} = \sum_{c=1}^{11} \sigma_c \times Circuit_{\,c} + \sum_{c=1}^{11} \tau_c \times \mathrm{p}ostCAFC_{ct} + \nu_C\, Claims_{\,p} + \nu_B\, BusinessPat_{\,p} + \nu_T\, Tech_{\,p} + \nu_O\, OwnerDef_{\,p} + \nu_H\, HomeCircuit_{\,p} + \nu_t + \varepsilon_{pct}.$$

— Equation 1 —

Among the explanatory variables, $Circuit_{\,c}$ indicates the circuit, and $\mathrm{p}ostCAFC_{ct}$ indicates if the case was decided after the Federal Circuit in circuit c. Additionally, we include the number of claims ($Claims_{\,p}$), an indicator of whether the patent was assigned ($BusinessPat_{\,p}$), and certain fixed effects for each patent's technological classification ($Tech_{\,p}$),[34] which control for the scope of the technology underlying the invention and the amount that the patent owner would invest in litigation. Litigation characteristics, including indicators of the patent owner being the defendant ($OwnerDef_{\,p}$) and the case being tried in the assignee's home circuit ($HomeCircuit_{\,p}$), account for differences in the burden of proof in litigation and the home court advantage. Completing the equation, ν_t are year fixed effects, which abstract the analysis from general trends in patent law and litigation, and ε_{pct} is random error. The ν_h with $h = C, B, T, O, H$ are coefficients to be estimated.

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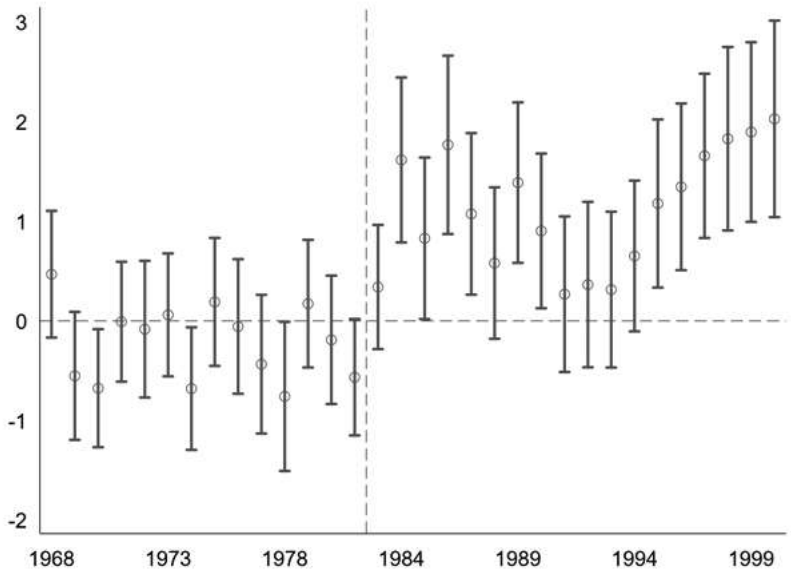
[33] *UGA Patent Litigation Datafile*, *supra* note 7, at 12 (explaining that the "likelihood that a patent case is appealed to a decision . . . is fairly steady across time").

[34] Bronwyn H. Hall et al., *The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools* 12–13. (Nat'l Bureau of Econ. Rsch., Working Paper No. 8498, 2001).

Figure 2. Federal Circuit and appeals.



Note: Figure 2 depicts coefficients of year indicators in logit regression of specification (1), with dependent variable being whether case was decided by appeal court.

The regression allows the rates of appeals to differ across circuits both before and after the Federal Circuit. Figure 2 depicts the coefficients of the year indicators, ν_t, which represent the average change in the rate of appeals across circuits with 1982 being the base year. Evidently, the Federal Circuit was associated with a substantial nationwide increase in the rate of appeals, which is not consistent with the timing and direction of the Federal Circuit rulings having been anticipated. By the early 1990s, the rate of appeals had settled down to the pre-Federal Circuit level and then began to climb again in the mid-1990s.[35]

[35] The reasons for the growth of appeals from the mid-1990s are beyond the scope of the present research. Some possible explanations are CAFC decisions on choice of venue in VE Holding Corp. v. Johnson Gas Appliance Co., 917 F.2d 1574, 1583 (Fed. Cir. 1990), the right of patent owners to limit resale of patented items in Mallinckrodt, Inc. v. Medipart, Inc., 976 F.2d 700 (Fed. Cir. 1992), and the "doctrine of equivalents," which regulates patent scope in Hilton Davis Chem. Co. v. Warner-Jenkinson Co., Inc., 62 F.3d 1512 (Fed. Cir. 1995).

III. Federal Circuit Index

To gauge the effect of the Federal Circuit on the commercial value and technological quality of patents, we first develop an index to represent the pro-patentee shift in the interpretation of patent law by circuit. A simple construct would compare court rulings in favor of patent owners before and after the Federal Circuit in each circuit court, but it might be confounded by differences in invention quality and litigation. To avoid such confounds, we apply multiple regression techniques when constructing the index.

Let the court ruling, Z_{pct}, on patent p in circuit c at time t depend on a continuous latent variable which represents the likelihood of a patent not being held invalid, Z^*_{pct}. Suppose that the latent variable depends on the interpretation of the law by circuit, characteristics of the patent, litigation of the patent, and time according to:

$$\begin{aligned} Z^*_{pct} = {} & \textstyle\sum_{c=1}^{11} \eta_c \times \mathit{Circuit}_{\,c} + \sum_{c=1}^{11} \lambda_c \times \mathrm{post}CAFC_{ct} \\ & + \mu_C \, \mathit{Claims}_{\,p} + \mu_B \, \mathit{BusinessPat}_{\,p} + \mu_T \, \mathit{Tech}_{\,p} \\ & + \mu_O \, \mathit{OwnerDef}_{\,p} + \mu_H \, \mathit{HomeCircuit}_{\,p} + \mu_A \, \mathit{Appeal}_{\,p} + \mu_t + \epsilon_{pct}. \end{aligned}$$

— Equation 2 —

The explanatory variables above are the same as in (1), with the addition of the indicator of the case being decided by an appellate court, $\mathit{Appeal}_{\,p}$, which account for differences in district and appellate courts. Like (1), the equation includes year fixed effects, μ_t, which abstract the analysis from general trends in patent law and litigation, and random error, ϵ_{pct}.

Ranging from the least to most favorable for the patent owner, the court could rule that the patent was invalid ($Z_{pct} = 0$), valid but not infringed ($Z_{pct} = 1$), or valid and infringed ($Z_{pct} = 2$). Formally:

$$Z_{pct} = \begin{cases} 0 & \text{if} Z^*_{\mathrm{pct}} \le \mathrm{k}_1 \\ 1 & \text{if} \mathrm{k}_1 < Z^*_{\mathrm{pct}} \le \mathrm{k}_2 \\ 2 & \text{if} Z^*_{\mathrm{pct}} \ge \mathrm{k}_2, \end{cases}$$

— Equation 3 —

where k_1 and k_2 are cutpoints between patent invalidity and non-infringement and between patent non-infringement and infringement, respectively. Assuming the distribution of the error term in (2), ϵ_{pct}, to be logistic, we estimate equation (2) as ordered logit model by maximum likelihood. The coefficients, η_c, λ_c, μ_h $(h = C, B, T, O, H, A)$, μ_t, and cutpoints, k_1 and k_2, are parameters to be estimated. Of

particular interest are η_c, which characterize the pre-Federal Circuit law, and λ_c, which characterize the pro-patentee shift in the law due to Federal Circuit by circuit. Cross-sectional variations in λ_c and longitudinal variations in the timing of the establishment of Federal Circuit would jointly isolate the change in patent value due to the pro-patentee shift in patent law from other factors.

The estimator cannot identify all of the coefficients, η_c and λ_c. So, following a validity model from a previous study,[36] we designate the Third Circuit,which, prior to the Federal Circuit, was least the favorable to patent owners, as the reference group, and we stipulate that $\eta_3 = 0$. Accordingly, the coefficients are estimated relative to the pre-Federal Circuit interpretation of the law in the Third Circuit.

To estimate (2), we use the UGA Patent Litigation dataset of patent decisions, which was constructed by matching patent documents with decisions of district and appeals courts published in the U.S. Patents Quarterly (USPQ). The dataset is fairly comprehensive as "virtually every appellate court decision is recorded in the USPQ, as well as a large sample of district court decisions."[37]

We limit the estimation sample to the period, 1968–2000 (please refer to the Appendix, Section A1, for details). While this period might seem quite long, it is consistent with the durability of judicial precedents. For instance, in adopting the decisions of the CCPA as binding precedent,[38] the Federal Circuit cited CCPA decisions in 1930, 1947, 1951 and 1960.[39] The estimation sample comprises 2,559 patent cases regarding 2,455 patents.

By late 1985, it had become widely known that the Federal Circuit had shifted patent law in favor of patent owners.[40] Accordingly, we divide the period of study into the pre-Federal Circuit period (1968–1982), a transitional period during which the Federal Circuit issued key precedents shifting the law in favor of patent owners (1983–1985), and the post-Federal Circuit period (1986–2000). Referring to Table 1, Panel A, the creation of the Federal Circuit changed the rates at which patents were held (1) invalid, (2) valid but not infringed, or (3) valid and infringed from 58%, 11%, and 31% to 24%, 34%, and 42% respectively.

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[36] Atkinson et al., *supra* note 6, at 432.

[37] Henry & Lerner, *supra* note 6, at 7.

[38] South Corp. v. United States, 690 F.2d 1368, 1369 (Fed. Cir. 1982) ("We hold that the holdings of our predecessor courts, the United States Court of Claims and the United States Court of Customs and Patent Appeals, . . . shall be binding as precedent in this court.").

[39] *Id.* at 1374 (first citing Beaver Products Co. v. United States, 17 C.C.P.A. 434 (1930); then citing United States v. Western Operating Corp., 35 C.C.P.A. 71 (1947); then citing United States v. American Whaling Co., 38 C.C.P.A. 164 (1951); and then citing John B. Hewett Co. v. United States, 48 C.C.P.A. 24 (1960)).

[40] *See, e.g.*, Daniel Moskowitz, *Patent Owners Gaining Clout*, WASH. POST, July 15, 1985, at 7; Eric Schmitt, *Business and the Law: Judicial Shift in Patent Cases*, N.Y. TIMES, January 21, 1986, at D2.

– Table 1. Summary Statistics –

VARIABLE	Unit	1982 and earlier		1986 and later	
		N	Mean	N	Mean
Panel A: Patent litigation					
Invalid		1299	0.58	1260	0.24
Valid but not infringed		1299	0.11	1260	0.34
Valid and infringed		1299	0.31	1260	0.42
Appeal		1299	0.63	1260	0.75
Home circuit		1299	0.45	1260	0.47
Panel B: Patents					
Stock market value	$ million	91498	5.06	94903	8.47
Forward citations (excluding self-citations)		91498	0.19	94903	0.69
Citations to scientific publications		91498	10.78	94903	13.90
Minimum of word count in independent claims		91470	2.30	94900	2.56
Claims		91498	0.19	94903	0.69
Backward citations		91498	1.14	94903	5.76
Panel C: Companies					
Employment		5089	16679	5164	12553
PPE per employee	$ million	5089	0.04	5164	0.06
Revenue per employee	$ million	5089	0.16	5164	0.19
R&D expenditure per employee	$ million	5089	0.00	5164	0.01
Tobin's Q		5089	1.03	5164	1.64

Notes: Panel A presents summary statistics for patent cases from 1976 to 2000 in the UGA Patent Litigation datafile, used to estimate (1). Panel B presents the summary statistics of patents granted to publicly listed companies from 1976 to 1992 in the sample used to estimate (3). Panel C presents the summary statistics of all parent companies that ever patented from 1976 to 1992.

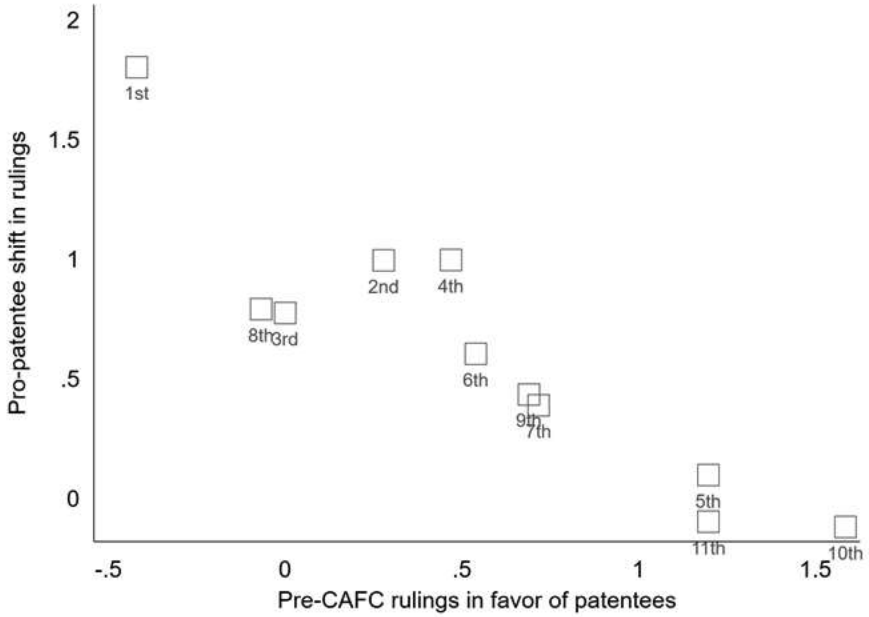
While intuitive, these patterns might be confounded by substantive differences in the patents and litigation. To avoid such confounds, we turn to regression estimates of (2). Referring to Appendix Table A1, several substantive characteristics of patents and litigation are significant or marginally significant, validating the regression approach. In Table A1, Column (a), the estimated η_c represents the pre-Federal Circuit interpretation of the law. The wide dispersion of the estimates is consistent with substantial variation in pre-Federal Circuit rulings across the circuits.[41] Table A1, Column (b), presents the estimates of λ_c, i.e., the Federal Circuit index, which

[41] *See* Henry & Lerner, *supra* note 6, at 86–87, 102; Atkinson et al., *supra* note 6, at 421.

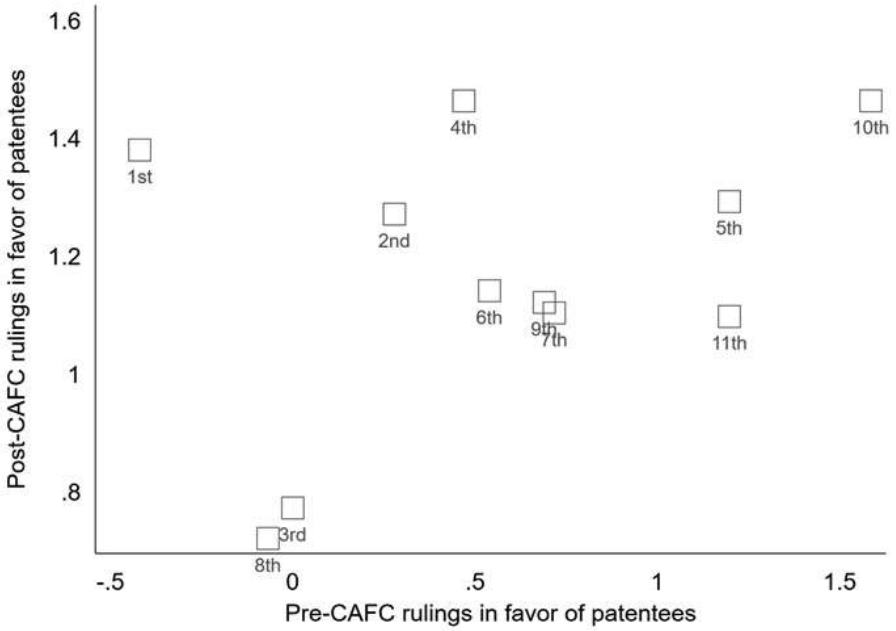
represents changes in the rulings in favor of patent owners.

Figure 3. Federal Circuit: Court Rulings.

A. Changes in Rulings



B. Before and After the CAFC



Notes: Panel A depicts a change in rulings in favor of patent owners due to the CAFC (the CAFC index), λ_c, and Panel B depicts post-CAFC rulings, $\eta_c + \lambda_c$. Each point represents one federal judicial circuit.

To visualize, Figure 3, Panel A, graphs the changes, λ_c, against the pre-Federal Circuit law, η_c. Evidently, as Congress intended, the Federal Circuit harmonized the interpretation of the law (at least partially). Circuits whose district courts were more strongly anti-patentee in the pre-Federal Circuit period experienced a larger pro-patentee shift in their rulings, by contrast with circuits whose district courts were less anti-patentee and experienced a comparatively smaller pro-patentee shift. On average, the Federal Circuit shifted rulings nationwide in favor of patentees by 107%.

Importantly, the change in the interpretation of the law varied substantially across the circuits. For example, compare the effect of the Federal Circuit on First Circuit district courts versus Tenth Circuit district courts. In the First Circuit, courts shifted markedly in favor of patentees from -0.420 to 1.379. In the Tenth Circuit, pre-Federal Circuit courts were already very pro-patentee, and the legal protection of patents actually decreased slightly from 1.585 to 1.463. After the Federal Circuit assumed jurisdiction over patent appeals, the likelihood of a patent being held to be valid and infringed rose by 32.8% in Massachusetts but declined slightly by 2.35% in Colorado (with Appendix Section A2 explaining the calculations of these effects).

Figure 3, Panel B, depicts the state of the law pre- and post-Federal Circuit. Evidently, the Federal Circuit did not completely harmonize the law across the Circuits; the First, Fourth, and Tenth Circuits favored patentees relatively more than the Third and Eighth Circuits. Formally, a likelihood ratio test rejects the hypothesis that post-Federal Circuit ruling were homogenous across all circuits: $\eta_c + \lambda_c = constant$ ($\Pr(\chi^2(10) > 18.39) = 0.05$). Hence, we conclude that, even in the Federal Circuit era, rulings still varied across circuits.[42]

IV. Patent Exchange Balance

We aim to examine the effect of the Federal Circuit on the commercial value and technological quality of patented inventions and, particularly, to investigate whether patent owners disclosed technology commensurate with an increase in the value of the exclusive rights. We exploit differences in the shift of the law across circuits before and after the creation of the Federal Circuit, identified in equation (2) as λ_c.

To estimate the effect of the Federal Circuit, consider the following equation for patent p, in technological class k and granted to businesses operated by company i in industry j in circuit c at time t:

$$\xi_{pkijct} = \beta \cdot CAFC_c \times Post_t + \beta_X \cdot X_{it} + \beta_Z \cdot Z_p + \nu_c + \omega_{kit} + \varepsilon_{pkict}. \quad (1)$$

The outcome, ξ_{pkict}, is the commercial value or technological quality of the patented invention, while $CAFC_c$ is the Federal Circuit index, λ_c represents the pro-patentee shift in the law in circuit c due to the Federal Circuit, and $Post_t$ indicates post-Federal Circuit patents. Among the control variables, X_{it} are time-varying parent-company factors and Z_p are patent characteristics that might affect patent value, and ν_c and ω_{kit} are respectively fixed effects for circuit and technological class industry year (for brevity, technology-industry-year). The circuit fixed effects abstract the estimate from non-time-varying differences across circuits in the institutional innovation environment. Further, the technology-industry-year fixed effects account for the differing importance of technology classes to various industries over time and also abstract the analysis from shifts in overall stock prices and other general industry-level changes over time.[43]

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[42] Atkinson et al., *supra* note 6, at 435.

[43] We do not control for company fixed effects as the commercial value of patents is constructed from a regression of stock market prices including company-year fixed effects. Kogan et al., *supra* note 11,

In equation (1), the coefficient, β, is a difference-in-difference estimator comparing patents granted before and after the creation of the Federal Circuit in circuits where the Federal Circuit shifted the law to different degrees. Essentially, β is identified by comparing fairly similar patents (within the same technological class that were granted to businesses within the same industry in the same year) across circuits before and after the creation of the Federal Circuit.

In setting up the empirical analysis, the key issue is determining which Federal Circuit index applies to each patent. We relate each patent to the Federal Circuit index of the circuit in which the assignee was located. Until September 2012, the ownership of USPTO patents vested in the named inventor(s), and employers could own a patent only through assignment by the inventor(s).[44] We deem the patent to be located in the circuit of the assignee and match to the Federal Circuit index accordingly. Essentially, this "home circuit assumption" posits that patent owners would be guided by their home circuit's interpretation of patent law. One justification is that patent owners would more likely litigate in their home circuit, as litigation costs would be lower and they might benefit from home-court advantage.[45] In fact, almost half of the cases in the UGA Patent Litigation dataset were litigated in the home circuit.[46]

Still, it is important to consider whether litigation outside the home circuit might bias the estimate of β. Until October 1990, when the Federal Circuit first applied the general venue residency requirement to patent suits, patent-specific venue rules were more limited relative to general venue rules.[47] Generally, if patent owners sought a more favorable circuit without constraint in choice of venue, all would have chosen the most favorable circuit, regardless of their home circuit. This would be true both pre- and post-Federal Circuit. Hence, among these (unconstrained) forum shoppers, the pro-patentee shift in the law due to the Federal Circuit would be absorbed by yearly, fixed effects.

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at 683–84. Controlling for company fixed effects reduces the within R-squared of the regression to almost zero.

[44] Alan C. Marco et al., *The USPTO Patent Assignment Dataset: Descriptions and Analysis* 7 (USPTO Econ. Working Paper, Paper No. 2015-2, 2015).

[45] Atkinson et al., *supra* note 6, at 412–13, 420.

[46] *See generally UGA Patent Litigation Datafile*, *supra* note 7.

[47] Colleen V. Chien & Michael Risch, *Recalibrating Patent Venue*, 77 MD. L. REV. 47, 54–58 (2017).

As for constrained forum shoppers, they would choose the most favorable circuit permitted by the law, if it is not the home circuit. Their pre-Federal Circuit legal protection of patents would be higher than it would be in their home circuit, and with harmonization, their post-Federal Circuit legal protection would be closer to the protection in their home circuit. Hence, our home circuit assumption would overestimate the change in the legal protection and thus underestimate the effect of the change on the commercial value and technological quality of patents. In checking for robustness, we present evidence of whether and how forum shopping might affect the results.

An econometric issue in estimating standard errors is "generated regressor bias." The Federal Circuit index is estimated by the regression of equation (2). If the patent estimate does not account for sampling error in the Federal Circuit estimate, the standard errors may be biased downward.[48] Further, the standard errors for patents located in the same circuit or belonging to the same parent company may be serially correlated. A solution to this issue is to cluster the standard errors two-way by circuit and company. To address this generated regressor bias, we employ a two-step bootstrapping algorithm, repeated 1,000 times, to compute the standard errors. Moreover, because there are only eleven geographical circuits, we use clustered bootstrapping in the second step to account for the small number of clusters.[49]

We assemble a sample of patents and their various characteristics that potentially affect the commercial value of each patent, including backward citations and patent scope,[50] from the NBER Patent Dataset[51] of USPTO patents granted to publicly-listed companies in the years 1976–82 and 1986–92. The NBER Patent Dataset began its coverage in 1976. To balance the before/after time periods around the Federal Circuit transition, we end the study in 1992.

To represent the commercial value of patents, we use the natural logarithm of the change in the stock market value of the company around the date of the patent grant, deflated by the U.S. urban consumer price index[52] and winsorized at the 1st and 99th percentiles. To account for technological quality, we use the number of forward citations by other companies (i.e., excluding self-citations). Forward

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[48] *See* Adrian Pagan, *Econometric Issues in the Analysis of Regressions with Generated Regressors*, 25(1) INT'L ECON. REV. 221, 233 (1984).

[49] Specifically, we first draw a random sample with replacement from the UGA Patent Litigation Datafile sample, stratified by circuit before and after the establishment of the CAFC to ensure the estimation of circuit-fixed effects and estimate the CAFC index. In the second stage, we estimate the patent regression on a random sample drawn with replacement from the patent sample with clusters, specified as parent company and circuit, to account for serial correlation, and then we store the estimates. We repeat this process of two-step bootstrap sampling 1,000 times and then calculate the bootstrap standard errors as the standard deviations of the 1,000 point estimates of the second stage regression coefficient.

[50] Jean O. Lanjouw et al., *Protecting Intellectual Property Rights: Are Small Firms Handicapped?*, 47 J. L. & ECON. 45, 52 (2004).

[51] Hall et al., *supra* note 34.

[52] Kogan et al., *supra* note 11, at 704.

citations represent the knowledge embodied in the patent as well as contributions to a field of inventive activity.[53] Alternatively, we use citations to scientific publications[54] and the minimum of the word counts across all independent claims.[55]

Table 1, Panel B, summarizes the patent dataset. The average stock market value of a patent increased from $5.06 million to $8.47 million (at 1982 prices). Concurrently, the technological quality of the patented inventions, as measured by forward citations, increased from 0.19 to 0.69. As measured by citations to scientific papers, the technological quality increased from 10.78 to 13.90. Finally, when measured by the minimum word count across all independent claims, the technological quality increased from 2.30 to 2.56. However, these comparisons should be interpreted with caution as they might be confounded by technological trends and company-level changes in financial and operationial strategy.

[53] Hall et al., *supra* note 34, at 21.

[54] *See, e.g.*, Matt Marx & Aaron Fuegi, *Reliance on Science: Worldwide Front-Page Patent Citations to Scientific Articles*, 41 STRATEGIC MGMT. J. 1572 (2020).

[55] Alan C. Marco et al., *Patent Claims and Patent Scope*, 48 RSCH. POL'Y 1, 9 (2019).

Table 2. Federal Circuit and patents: Commercial value and technological quality.

	Commercial value			Technological quality		
VARIABLES	(a) All	(b) Effectiveness: Product	(c) Effectiveness: Process	(d) Forward citations	(e) Citations to science	(f) Independent claims
CAFC x Post	0.183*	0.038	0.046	-0.062	-0.251	0.064**
	(0.108)	(0.110)	(0.121)	(0.051)	(0.271)	(0.025)
CAFC x Low effectiveness (product)		-0.561*				
		(0.314)				
CAFC x Post x Low effectiveness (product)		0.472**				
		(0.237)				
CAFC x Low effectiveness (process)			-0.409			
			(0.272)			
CAFC x Post x Low effectiveness (process)			0.366*			
			(0.215)			
Technology-Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Circuit FE	Yes	Yes	Yes	Yes	Yes	Yes
Patents	178,269	123,427	54,842	178,227	105,104	88,695
Companies	2001	1328	673	2001	1386	2201
Adjusted R-squared	0.676	0.643	0.750	N.A.	N.A.	N.A.
Chi-Squared	N.A.	N.A.	N.A.	2820	N.A.	1490
Economic effect (%)	11.7			-3.6	-22.2	3.9
95% CI	[-2.8, 48.4]			[-15.0, 3.9]	[-54.2, 32.3]	[1.5, 11.9]
Low effectiveness economic effect (%)		66.4	51.1			
95% CI		[9.5, 153.1]	[4.8, 117.9]			

Notes: Unit of analysis: patent. All estimates control for employment (ln), revenue per employee (asinh), PPE per employee (asinh), R&D per employee, Tobin's Q, total number of backward citations, total number of claims, technology-year-industry fixed effects, and circuit fixed effects. Columns (a)-(c): estimated by ordinary least squares (Stata routine, reghdfe). Dependent variable: changes in stock market value of a company on the date of patent grant. Column (a): the effect of the CAFC on all industries. Column (b): comparing the effect of the CAFC on industries with patents being more or less effective in appropriating returns from product innovation. Column (c): comparing the effect of the CAFC on industries with patents being more or less effective in appropriating returns from process innovation.

Columns (d)-(f): estimated by Poisson quasi-maximum likelihood (Stata routine, ppmlhdfe). Column (d): dependent variable representing forward citations of the patent by others. Column (e): dependent variable representing the number of backward citations to scientific papers. Column (f): dependent variable representing the minimum of the word counts across all independent claims. CAFC economic effect is calculated as $exp(coefficient\ of\ CAFC\ index \times change\ in\ CAFC\ index) - 1$. Two-sample bootstrapped standard errors corrected for generated regressor bias, clustered two ways by both parent company and circuit at the second stage, in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

To control for the financial and operational strategy of the business that is correlated with a patent's value, we extract the relevant data of the parent company from Compustat: industry (4-digit SIC), number of employees, sales revenue, net expenditure on property, plant, and equipment (PPE), and research and development (R&D). We drop 0.27% of the observations with negative sales revenue or PPE. We then deflate R&D expenditure by the U.S. deflator for gross private domestic investment and other financial indicators by the U.S. GDP deflator, and we merge these values to patents by grant year. It is not feasible to match by the year of patent application, as prior to the American Inventors Protection Act of 1999, patent applications could be kept secret.[56] Table 1, Panel C, presents the parent company data.

To examine the effects of the Federal Circuit on the commercial value of patents more rigorously, particularly accounting for technological trends and company-level changes in finance and operations, we turn to the regression estimates of equation (1) . Referring to Table 2, column (a), for all industries, the coefficient of Federal Circuit, $0.183 (s.e. 0.108, p = 0.09)$, is positive and marginally significant, suggesting that the Federal Circuit was associated with an increase in the commercial value of patents. To appreciate the managerial and economic significance of the estimate, consider the implied effect in proportionate terms. The average Federal Circuit index is 0.603, representing the increase in the legal protection of patents from 0.562 to 1.17. Hence, the estimated coefficient of Federal Circuit implies that the Federal Circuit was associated with the commercial value of a patent rising by $0.183 \times 0.603 = 0.11$ log points, or 11.7%, with a 95% confidence interval, [-2.8, 48.4].

Regionally, the Federal Circuit index increased the legal protection of patents by 1.799 in the First Circuit and reduced it by 0.1 in the Tenth Circuit. These estimates imply that the Federal Circuit was associated with the commercial value of a patent in Massachusetts (First Circuit) rising by 39%, while declining by a marginal 1.8% in Colorado (Tenth Circuit).

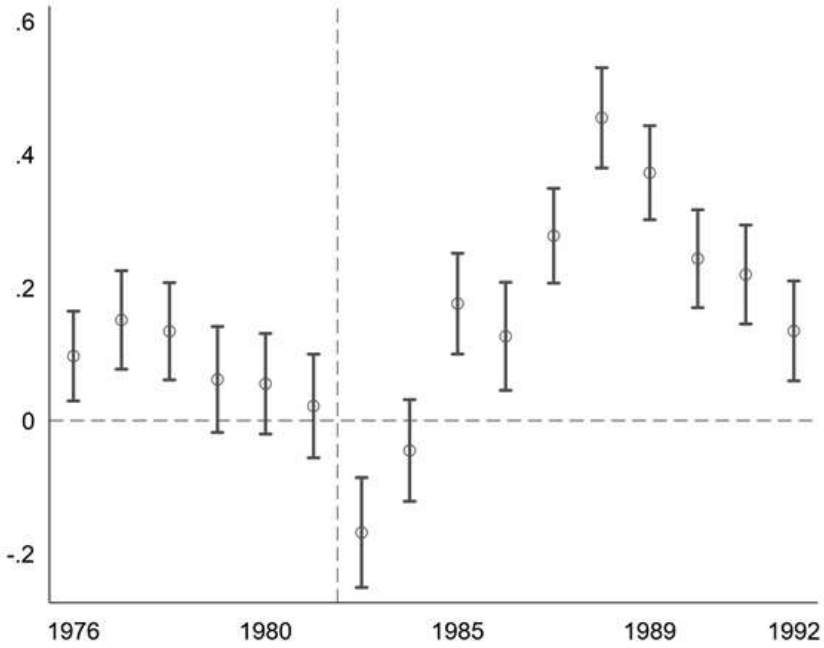
[56] Stuart Graham & Deepak Hegde, *Do Inventors Value Secrecy in Patenting? Evidence From the American Inventor's Protection Act of 1999* 2 (Dec. 2, 2014) (unpublished manuscript), https://ssrn.com/abstract=2170555.

The effectiveness of patents as an appropriability mechanism differs by industry. It is interesting to investigate how the effect of the Federal Circuit varied with the effectiveness of patents in appropriability. We divide industries into below- or above-median effectiveness of their patents in the appropriability of product and process innovations,[57] and we investigate the interactions between the Federal Circuit index and an indicator for industries with below-median patent effectiveness. Referring to Table 2, columns (b) and (c), on average, the Federal Circuit was associated with the commercial value of patents increasing by 66.4% and 51.1% respectively in industries where patents were less effective in protecting product and process innovations. Evidently, the effect of the Federal Circuit was concentrated in industries where patents were relatively less effective in appropriating any returns to innovation.

Our empirical strategy is predicated on the timing and direction of rulings of the Federal Circuit not being anticipated. The discussion above, and particularly Figure 2 showing an increase in the rate of appeal, justifies this premise. To validate this further, we carry out an event study in which the Federal Circuit rulings are hypothetically stipulated to have been handed down in each of the years 1976–1992. We then estimate (1) with patent law being represented by a series of interactions between the Federal Circuit index by circuit in each of the years, omitting 1982 (the year in which Federal Circuit was established) as the reference year.

[57] *Cf.* Cohen et al., *supra* note 8 (using a similar methodology to compare data).

– Figure 4. Federal Circuit and commercial value of patents: Event study –



Notes: Figure 4 plots the interaction of the CAFC index by circuit with each of the years 1976–1992, excluding 1982, when CAFC was established, as a reference, in an estimate of (3) in which the dependent variable is the natural logarithm of the change in stock market value of the company around the date of the patent grant deflated by the U.S. urban consumer price index,[58] winsorized at the 1st and 99th percentiles, and the shift in pro-patentee rulings due to the CAFC is hypothetically stipulated to take place in that year only.

Figure 4 presents the event study of the commercial value of patents. The estimated coefficient is slightly positive in the years before the Federal Circuit, negative during the transitional period 1983–1985, and then positive. The evolution of the coefficients over time validates our identification assumption. During the transitional period, as the Federal Circuit decided the key precedents, there would have been substantial uncertainty, which might explain the negative coefficients. Apparently, the effect of the Federal Circuit on the commercial value of patents peaked in 1988 and remained positive thereafter.

[58] Kogan et al., *supra* note 11.

Next, we examine the effect of the Federal Circuit on the technological quality of the patented inventions, using equation (1). Referring to Table 2, column (d), with technological quality represented by forward citations, the coefficient of CAFC, -0.062 $(s.e.0.051)$, is negative but statistically insignificant. The estimate implies a proportionate effect of -3.6%. Notably, the estimated effect is smaller than the lower confidence limit of the estimated effect on the commercial value of patents. This difference suggests that the Federal Circuit was associated with an increase in the commercial value that was significantly larger than the increase in the technological quality of the underlying inventions.

Given the limitations of citations as a measure of technological quality,[59] we consider two other measures. Table 2, column (e), reports an estimate of backward citations to scientific publications in the main body of the patent (citations in the main body tend to be drafted by inventors rather than lawyers).[60] Inventions that draw from science advance the state of the art relatively more and would be more valuable to society.[61] The coefficient of CAFC, $-0.251(s.e.0.271)$, is negative but statistically insignificant. The implied economic effect, -22.2%, is an order of magnitude larger than that implied by forward citations.

Table 2, column (f), reports an estimate representing the technological quality of a patent by the minimum of the word counts of the independent claims. The coefficient of CAFC, 0.064 $(s.e.$ $0.025)$, is positive and significant. The positive coefficient suggests that the Federal Circuit elicited less innovative patents in the sense that their claims required more delineation. This estimate is helpful in validating the finding that the Federal Circuit was associated with patented inventions generally being of significantly lower quality.

A. Robustness

Our empirical approach relies on the home circuit assumption. Above, we explained why it is reasonable to relate the commercial value of patents to the Federal Circuit index of the home circuit. However, readers might be concerned that patent owners could litigate outside their home circuit. Here, we report two robustness tests that account for this phenomenon, also known as forum shopping.

First, we construct a Federal Circuit index that is weighted to account for forum shopping using patent litigation data. In this index, we first calculate, for any circuit, the likelihood of patents being litigated in other circuits. Then, we weight the circuit-

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[59] *See generally* Juan Alcacer & Michelle Gittelman, *Patent Citations as a Measure of Knowledge Flows: The Influence of Examiner Citations*, 88 REV. ECONS. & STATS. 774 (2006); Ryan Lampe, *Strategic Citation*, 94 REV. ECONS. & STATS. 320 (2012); Jeffrey Kuhn et al., *Strategic Citation: A Reassessment*, 105 REV. ECONS. & STATS. 458 (2023).

[60] *See generally* Marx & Fuegi, *supra* note 54.

[61] Madeline K. Kneeland et al., *Exploring Uncharted Territory: Knowledge Search Processes in the Origination of Outlier Innovation*, 31 ORG. SCI. 535, 535 (2020).

fixed effects by the likelihood of patents being litigated in the other circuit before and after the establishment of the Federal Circuit reported in Table A1, columns (a) and (b), for each circuit. We sum up these weighted indexes and calculate the change as our weighted Federal Circuit index. Referring to Table 3, column (b), the coefficient of the weighted index, 0.237, is larger than the coefficient in the preferred estimate. This finding is consistent with our argument in the main text that failing to account for forum shopping would bias our estimates downward.

– Table 3. Federal Circuit and commercial value: Robustness tests –

VARIABLES	(a) Preferred estimate	(b) Weighted index	(c) Forum shoppers
CAFC index	0.183*	0.237*	
	(0.108)	(0.136)	
CAFC index (home circuit)			0.216*
			(0.112)
CAFC index (forum shoppers)			0.145
			(0.134)
Technology-Industry-Year FE	Yes	Yes	Yes
Circuit FE	Yes	Yes	Yes
Patents	178,269	178,269	178,269
R-squared	0.676	0.677	0.676

Notes: Unit of analysis: patent. Estimated by OLS (Stata routine, reghdfe). Dependent variable: changes in stock market value of a company on the date of patent grant. All estimates control for employment (ln), revenue per employee (asinh), PPE per employee (asinh), R&D per employee, Tobin's Q, total number of backward citations, total number of claims, technology-year-industry fixed effects, and circuit fixed effects. Column (a) replicates Table 2, column (a). Column (b) replaces the CAFC index with a weighted CAFC index that accommodates the likelihood of litigating at circuits other than the home circuit. Column (c) replaces the CAFC index with the CAFC index for businesses satisfying the home circuit assumption and the CAFC index for forum shoppers, both constructed from patent citations. Two-sample bootstrapped standard errors corrected for generated regressor bias, clustered two ways by parent company and circuit at the second stage, in parentheses (*** $p<0.01$, ** $p<0.05$, * $p<0.1$).

Next, we construct a Federal Circuit index that is weighted to account for forum shopping using patent citations. We stipulate the likelihood of forum shopping to be the percentage of forward citations received in circuits other than the home circuit, and we stipulate the likelihood of complying with the home circuit assumption to be

the percentage of forward citations made by other companies in the same circuit (or one hundred percent if there were no forward citations received). We then construct the CAFC for forum shoppers as the interaction between the Federal Circuit index and the likelihood of forum shopping, and we construct the CAFC for the home circuit as the interaction between the Federal Circuit index and the likelihood of satisfying the home circuit assumption. Referring to Table 3, column (c), the home circuit coefficient for companies satisfying the home circuit assumption is positive, marginally significant, and larger than our preferred estimate. Interestingly, even among forum shoppers, the coefficient of CAFC is positive but not significant.

B. Alternative Explanations

We find that the Federal Circuit was associated with an increase in the commercial value of patents, which we attribute to the Federal Circuit shifting the interpretation of patent law in favor of patent owners. However, the empirical relation might be explained in other ways, the most obvious being that the patented inventions increased in technological quality. This seems unlikely given that the Federal Circuit did not affect, or perhaps actually diminished, the technological quality of patented inventions.[62]Moreover, the estimates of commercial value controlled for R&D intensity, which would at least partially absorb improvements in the underlying technology.

Still, to check further, we explicitly consider alternative explanations of this empirical relation. First, we consider whether the relation was due to patented inventions increasing in technological quality. Table 4, columns (b)-(d), report estimates controlling for alternative measures of the technological quality of the patented inventions—forward citations, citations to science, and the length of independent claims. In all of these estimates, the coefficient of CAFC is almost identical to that in the estimate without controlling for technological quality, which suggests that the increase in the commercial value of patents was not due to the patented inventions being of higher technological quality.

[62] *See infra* tbl.2, cols. d–f.

Table 4. Federal Circuit and commercial value: Alternative explanations

VARIABLES	(a) Preferred estimate	(b) Forward citations	(c) Science citations	(d) Patent scope	(e) Scientific progress	(f) R&D
CAFC index	0.183*	0.184*	0.183*	0.184*	0.292*	0.191*
	(0.108)	(0.109)	(0.108)	(0.108)	(0.176)	(0.113)
Forward citations		0.001**				
		(0.000)				
Citations to scientific publications			-0.004			
			(0.004)			
Minimum word count of independent claims				-0.000		
				(0.000)		
PhD per million population					-0.003	
					(0.004)	
R&D per capita						-0.000
						(0.000)
Technology-Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Circuit FE	Yes	Yes	Yes	Yes	Yes	Yes
Patents	178,269	178,269	178,269	178,269	178,269	178,269
Companies	2001	2001	2001	2001	2001	2001
Adjusted R-Squared	0.676	0.676	0.676	0.676	0.676	0.676

Notes: Unit of analysis: patent. Estimated by OLS (Stata routine, reghdfe). Dependent variable: changes in stock market value of a company on the date of patent grant. All estimates control for employment (ln), revenue per employee (asinh), PPE per employee (asinh), R&D per employee, Tobin's Q, total number of backward citations, total number of claims, technology-year-industry fixed effects, and circuit fixed effects. Column (a) replicates Table 2, column (a). Column (b) controls for the total number of forward citations in patents assigned to other companies. Column (c) controls for (backward) citations to scientific journals. Column (d) controls for the minimum of the word count across the independent claims. Column (e) controls for the number of PhD recipients per million people in the circuit. Column (f) controls for R&D expenditure per capita in the circuit. Two-sample bootstrapped standard errors corrected for generated regressor bias, clustered two ways by both parent company and circuit at the second stage, in parentheses (*** $p<0.01$, ** $p<0.05$, * $p<0.1$).

Another possible explanation for this empirical relation is other changes in the law that varied by judicial circuit, with the main change being that the Federal Circuit limited the doctrine of equivalents, narrowing the scope of patent protection.[63] The

[63] Dreyfuss, *supra* note 5, at 28; Glynn S. Lunney, Jr., *Patent Law, the Federal Circuit, and the Supreme*

consequence would be a shift towards narrower, less impactful inventions, which would be less (not more) commercially valuable. However, this should not explain our results, as we controlled for both the number of backward citations to prior art and the number of claims. Further, the estimate in Table 4, column (d), controls for technological scope as represented by the length of independent claims.[64]

Yet another possible explanation is that there were differences in scientific discoveries across circuits. To test this explanation, Table 4, columns (e) and (f), reports estimates controlling for the number of PhDs per million people and R&D expenditure per capita in the geographical area of the circuit. Neither of these variables are significant, and the coefficient of CAFC is actually larger than the preferred estimate.

V. Discussion

Patents embody an exchange of an exclusive right of limited duration for the disclosed technology so that others may freely use the technology after the period of exclusivity. Here, we employ a quasi-natural experiment arising from the Federal Circuit assuming jurisdiction over patent appeals to examine the effect of a pro-patentee shift in the law on the balance in the patent exchange. We find that the Federal Circuit was associated with an increase in the commercial value of patents by 11.7%, which amounted to a windfall gain of at least U.S.$6.16 billion per year at 1982 prices.[65] It is important to note that this is a severe under-estimate as it is limited to patents owned by publicly-listed companies. By contrast, the Federal Circuit was not associated with any significant increase in the technological quality of the patented inventions.

Unless the pre-Federal Circuit law was somehow excessively tilted against patent owners, our findings suggest that the establishment of the Federal Circuit upset the patent exchange. Moreover, changes in the administration of the patent system subsequent to the Federal Circuit mostly favored patent owners,[66] further tilting the patent exchange against society in general and against users of technology in particular. Our findings do not support legislative efforts to further shift patent law in favor of patent owners,[67] such as the STRONGER Patents Act of 2019,[68] which would have made it more difficult to invalidate a patent, and the Restoring America's

Court: A Quiet Revolution, 11 SUP. CT. ECON. REV. 1, 2–3 (2004).

[64] *Cf.* Marco, *supra* note 55, at 9 (using the length of indpendent claims as a metric).

[65] The gain is calculated as 13,926 patents × median value of U.S. $3.78 million per patent × 0.117 = $6.16 billion.

[66] *See* Adam B. Jaffe & Josh Lerner, *Innovation and its Discontents*, 6 INNOVATION POL'Y & ECON. 27, 29 (2005) at 27; Carl Shapiro, *Patent Reform: Aligning Reward and Contribution*, 8 INNOVATION POL'Y & ECON. 111, 117–18 (2007).

[67] *See, e.g.*, Zuhn, *supra* note 12 (describing an movement by Senators to implement a sequenced examination approach to patent examination).

[68] *See generally* STRONGER Patents Act, S. 2082, 116th Cong. (2019).

Leadership in Innovation Act of 2021,[69] which would have relaxed the standard for what may be patented. By contrast, our findings do support the Restoring the America Invents Act of 2021,[70] which would help alleged infringers defend against low-quality patents.

Finally, we note that the increase in the commercial value of patents was concentrated in industries where patents were considered to be relatively less effective in appropriability. Businesses in such industries tend to patent for strategic purposes, like negotiating for licences to complementary technologies or blocking competitors efforts, rather than the conventional purpose of securing exclusivity to appropriate the returns to research and development.[71] Indeed, we find that the Federal Circuit had no effect on the technological quality of patented inventions in those industries.[72] The welfare effect of strengthening patents in those industries is concerning. In future research, it would be important to study the effect of the Federal Circuit on strategic patenting, particularly in industries where patents are less effective in appropriability.[73]

VI. Appendix

A1. Patent litigation dataset

We estimate (1) with the UGA Patent Litigation Dataset limited to cases decided between 1968 and 2000, covering 15 years before and after the creation of the Court of Appeals for the Federal Circuit (CAFC), excluding the transitional period 1983-85. The number of patent cases in the dataset varies by circuit, with the top three circuits (the Ninth Circuit, the Seventh Circuit, and the Sixth Circuit) accounting for 45% of all cases. In estimating (1), we limit the sample to circuits with at least five cases both before and after the CAFC. This criterion drops the District of Columbia Circuit. In October 1981, the states of Alabama, Florida, and Georgia were detached from the Fifth Circuit to form the Eleventh Circuit. As the Eleventh Circuit had just three pre-Federal Circuit cases, we dropped these cases and assumed the pre-Federal Circuit legal stance in the Eleventh Circuit to be that in the Fifth Circuit.

We code the ruling, Z_{pct}, according to the decision of (i) the original district court if not appealed or if appealed and affirmed by the appellate court, (ii) the second district court if the appellate court vacated the original district court judgment and remanded the case back to the district court, or (iii) the appellate court if it ruled on the case. A case is classified as post-CAFC if it was (a) appealed and decided by the

[69] *See generally* Restoring America's Leadership in Innovation Act, H.R. 5874, 117th Cong. (2021).
[70] *See generally* Restoring the America Invents Act, S. 2891, 117th Cong. (2021).
[71] Cohen et al., *supra* note 8.
[72] *See infra* app., § A3.
[73] Yun Hou et al., *When Stronger Patent Law Reduces Patenting: Empirical Evidence*, 44 STRATEGIC MGMT. J. 977, 1012 (2023).

CAFC or (b) decided by a district court after October 1982 with no appeal.[74]

A2. CAFC index

As described in the main text, we constructed an index of the changes in laws due to the CAFC from the estimates of equation (1), as reported in Table A1. Referring to Table A1, column (a), three of the control variables are at least marginally significant, which validates the concern that the outcome of litigation might vary with the characteristics of the patent and its litigation. The "business patentee" coefficient is positive (albeit only marginally significant), which is consistent with business patent owners investing more resources in the assessment of their patents. The "patentee as defendant" coefficient is negative and marginally significant, which is consistent with the owners of relatively stronger patents suing infringers. Interestingly, the "appeal decisions" coefficient is negative and significant. Possible explanations for this are that infringers of patents were more likely to appeal and that appellate courts were relatively less friendly to patent owners than district courts were.

Table A1. CAFC: Rulings

	(a) Pre-CAFC rulings, η_c	(b) CAFC index, λ_c	(c) Post-CAFC rulings, $\eta_c + \lambda_c$
First Circuit	-0.420	1.799**	1.379**
	(0.449)	(0.565)	(0.504)
Second Circuit	0.279	0.992**	1.271**
	(0.295)	(0.459)	(0.479)
Third Circuit	0	0.772	0.772
		(0.472)	(0.472)
Fourth Circuit	0.469	0.994**	1.463***
	(0.320)	(0.488)	(0.491)
Fifth Circuit	1.197***	0.094	1.292**
	(0.290)	(0.469)	(0.499)
Sixth Circuit	0.539*	0.601	1.141**
	(0.305)	(0.435)	(0.477)
Seventh Circuit	0.717**	0.386	1.103**
	(0.275)	(0.443)	(0.482)
Eighth Circuit	-0.068	0.788	0.720
	(0.453)	(0.590)	(0.511)
Ninth Circuit	0.690**	0.431	1.121**
	(0.284)	(0.436)	(0.470)
Tenth Circuit	1.585***	-0.122	1.463**
	(0.387)	(0.581)	(0.538)
Eleventh Circuit	1.197	-0.100	1.097**
		(0.479)	(0.506)

[74] Atkinson et al., *supra* note 6, at 428.

Business Patentee	0.160*
	(0.087)
Number of Claims	0.004
	(0.003)
Patentee as Defendant	-0.216*
	(0.129)
Home Circuit	-0.109
	(0.081)
Appeal	-0.211**
	(0.088)
/cut1	0.965**
	(0.323)
/cut2	1.995***
	(0.326)
Technology Fixed Effects	Yes
Cases	2559
Patents	2455
lnL	-2555.53

Notes: Unit of analysis: patent case. Method: ordered logit (stata routine ologit). Dependent variable: ruling (invalid, not infringing, or valid and infringed). Columns (a) and (b): estimated coefficients. Column (c): post-CAFC law = (a) + (b). Pre-CAFC law in the Third Circuit is stipulated to be zero, and in the Eleventh Circuit it is assumed to be same as the Fifth Circuit. Robust standard errors are reported in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

To better appreciate the economic effect of the CAFC, we contrast the change in the likelihood of a patent being held to be valid and infringed in the First Circuit and Tenth Circuit. By equations (1) and (2), the likelihood of a patent being held to be valid and infringed is:

$$\Pr\left(Z^*_{pct} \geq k_2\right) = \Pr\left(\epsilon_{pct} \geq k_2 - X_{pct}\beta\right)$$

For each circuit *c*, the marginal effect of the CAFC on the likelihood of patents being held valid and infringed is:

$$\Pr\left(\epsilon_{pct} \geq k_2 - X_{pct}\beta \mid circuit_c = 1, postCAFC_{ct} = 1\right) - \Pr\left(\epsilon_{pct} \geq k_2 - X_{pct}\beta \mid circuit_c = 1, postCAFC_{ct} = 0\right)$$

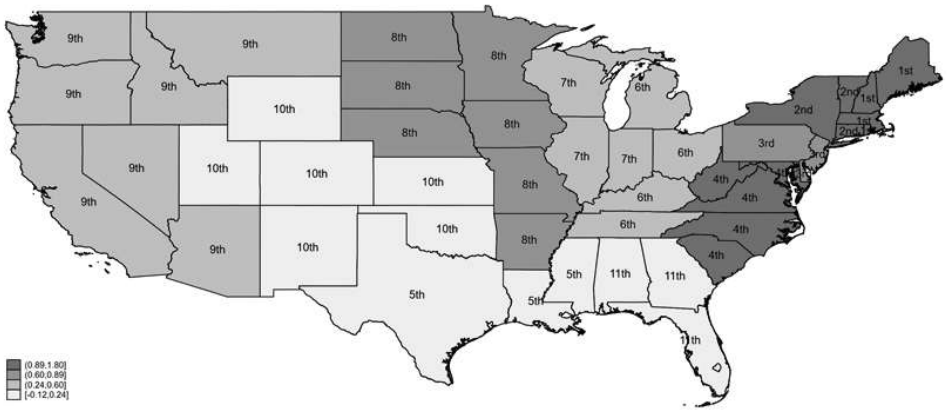
While holding other variables constant, this is calculated using the Stata routine, "margins."[75] Based on this calculation, after the CAFC assumed jurisdiction over patent appeals, the likelihood of a patent being held to be valid and infringed rose by

[75] Benn Jamm, *Predictive Margins and Marginal Effects in Stata*, U. BERN (June 7, 2013), https://www.stata.com/meeting/germany13/abstracts/materials/de13_jann.pdf.

32.8% in Massachusetts (First Circuit) and decreased slightly by 2.35% in Colorado (Tenth Circuit).

Figure A1 depicts the geographical variation in the legal changes by federal judicial circuit.

Figure A1. CAFC: Pro-patentee Change in Rulings

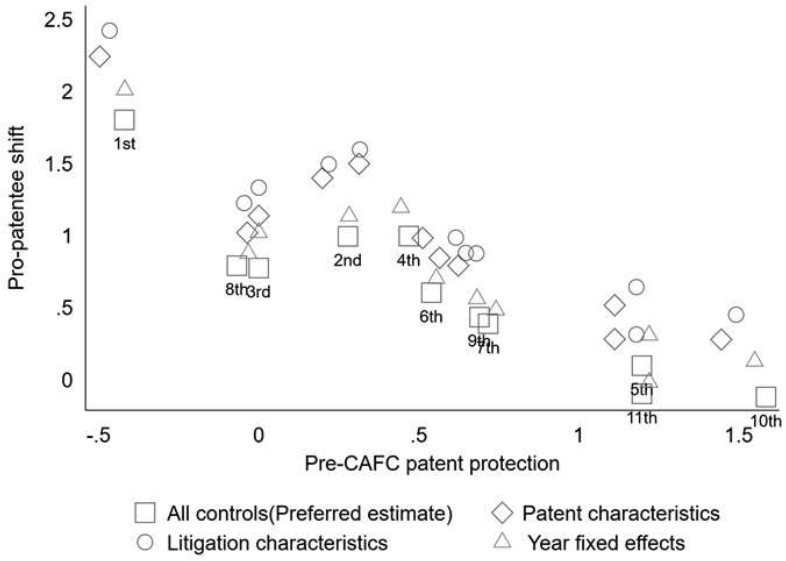


Note: The map represents the quartiles of the shift of rulings in favor of patent owners by each geographical circuit. Darker colors represent larger increases.

Our main objective is to use the CAFC index to investigate the effect of changes by each circuit in the law, due to the creation of the CAFC, on the commercial value and technological quality of patent. The key identifying assumption for the index to be unbiased is that the judgments on patents (whether invalid, valid but not infringed, or valid and infringed) was driven by the extent to which the circuit courts changed their interpretation of patent law before and after the establishment of the CAFC.

As a rough check on the sensitivity of the CAFC index to confounding factors, we estimate three alternative indexes -- with year-fixed effects only, with year-fixed effects and patent characteristics, and with year-fixed effects and litigation characteristics. Figure A2 depicts the preferred index and the three alternatives. All four indexes are quite similar, and formally, Hausman tests do not reject the null hypothesis that the coefficients in the preferred estimate differ from those in other specifications. While we cannot rule out sensitivity to unobservable selection, the preferred index seems quite robust to selection on observables.

Figure A2. CAFC Index: Robustness



Note: The figure depicts a change in the direction of rulings implied by estimates of ordered logit models of rulings, with different sets of controls, as indicated. Relevant patent characteristics are the patent class, number of claims, and whether patent was assigned. Relevant litigation characteristics are whether the patent owner was the defendant, whether the case was tried in a home circuit of the patent owner, and whether the case was decided on appeal. Year fixed effects abstract from national trends in patent law and litigation. Hausman tests fail to reject the null hypothesis that our preferred estimate is no different from each of the other estimates.

It is certainly true that the cases which are tried in court are the minority which the parties did not settle.[76] Settlement negotiations would anchor on the stance of the courts. In pro-patentee circuits, owners of patents would demand more and infringers would concede more, while in anti-patentee circuits, owners of patents would demand less and infringers would concede less. There is no obvious reason why the degree of uncertainty over rulings would have varied systematically between the circuits by the degree to which the CAFC shifted the law.

The one possibility that we can imagine is that the uncertainty would be higher in the First Circuit, where the CAFC shifted the law the most. In our analysis of the

[76] George L. Priest & Benjamin Klein, *The Selection of Disputes for Litigation*, 13 J. LEGAL STUD. 1, 47 (1984); Steven Shavell, *Any Frequency of Plaintiff Victory at Trial is Possible*, 25 J. LEGAL STUD. 493, 495 (1996).

commercial value of patents, we include a robustness test that excludes patents held by assignees in that circuit.

A3. Technological quality: Contingencies

In parallel with Table 2, columns (a)-(c), for the commercial value of patents, Table A2 presents estimates of the effect of the CAFC on technological quality contingent on the reported effectiveness of patents as an appropriability mechanism.[77]

Table A2. CAFC and technological quality

VARIABLES	(a) All	(b) Effectiveness: Product	(c) Effectiveness: Process
CAFC x Post	0.183*	-0.061	-0.085
	(0.108)	(0.059)	(0.067)
CAFC x Post x Low effectiveness (product)		-0.032	
		(0.110)	
CAFC x Post x Low effectiveness (process)			0.072
			(0.095)
Technology-Year-Industry FE	Yes	Yes	Yes
Circuit FE	Yes	Yes	Yes
Patents	178,227	178,227	178,227
Companies	2001	2001	2001
Chi-squared	2820	2848	2826

Notes: Unit of analysis: patent. Estimated by Poisson quasi-maximum likelihood (Stata routine, ppmlhdfe). Dependent variable: forward citations of the patent by others. All estimates control for employment (ln), revenue per employee (asinh), PPE per employee (asinh), R&D per employee, Tobin's Q, total number of backward citations, total number of claims, technology-year-industry fixed effects, and circuit fixed effects. Columns (a): replication of Table 2, column (d). Column (b): comparing the effect of the CAFC on industries with patents being more or less effective in appropriating returns from product innovation. Column (c): comparing the effect of the CAFC on industries with patents being more or less effective in appropriating returns from process innovations. Two-sample bootstrapped standard errors corrected for generated regressor bias, clustered two ways by both parent company and circuit at the second stage, in parentheses (*** $p<0.01$, ** $p<0.05$, * $p<0.1$).

[77] Cohen et al., *supra* note 8.