

Technological Change and the Evolution of Patent Rights

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Technological Change and the Evolution of Patent Rights

*Paul Rogerson**

The history of patent law is characterized by a striking pattern: dramatic, recurring cycles between eras of stronger and weaker patent rights. One theory is that patent law has been adapting to waves of technological change. In periods of rapid technological progress, following major breakthroughs (like the steam engine or the microprocessor), freely granting patents tends to create thickets of overlapping claims that block innovation, and courts have reacted by weakening rights (raising the standard to obtain and enforce a patent).

Existing histories, relying on qualitative methods, have argued that this theory explains certain nineteenth-century legal developments, but have questioned whether it can explain the post-nineteenth-century period. This Article introduces new, complementary evidence that is based on a quantitative approach and covers substantially the entire two-century doctrinal history.

In particular, the Article presents a model for the correlation predicted by the technological theory (changes in the law lag behind changes in the pace of technological progress) using a dynamic ordered probit. To measure the rate of technological progress, it uses two quantitative measures from economic history: (1) the rate of productivity growth, and (2) the number of technologically significant patents issued by the United States Patent and Trademark Office. To measure changes in the law over time, it focuses on changes to an especially central doctrine—the standard of invention—and uses the judgments of doctrinal commentaries to code the law in each year.

The results both replicate the prior qualitative analyses of the nineteenth century and show that the same story extends to future periods. For nearly two centuries, courts have consistently weakened patent rights after the rate of technological progress rose, and vice versa, at a lag of roughly a decade. A one-percent rise in the rate of productivity growth, or one more technologically significant patent in force per five thousand people, has been associated with at least one step upward in the stringency of the standard of invention.

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I. INTRODUCTION

A major debate in patent law is whether technological progress will be best encouraged by “strong” patent rights (lenient legal standards that make patents easy to obtain and enforce) or “weak” patent rights (strict legal standards that make patents difficult to obtain and enforce).¹ This choice is thought to involve a tradeoff between the benefits of privatization and the benefits of open access.² On the one hand, stronger, more expansive patent rights may encourage innovation by creating more powerful incentives for inventors. On the other hand, they may also discourage innovation by fencing off the intellectual commons and blocking the work of future inventors.

The record of changes in the strength of patent rights over more than two hundred years since the founding of the U.S. patent system reveals a striking feature: dramatic, recurring cycles between eras of stronger and weaker patent rights. The most recent of these cycles is well known.³ In the 1980s, courts and legislators began to worry that excessively weak patent protection in the middle decades of the twentieth century had discouraged innovation, so they moved to strengthen patent rights in a variety of ways.⁴ The mood then swung in the opposite direction in the 1990s and early 2000s; a new generation worried that the reforms of the 1980s had spawned a “wave of bad patents” that would choke off innovation, and these reformers weakened patent rights in the 2000s and 2010s.⁵

But histories of patent law report that these cycles are nothing new. Instead, they seem to repeat continuously throughout the history of patent law, tracing back to its earliest days. For example, more than a century ago, one could find the leading patent law treatise of the late nineteenth century complaining bitterly (in words that might have been written today) of the “remarkable changes in the attitudes of our courts towards

¹ *E.g.*, Mark A. Lemley, *The Surprising Resilience of the Patent System*, 95 TEX. L. REV. 1, 50 (2016) (“Much of the academic and policy debate over patent law in the past twenty years has focused on the relative dangers of overprotection and underprotection.”).

² *See e.g.*, Petra Moser, *Patents and Innovation: Evidence from Economic History*, 27 J. ECON. PERSPECTIVES 23, 23 (2013) (“[P]roviding stronger patents for early generations of inventors may also weaken incentives to invest in research and development for later generations”); Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, 5 J. ECON. PERSPECTIVES 29, 30, 33 (1991); Saul Levmore, *Property’s Uneasy Path and Expanding Future*, 70 U. CHI. L. REV. 181, 184–85 (2003).

³ *See* Lemley, *supra* note 1, at 7–13.

⁴ *Id.*; *see also* *Ferring B.V. v. Barr Lab’ys, Inc.*, 437 F.3d 1181, 1195 (Fed. Cir. 2006) (Newman, J., dissenting) (“[P]atents were not a reliable support for commercial investment.”).

⁵ Lemley, *supra* note 1, at 8–11.

patentees during the past few years,” swinging from “an extreme liberality” in the early decades of the nineteenth century to “an equally extreme strictness” at the century’s close.⁶ This dynamic has been given a long list of nicknames by doctrinal commenters, such as the “swinging pendulum in patent law,”⁷ “recurrent fluctuations” in patent rights,⁸ and “cyclical judicial hostility toward patents.”⁹

Legal scholars have offered three different explanations of the source of this dynamic, each with different lessons for patent law.¹⁰ One story is that patent law has been trapped in a pathological cycle of overcorrection. For example, Professor Mark A. Lemley suggests that “[t]hese may in fact be cycles of over- and underprotection,” where “every generation of Congresses, judges, and patent lawyers sees the imperfections of the decades before and overreacts to it.”¹¹ Likewise, economists Adam B. Jaffe and Josh Lerner argue in their history of debates over patent rights that “[f]estering problems often lead to a dramatic shift in patent administration, which often goes too far in the other direction, generating a new set of problems of its own,” which in turn sows the seeds of the next overcorrection.¹² In this story, the lesson of history is that legal actors should resist calls for dramatic reform of the patent system and instead focus on incremental changes.

A second story is that swings in patent law have been driven by political competition between interest groups.¹³ Patent law not only creates incentives for innovation *ex ante*—it also divides the spoils *ex post*. Different legal regimes distribute wealth in distinct

⁶ 1 WILLIAM C. ROBINSON, *THE LAW OF PATENTS FOR USEFUL INVENTIONS* 36, § 23 n.1 (1890).

⁷ Lemley, *supra* note 1, at 13; see ADAM B. JAFFE & JOSH LERNER, *INNOVATION AND ITS DISCONTENTS* 79 (2007).

⁸ H.R. Mayers, *The United States Patent System in Historical Perspective*, 3 *PAT., TRADEMARK & COPYRIGHT J. RSCH. & EDUC.* 33, 50 (1959).

⁹ Simone A. Rose, *Patent “Monopolyphobia”: A Means of Extinguishing the Fountainhead?*, 49 *CASE W. L. REV.* 509, 526–27 (1999).

¹⁰ Readers will notice that each of these stories bears at least a family resemblance to a classic story that has been told about the evolution of *real* property rights. See, e.g., Carol M. Rose, *Crystals and Mud in Property Law*, 40 *STAN. L. REV.* 577, 595–604 (1988) (property law’s internal dynamics produce cycles between competing approaches); Harold Demsetz, *Toward a Theory of Property Rights*, 57 *AM. ECON. REV.* 347, 350–54 (1967) (changes in property rights have been a rational adaptation to changing social conditions); Saul Levmore, *Two Stories About the Evolution of Property Rights*, 31 *J. LEGAL STUD.* S421, S427 (2002) (changes in property rights have been the product of interest-group politics).

¹¹ Lemley, *supra* note 1, at 14.

¹² JAFFE & LERNER, *supra* note 7.

¹³ See, e.g., STEPHEN H. HABER & NAOMI R. LAMOREAUX, *THE BATTLE OVER PATENTS: HISTORY AND POLITICS OF INNOVATION* 1–5 (2021); Eli Dourado & Alex Tabarrok, *Public Choice Perspectives on Intellectual Property*, 163 *PUB. CHOICE* 129, 146–47 (2015).

ways, and over time firms with differing business models have lobbied for their preferred outcomes, with varying success. The content of patent law in any given era has therefore been “the product of contending interests battling over surplus”¹⁴ And the lesson of history is that would-be patent reformers should be skeptical of the pretexts for patent reform offered by interested parties—these same stories have been told many times before, in service of the same economic interests.¹⁵

A third story is that patent law has been adapting to waves of technological change.¹⁶ Historians of technology have often argued that technological progress tends not to occur at a smooth, constant rate over time, but rather in “leaps” or “waves,” driven by the introduction of major new technologies (like the steam engine or the microprocessor) that temporarily open up new opportunities for follow-on innovation, sometimes called “macroinventions” or “general purpose technologies.”¹⁷ The theory is that, during these technological booms, strong patent rights tend to hinder innovation—freely granting patents tends to clog the intellectual commons with conflicting legal claims. And, when these technological waves have occurred, courts have seen legal conflicts in litigated patent cases as well as public complaints from inventors, developed negative views of patents (without necessarily holding a worked-out theory about *why* strong patent rights seem to be creating problems), and reacted by weakening patent rights. Eventually, the wave of progress abates, the conflicts wane, and a new generation of judges come to view patents more positively.

The evidence for this third, technological theory is based largely on historical studies of the nineteenth century, which focus on the effects of the Second Industrial Revolution on an especially central doctrine of patent law—the standard of invention.¹⁸ This legal doctrine sets the bar for how original an idea must be to

¹⁴ HABER & LAMOREAUX, *supra* note 13, at 4.

¹⁵ *See id.*

¹⁶ *See, e.g.*, William K. Townsend, *Patents, 1701–1901*, in *TWO CENTURIES’ GROWTH OF AMERICAN LAW, 1701–1901*, at 394–96 (Members of the Faculty of the Yale Law Sch. eds., 1901); Edmund W. Kitch, *Graham v. John Deere Co.: New Standards for Patents*, 1966 SUP. CT. REV. 293, 319–22; B. Zorina Khan, *Technological Innovations and Endogenous Changes in U.S. Legal Institutions, 1790–1920*, at 16–17 (Nat’l Bureau of Econ. Rsch., Working Paper No. 10346, 2004); John F. Duffy, *Inventing Invention: A Case Study of Legal Innovation*, 86 TEX. L. REV. 1, 17–18 (2007).

¹⁷ *See, e.g.*, Joel Mokyr, *Punctuated Equilibria and Technological Progress*, 80 AM. ECON. REV. 350, 350–52 (1990); Timothy F. Bresnahan & M. Trajtenberg, *General Purpose Technologies ‘Engines of Growth’?*, 65 J. ECONOMETRICS 83, 83–84 (1995).

¹⁸ *See* sources cited *supra* note 16.

qualify for patent protection. A lower standard demands less originality (allows more patents and protects “stronger” rights), while a higher standard demands more originality (allows fewer patents and protects “weaker” rights). In the early decades of the nineteenth century, patent law set a very low standard, and then raised it following the Civil War.¹⁹ The theory is that this rise in the standard of invention was a response to the faster pace of technological progress ushered in by the Second Industrial Revolution in the late nineteenth century. This “quickening pace of technological progress . . . threatened to bring every commodity within a private patent grant,” and courts reacted by tightening patentability standards.²⁰

The analysis in these histories is extremely plausible, but it is also limited in some respects. One is that the arguments rely on a qualitative, informal notion of technological progress, which raises questions about how closely the legal and technological timelines correspond. For example, Townsend’s history provides a list of “great inventions” that supposedly generated the legal conflicts in the late nineteenth century.²¹ However, a number of these inventions were either developed early in the nineteenth century, decades before the law switched to a higher standard,²² or had their most consequential social impacts only decades afterward, in the twentieth century.²³

A second limitation is scope. These histories are largely focused on events in the nineteenth century. But the story does not end there—the standard of invention has continued to cycle up and down throughout the twentieth and twenty-first centuries. And, to the extent these histories have considered later time periods, they have been skeptical that legal changes in the twentieth and twenty-first centuries are explained by technological forces, and have instead viewed them as mistakes or confusions by the courts.²⁴ But it is difficult to evaluate these claims without a clear measure of how the pace of progress has changed over time.

The goal of this Article is to add new, complementary evidence on the technological theory. The most basic prediction of this

¹⁹ See Kitch, *supra* note 16, at 309–19.

²⁰ *Id.* at 304.

²¹ See Townsend, *supra* note 16, at 395.

²² See, e.g., *O’Reilly v. Morse*, 56 U.S. 62, 107–12 (1853) (telegraph).

²³ See, e.g., Paul David, *The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox*, 80 AM. ECON. REV. 355, 356–59 (1990) (electricity).

²⁴ See Kitch, *supra* note 16, at 323–24 (describing later changes to the standard of invention as a “story of failure”); Duffy, *supra* note 16, at 41, 67 (arguing that twentieth-century legal changes might be best viewed as unsuccessful “experiments”).

theory is simply that legal and technological changes have been correlated over time—the law has lagged behind movements in the pace of technological progress. The Article presents a new test of whether this prediction matches the broad shape of the doctrinal history. Its strategy has two main features.

One, the Article continues to focus on changes to the standard of invention. This doctrine is a good choice not only because existing histories have started there, but also because it has several desirable features that make it a useful and revealing window into patent law as a whole. First, it is often considered the single most important component of the strength of patent rights. Townsend’s history reports that, in the nineteenth century, “[t]he changes in the law on this subject make the history of patent law in the United States.”²⁵ And the doctrine has kept its central place in the legal scheme. Modern commenters have called today’s standard of invention “the most important of the basic patent requirements,” “the key to defining what is a patentable invention,” and “the ultimate condition of patentability,” among other superlatives.²⁶ In modern patent litigation, this doctrine is “the most common invalidity issue” and is “contested in a large majority of patent cases.”²⁷ Second, historically, the standard of invention has also been the most consistent policy lever used to change the strength of patent rights. Every era with a substantial change in the legal system’s basic attitude toward patents has seen that change embodied in a revision to the standard of invention (alongside a changing mix of revisions to various other doctrines).²⁸ Third, and finally, the evolution of this doctrine is (relatively) straightforward to describe. Legal commentaries have described the law as cycling between three major legal regimes that impose higher or lower standards of patentability: (1) “substantial novelty” (lowest standard); (2) “nonobviousness” (intermediate standard); and (3) “genius” (highest standard).²⁹

Two, with this focus, the Article uses a quantitative approach. In particular, it presents a model for the suggested historical relationship between the pace of technological progress and the

²⁵ Townsend, *supra* note 16, at 396.

²⁶ Michael Abramowicz & John F. Duffy, *The Inducement Standard of Patentability*, 120 YALE L.J. 1590, 1593 (2011).

²⁷ Dmitry Karshedt, *Nonobviousness: Before and After*, 106 IOWA L. REV. 1609, 1611 & n.3 (2021).

²⁸ See *infra* Part II.

²⁹ See Kitch, *supra* note 16, at 297–303. Notice that Kitch uses the label “novelty” rather than “substantial novelty.” See *id.*; Duffy, *supra* note 16, at 18.

standard of invention (changes in the law lag behind changes in technology), using a dynamic ordered probit framework.³⁰ This framework is able to capture two essential features of the legal history: (1) time dependence (the legal standard today is not independent of the legal standard yesterday), and (2) the nature of the available observations (legal regimes that can be ordered by *relative* strictness).

This Article's approach to data consists of the following. To measure the rate of technological progress in each year, the Article uses two major quantitative measures of technological change that have been developed by economic historians: (1) the rate of productivity growth, and (2) the number of technologically significant patents issued by the United States Patent and Trademark Office (USPTO). Both measures are available over the long run, extending back to the early or mid-nineteenth century, and therefore cover substantially all of the relevant doctrinal history. To measure changes in the standard of invention over time, the Article draws on the legal regimes used by doctrinal commentators to describe the evolution of the doctrine ("substantial novelty," "nonobviousness," and "genius"). In particular, relying on the judgments made by these commentaries, the Article codes the law in each year as falling into a particular legal regime.

The core result is a consistent, long-term correlation between the rate of technological progress and the standard of invention throughout substantially the entire two-hundred-year history of the U.S. patent system. This result both replicates the earlier analysis of the nineteenth century and shows that the same story extends to future periods. Qualitatively, the two series are well-matched—legal actors have switched to stricter legal regimes following rises in the rate of technological progress, and vice versa, at a lag of roughly a decade. And, in the model, the coefficient on the rate of technological progress is large, positive, and has a ninety-five percent confidence interval bounded above zero. Over the long run, a one-percent rise in the rate of productivity growth, or one additional technologically significant patent in force per five thousand people, is associated with at least one step upward in the strictness of the legal regime.

These results are broadly robust to a range of plausible changes in the model's inputs, including different estimates of the

³⁰ See Barry Eichengreen et al., *Bank Rate Policy Under the Interwar Gold Standard: A Dynamic Probit Model*, 95 *ECON. J.* 725, 733–35 (1985).

rate of technological progress (from different economic historians) and different ways of coding the doctrinal history (reflecting the margins of disagreement among different historical commentaries), with one important qualification. The two measures of technological progress—productivity growth and technologically significant patents—track each other closely for most of the history but diverge to some extent in the most recent decades (1980s to early 2000s). Both measures show a recent wave of technological progress, but differ on its size. In these years, the productivity data is a somewhat better fit for the doctrine.

In sum, this Article makes two main contributions. First, it draws a missing link between patent law and the measurement of technological progress in economic history. It shows that the major quantitative measures of technological change used by economic historians track changes in the strength of patent rights over time. Second, it contributes to a long-running debate about the history of patent law. The results create clearer evidence that the doctrinal record fits the technological theory, providing a stronger reason to believe that cycles in patent law have been a *positive* feature of the legal history. Courts have plausibly adopted legal regimes that best encourage technological innovation in different social conditions.

The rest of the Article is organized as follows: Part II describes the doctrinal history, Part III explains the technological theory and presents a model that captures its core claim, Part IV describes the data, and Part V carries out the analysis. A brief conclusion follows.

II. DOCTRINAL HISTORY

This section begins by simply describing the changes in the standard of invention over time (which the technological theory seeks to explain). There is a broad consensus among commenters on the basic shape of this history. There are two noteworthy features worth highlighting at the top.

First, the courts have played a particularly large role in the development of this doctrine. The task of setting the standard of invention has always been delegated, in substantial part, to the courts. The Supreme Court has famously argued that this was always the plan—supposedly, Thomas Jefferson (head of the original patent board) felt that a standard of invention was necessary, but should be left to the courts to develop through case

law.³¹ The veracity of this claim has been (convincingly) questioned,³² but whatever the original intent, that is what happened. For the first century-and-a-half of the U.S. patent system, no statute set forth a general standard of invention; the doctrine was instead created by the courts through a common-law-like process.³³ The standard of invention was eventually codified by the Patent Act of 1952.³⁴ However, this legislation set forth a broad principle rather than detailed instructions, and, over time, different interpretations of the statute have waxed and waned in the case law.

Second, commenters have described the law as cycling between three basic legal regimes over time, which can be ranked as imposing higher or lower standards of invention. The regimes are as follows: (1) “substantial novelty” (lowest standard); (2) “nonobviousness” (intermediate standard); and (3) “genius” (highest standard).³⁵ Of course, it is not possible to make precise numerical statements about how strict or lenient each regime is, but it is at least possible to say that different regimes impose *relatively* higher or lower standards—that is, it is harder to obtain and enforce a patent under one regime compared to another. The cycles in patent law involve switches between these regimes over time (as well as occasional periods where the law was in between two regimes).

Broadly similar accounts of this history can be found in many different sources. Altogether, they describe six major historical periods from 1790 (the date of the first patent statute) to today. These six periods are discussed below.

A. “Substantial Novelty”

In the earliest decades of the patent system—the late eighteenth and early nineteenth centuries—patent law largely lacked a developed standard of invention, and was instead generally willing to grant a patent on any invention that was merely “novel” (literally new).³⁶ A famous early nineteenth-century

³¹ *Graham v. John Deere Co.*, 383 U.S. 1, 5–10 (1966) (“[T]he whole was turned over to the judiciary, to be matured into a system . . .”).

³² Kenneth J. Burchfiel, *Revising the “Original” Patent Clause: Pseudohistory in Constitutional Construction*, 2 HARV. J.L. & TECH. 155, 218 (1989).

³³ See Kitch, *supra* note 16, at 303–27.

³⁴ *Id.* at 293.

³⁵ *Id.* at 297–303; Duffy, *supra* note 16, at 18.

³⁶ See Townsend, *supra* note 16, at 394–95.

case, *Earle v. Sawyer*, which was decided by Justice Story while riding circuit, emphatically states this doctrine:

It is of no consequence whether the thing be simple or complicated – if it is new, if it is useful, if it has not been known or used before, it constitutes an invention within the very terms of the Act, and in my judgment within the very sense and intendment of the legislature.³⁷

As a number of commenters have noted, the regime that prevailed in these early decades was not quite a pure “novelty” regime.³⁸ Instead, it has often been given the label “substantial novelty.”³⁹ This “substantial novelty” regime prohibited patents not only on inventions that were literally identical to existing technology, but also on inventions that differed from existing technology only in trivial details, so that they could be said to be “substantially” identical.⁴⁰ A classic example was that merely varying the “form” or “proportions” of the parts of a machine—in a way that made no difference to the machine’s function—would not be enough for a patent.⁴¹ However, with that proviso, the law was otherwise inclined to issue patents.⁴²

A testament to the leniency of this early standard is the fact that, unlike in modern patent litigation—where the standard of invention is “the most common invalidity issue”⁴³—invention was rarely a central issue in patent litigation before the Civil War. Throughout almost the entire nineteenth century, the Supreme Court was the court of first (and last) appeal for patent disputes; it was not until the passage of the Evarts Act of 1891 that the intermediate circuits were created, and the Supreme Court was given certiorari power (at least in nonconstitutional cases).⁴⁴ During these years, the Supreme Court therefore carried a heavy patent docket. In the decades preceding the end of the Civil War, it issued eighty-three opinions in patent cases (with the lions’

³⁷ *Earle v. Sawyer*, 8 F. Cas. 254, 256 (C.C.D. Mass. 1825) (No. 4247).

³⁸ See Burchfiel, *supra* note 32, at 191–95; Edward C. Walterscheid, *The Hotchkiss Unobviousness Standard: Early Judicial Activism in the Patent Law*, 13 J. INTELL. PROP. L. 103, 106 (2005) [hereinafter Walterscheid, *Unobviousness Standard*]; Edward C. Walterscheid, *Novelty & the Hotchkiss Standard*, 20 FED. CIR. BAR J. 219, 227–28 (2010) [hereinafter Walterscheid, *Hotchkiss Standard*].

³⁹ Walterscheid, *Hotchkiss Standard*, *supra* note 38, at 228.

⁴⁰ *Id.* at 242–46.

⁴¹ See Burchfiel, *supra* note 32, at 196–97.

⁴² *Id.* at 191.

⁴³ See Karshedt, *supra* note 27, at 1611 n.3 (citing *Apple Inc. v. Samsung Elecs. Co.*, 839 F. 3d 1034, 1074 (Fed. Cir. 2016) (en banc) (Dyk, J., dissenting)).

⁴⁴ See DAVID P. CURRIE, *THE CONSTITUTION IN THE SUPREME COURT: THE SECOND CENTURY, 1888–1986*, at 5 (1990); see also Benjamin B. Johnson, *The Origins of Supreme Court Question Selection*, 122 COLUM. L. REV. 793, 823–28 (2022).

share coming in the 1840s, 1850s, and 1860s).⁴⁵ Yet, among these opinions, just a handful of them resolved a dispute over whether the standard of invention had been met.⁴⁶

B. “Nonobviousness”

A new legal regime, “nonobviousness,” then took hold in the post-Civil War years.⁴⁷ The essence of the “nonobviousness” regime is that “[not] all improvement is [] invention.”⁴⁸ Instead, to be entitled to a patent, an invention “must involve something more than what is obvious to persons skilled in the art to which it relates.”⁴⁹ In other words, even an invention that represents more than a “trivial” change to existing technology cannot be patented if it would have been an obvious idea to ordinary workers in the relevant technical field.⁵⁰

The earliest signs of the “nonobviousness” test are located in the Supreme Court’s first invention opinion, *Hotchkiss v. Greenwood*, a pre-Civil War case.⁵¹ *Hotchkiss* did not use the word “obviousness,” but it did refer to the skill of an “ordinary mechanic,” which sounds at least obviousness-like, particularly to modern readers.⁵² However, the common verdict, shared by all close histories of this period, is that this line in *Hotchkiss* was not understood as a doctrinal revolution at the time, “either by the Supreme Court or by legal commentators,” and “substantial novelty” remained the governing test for the next several decades.⁵³ For example, the year after *Hotchkiss* was decided, the author of the opinion, Justice Nelson, gave instructions in a patent case (while riding circuit) that ignored *Hotchkiss*.⁵⁴ Another justice who had joined the opinion did the same in the following year.⁵⁵ The handful of Supreme Court invention cases during subsequent

⁴⁵ This information comes from the Author’s database of Supreme Court patent cases.

⁴⁶ See *Kitch*, *supra* note 16, at 315–17 (“Cases before the Supreme Court raising issues of patentable novelty after *Hotchkiss* were infrequent.”).

⁴⁷ See *id.* at 319.

⁴⁸ *Pearce v. Mulford*, 102 U.S. 112, 118 (1880).

⁴⁹ *Id.*

⁵⁰ *Kitch*, *supra* note 16, at 301–03.

⁵¹ *Hotchkiss v. Greenwood*, 52 U.S. 248 (1851); Walterscheid, *Unobviousness Standard*, *supra* note 38, at 104.

⁵² Walterscheid, *Unobviousness Standard*, *supra* note 38, at 104.

⁵³ Burchfiel, *supra* note 32, at 202–09; *Kitch*, *supra* note 16, at 309, 314–16; Walterscheid, *Unobviousness Standard*, *supra* note 38, at 104; Walterscheid, *Hotchkiss Standard*, *supra* note 38, at 219–20.

⁵⁴ Walterscheid, *Unobviousness Standard*, *supra* note 38, at 116 n.82 (“One of the more remarkable aspects of the early treatment of the *Hotchkiss* standard was that its author, Justice Nelson, one year later refused to follow it in a circuit court opinion.”).

⁵⁵ Burchfiel, *supra* note 32, at 205.

decades continued to apply the governing “substantial novelty” rules.⁵⁶ And *Hotchkiss* was not cited by the Supreme Court in any invention case until 1875 and not by any lower court until 1882.⁵⁷

Instead, “[o]nly after the Civil War was non-obviousness regularly applied by courts as a general condition of patentability.”⁵⁸ The establishment of “nonobviousness” as the prevailing test (and the initial working-out of this new doctrine) was an incremental process accomplished through a decade of case law. In these post-Civil War years, only “slowly does the non-obviousness test come to the forefront,” and the first signs of the new regime were so subtle that they “may have been at the time imperceptible to both the Court and its bar.”⁵⁹

The beginning of the transition is generally dated to the early 1870s. In particular, two views about the timing are represented in the commentary. Edward C. Walterscheid and Kenneth J. Burchfiel identify 1870 as the starting point—that is the date of the Supreme Court’s first post-Civil War invention case, *Stimpson v. Woodman*.⁶⁰ Edmund W. Kitch is more conservative, and argues that the invention cases of the early 1870s continued to apply the old “substantial novelty” rules.⁶¹ He instead traces the first signs of the new “nonobviousness” approach to a pair of opinions issued in 1875, one of which (*Collar Co. v. Van Dusen*) is the Supreme Court’s first post-Civil War citation to *Hotchkiss*.⁶²

The endpoint of the transition is generally dated roughly a decade later, in the early 1880s. Again, one can find a range of views on the exact timing. Benjamin F. Lee, a late nineteenth-century lecturer in patent law at New York Law School, reports that the transition “culminated” in the “leading case” *Pearce v. Mulford*, which held that a patentable invention “must involve something more than what is obvious to persons skilled in the art

⁵⁶ *Id.* at 206–07 (“For nineteen years after the *Hotchkiss* decision, the Supreme Court did not invalidate a single patent on the basis of obviousness. More importantly, in sustaining the validity of patents before it, the Court routinely failed to conduct any inquiry into the degree of skill required to derive an invention over the disclosure of the prior art. . . . Lower courts and commenters continued to consider the degree of skill required legally immaterial.”); see also Kitch, *supra* note 16, at 309–16.

⁵⁷ Kitch, *supra* note 16, at 319 & n.120.

⁵⁸ Burchfiel, *supra* note 32, at 207–08.

⁵⁹ Kitch, *supra* note 16, at 319.

⁶⁰ Burchfiel, *supra* note 32, at 208 n.301; see Walterscheid, *Unobviousness Standard*, *supra* note 38, at 104; *Stimpson v. Woodman*, 77 U.S. 117 (1870).

⁶¹ Kitch, *supra* note 16, at 318.

⁶² *Id.* at 318–19; see *Collar Co. v. Van Dusen*, 90 U.S. 530 (1875).

to which it relates.”⁶³ Frank D. Prager locates the final doctrinal settlement in the 1882 case *Loom Co. v. Higgins*, which played a crucial role in establishing the doctrine of “secondary considerations” (or “objective evidence”) as a key part of the obviousness analysis.⁶⁴ 1882 is also the date of a telling anecdote, relayed by Burchfiel. In that year, the Supreme Court allowed a defendant to raise obviousness on appeal for the first time, when it had not been raised in the lower court.⁶⁵ In other words, in the early 1880s, there were at least some patent lawyers in the United States who had not previously understood they should raise obviousness, and now did. 1883 is the year of *Atlantic Works v. Brady*, often considered the “classic” invention opinion of the period.⁶⁶ Again, being the most conservative, Kitch asserts that the new rule only became clear in cases in 1885.⁶⁷

Supreme Court opinions of the time disclose the concerns that motivated the new approach. The Justices worried that a low standard of invention had produced overabundant, conflicting patent claims that ultimately served to block innovation. Justice Bradley’s 1883 *Atlantic Works* opinion is the leading statement of these concerns:

To grant to a single party a monopoly of every slight advance made, except where the exercise of invention somewhat above ordinary mechanical or engineering skill is distinctly shown, is unjust in principle and injurious in its consequences.

. . . Such an indiscriminate creation of exclusive privileges tends rather to obstruct than to stimulate invention. It creates a class of speculative schemers who make it their business to watch the advancing wave of improvement, and gather its foam in the form of patented monopolies, which enable them to lay a heavy tax upon the industry of the country, without contributing anything to the real advancement of the art. It embarrasses the honest pursuit of business with fears and apprehensions of concealed liens and unknown liabilities to lawsuits and vexatious accountings for profits made in good faith.⁶⁸

⁶³ Benjamin F. Lee, *What Constitutes a Patentable Subject Matter*, 3 COUNSELLOR 159, 164–65 (1894) (quoting *Pearce v. Mulford*, 102 U.S. 112, 118 (1880)).

⁶⁴ See Frank D. Prager, *Standards of Patentable Invention from 1474 to 1952*, 20 U. CHI. L. REV. 69, 80 (1952) (citing *Loom Co. v. Higgins*, 105 U.S. 580 (1882)).

⁶⁵ Burchfiel, *supra* note 32, at 208.

⁶⁶ ALBERT H. WALKER, TEXT-BOOK OF THE LAW OF PATENTS FOR INVENTIONS 26 (5th ed. 1917) (citing *Atlantic Works v. Brady*, 107 U.S. 192 (1883)).

⁶⁷ Kitch, *supra* note 16, at 319 (“Not until 1885, in *Thompson v. Boisselier*, did the Court take pains to point out that ‘it is not enough that a thing shall be new, in the sense that in the shape or form in which it is produced it shall not have been before known, and that it shall be useful, but it must, under the Constitution and the statute, amount to an invention or discovery.’”) (quoting *Thompson v. Boisselier*, 114 U.S. 1, 11 (1885)).

⁶⁸ *Atlantic Works v. Brady*, 107 U.S. 192, 200 (1883).

C. “Genius”

“Nonobviousness” remained the prevailing test through the early decades of the twentieth century.⁶⁹ During these years, the terminology was not yet entirely standardized, so the new test sometimes went by other names, such as “ingenuity.”⁷⁰ And there were a variety of “minor” trends and fluctuations in the case law—in some years, courts seemed to apply the test in ways that were somewhat stricter, or somewhat more lenient.⁷¹ But these fluctuations occurred within a broadly established framework, whose fundamental rules were not in dispute.

Then, several decades into the twentieth century, a “major” trend emerged toward a distinctly higher standard.⁷² The beginning of this shift is generally dated to the years around 1930. Judge Learned Hand—a prominent circuit judge, and the leading judicial chronicler of the Supreme Court’s evolving attitudes towards patents during this period⁷³—wrote in the 1942 opinion *Picard v. United Aircraft Corp.* that “the Supreme Court . . . has for a decade or more shown an increasing disposition to raise the standard of originality necessary for a patent,” amounting to “a pronounced new doctrinal trend.”⁷⁴ A later Judge Hand opinion, *Lyon v. Bausch & Lomb Optical Co.*, similarly gives the starting point of this trend as “twenty, or perhaps, twenty-five” years before 1952 (so, between 1927 and 1932).⁷⁵ Prager reports that the shift “started” under Chief Justice Hughes,⁷⁶ who ascended to the chiefship in 1930.⁷⁷ And Robert P. Merges tells us that 1930 is the starting point of the Supreme Court’s “most virulent anti-patent era.”⁷⁸ However, commentary at the time also acknowledged that—as with many gradual judicial trends—it was “difficult to establish which exact case first showed the Supreme Court’s new

⁶⁹ See Prager, *supra* note 64, at 81; see also Duffy, *supra* note 16, at 41.

⁷⁰ See Prager, *supra* note 64, at 80–81.

⁷¹ *Id.*; see also Duffy, *supra* note 16, at 41 (explaining that decisions during this period were not always “consistent,” with some cases seemingly applying a “high” standard and others seemingly applying a “lax” standard, but “[m]ore often, at least through the end of the nineteenth century and the first few decades of the twentieth century, the Court used language quite similar to the modern standard”).

⁷² See Prager, *supra* note 64, at 81–82.

⁷³ Richard A. Posner, *The Hand Biography and the Question of Judicial Greatness*, 104 *YALE L.J.* 511, 521 (1994).

⁷⁴ *Picard v. United Aircraft Corp.*, 128 F.2d 632, 636 (2d Cir. 1942).

⁷⁵ *Lyon v. Bausch & Lomb Optical Co.*, 224 F.2d 530, 535 (2d Cir. 1955).

⁷⁶ Prager, *supra* note 64, at 81.

⁷⁷ Currie, *supra* note 44, at 205–07.

⁷⁸ Robert P. Merges, *One Hundred Years of Solicitude: Intellectual Property Law, 1900–2000*, 88 *CAL. L. REV.* 2187, 2223 (2000).

attitude toward patents,”⁷⁹ and commentaries offered a range of estimates around the year 1930 for the precise starting point of this trend, from as early as 1925⁸⁰ to the late 1930s.⁸¹

The culminating point of this trend was the Supreme Court’s “infamous” 1941 decision in *Cuno Engineering Corp. v. Automatic Devices Corp.*⁸² It was in *Cuno* that the new regime “reached full maturity”⁸³ and “became clear.”⁸⁴ *Cuno* called for a “[s]trict application” of the test for invention.⁸⁵ It also contained the notorious line that a patentable invention “must reveal the flash of creative genius.”⁸⁶ The Supreme Court itself never coined a name for this new, “stricter” version of the “nonobviousness” test, preferring to insist that it was merely following the same old rules. But, taking their cue from *Cuno*, doctrinal commenters have generally referred to it as the “genius” or “flash of genius” test.⁸⁷

There was some dispute as to what legal test was actually contemplated by the phrase “flash of creative genius,” and two different views were advanced.⁸⁸ The “subjective” view interpreted this phrase to require that an invention be produced by a particular kind of mental process—a literally instantaneous “flash” of creative insight—thereby precluding protection for inventions that had been created through step-by-step experimentation.⁸⁹ On the other hand, the “objective” view construed “flash of creative genius” as merely a colorful way of saying that the standard was high, and viewed the test as simply requiring “objective” genius.⁹⁰ To the extent a judgment can be made, the “objective” interpretation seems better supported by the case law. Even in the 1940s, during the height of anti-patent sentiment on the Court, one of the few patents that every member of the Court was willing to sustain (including the anti-patent ringleaders Justices Douglas, Black, and Stone) was a patent on

79 Allen M. Krass, *Test of Patentability Under the 1952 Patent Act*, 2 WAYNE L. REV. 130, 133 (1956).

80 Donald J. Libert, *Section 103 of the Patent Act and the Standard of Invention: Comments on Lyon v. Bausch & Lomb Optical Co.*, 38 J. PAT. OFF. SOC’Y 304, 308–11 (1956).

81 Krass, *supra* note 79, at 132–33.

82 *Kitch, supra* note 16, at 323 (citing *Cuno Eng’g Corp. v. Automatic Devices Corp.*, 314 U.S. 84 (1941)).

83 Krass, *supra* note 79.

84 Prager, *supra* note 64, at 81.

85 *Cuno Eng’g Corp.*, 314 U.S. at 92.

86 *Id.* at 91.

87 *See, e.g., Kitch, supra* note 16, at 300–01; Duffy, *supra* note 16, at 18.

88 Duffy, *supra* note 16, at 18 (discussing the “subjective” and “objective” interpretations of the test of patentability).

89 *Id.*

90 *Id.*

an invention created through step-by-step experimentation.⁹¹ But, in any event, “genius” was a high bar.⁹² As Justice Jackson acidly wrote in a 1949 dissent, the Supreme Court had developed such a “strong passion” for striking down patents that “the only patent that is valid is one which this Court has not been able to get its hands on.”⁹³

Much like in the late nineteenth century, opinions of the time described the concerns underlying these changes to the standard of invention. The opinions harshly criticized perceived abuses in the patent system and characterized patents as dangerous monopolies that would impede innovation, if granted too freely. The *Cuno* opinion is the leading expression of these views, and quotes Justice Bradley’s remarks in *Atlantic Works* with approval:

Strict application of [the test for invention] is necessary lest in the constant demand for new appliances the heavy hand of tribute be laid on each slight technological advance in an art. The consequences of the alternative course were forcefully pointed out by Mr. Justice Bradley in *Atlantic Works v. Brady*: “Such an indiscriminate creation of exclusive privileges tends rather to obstruct than to stimulate invention.”⁹⁴

D. The Patent Act of 1952

The next era of invention doctrine was ushered in by the passage of the Patent Act of 1952 (1952 Act).⁹⁵ This legislation, for the first time, codified the standard of invention, and used the language of “obviousness” to do it. The statutory standard, which largely endures to this day, provided that a patent will not be granted on an invention that “would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains,” and added that “[p]atentability shall not be negated by the manner in which the invention was made.”⁹⁶ These provisions were codified at 35 U.S.C. § 103 and are often referred to as “Section 103.”

After the passage of this legislation, a debate immediately broke out among the circuit courts (and scholars) about its effect

⁹¹ See *Graver Tank & Mfg. Co. v. Linde Air Prods. Co.*, 336 U.S. 271, 274 (1949) (“[The inventors] collaborated for some six months in conducting a series of about 500 experiments in the course of which they compounded 75 different flux compositions. They finally produced the invention for which a patent was sought.”).

⁹² Duffy, *supra* note 16, at 42.

⁹³ *Jungersen v. Ostby & Barton Co.*, 335 U.S. 560, 572 (1949) (Jackson, J., dissenting).

⁹⁴ *Cuno Eng’g Corp. v. Automatic Devices Corp.*, 314 U.S. 84, 92 (1941) (citation omitted) (quoting *Atl. Works v. Brady*, 107 U.S. 192, 200 (1883)).

⁹⁵ Patent Act of 1952, Pub. L. No. 82-593, 66 Stat. 792 (codified as amended at 35 U.S.C. §§ 1–293).

⁹⁶ *Id.* § 103, 66 Stat. at 798 (codified as amended at 35 U.S.C. § 103).

on the standard of invention.⁹⁷ One view was that the 1952 Act lowered the standard of invention, turning the clock back to 1930 and undoing the prior two decades of Supreme Court precedent.⁹⁸ Another view was that the 1952 Act largely codified the existing doctrine (and the standard of patentable invention) as it stood in 1951. Under this view, the statute perhaps rejected the *subjective* version of the “genius” test (by providing that “[p]atentability shall not be negated by the manner in which the invention was made”), but it left *objective* “genius,” and the general level of patentable invention, unchanged.⁹⁹

Both sides found support in the legislative history, and ultimately the circuits split nearly evenly. Six of the eleven circuits took the position that Congress did not intend to lower the standard of patentability, but rather sought to codify preexisting case law, while the other five circuits held that Congress had intended that “the rigid test of patentability as laid down by the recent Supreme Court cases be somewhat relaxed by Section 103.”¹⁰⁰ There is some evidence that these doctrinal differences were not distinctions without a difference. The circuits’ “conflicting interpretations” were correlated with a “wide disparity in the percentage of patents being held valid—from 8% in the Eighth Circuit to 82% in the Tenth Circuit.”¹⁰¹

This dispute was never clearly resolved by the Supreme Court. The Court’s first post-1952 invention opinion—*Graham v. John Deere Co.*, issued fourteen years after the passage of the 1952 Act—confusingly seemed to point in both directions.¹⁰² Contemporary commentary described the mixed signals that the decision sent to patent lawyers:

The *Graham v. Deere* opinion generated some euphoria. It was mild and respectful of the patent system. It was free of the extreme expressions and special requirements to be found in some earlier

⁹⁷ E.g., John M. Webb, *The Changing Standard of Patentable Invention: Confusion Compounded*, 55 MICH. L. REV. 985, 990–97 (1957); Hillel Marans, *Some Aspects of the Patent Act of 1952 as Interpreted by Recently Published Decisions*, 39 J. PAT. OFF. SOC’Y 177, 189–91 (1957); Gay Chin, *The Statutory Standard of Invention: Section 103 of the 1952 Patent Act*, 3 PAT. TRADEMARK & COPYRIGHT J. RSCH. & EDUC. 317, 318–28 (1959); William J. Keating, *The Supreme Court Interprets the Patent Statute: A Trilogy of Cases and Their Effect Today*, 72 DICK. L. REV. 244, 249–50, 257–67 (1967).

⁹⁸ Chin, *supra* note 97, at 323.

⁹⁹ See *id.* at 321–22.

¹⁰⁰ *Id.* at 322; see also, e.g., Keating, *supra* note 97, at 257–65.

¹⁰¹ Keating, *supra* note 97, at 250. Of course, litigation statistics like these must be viewed with caution—cases are neither randomly selected for litigation nor randomly assigned to different circuits. But these data provide at least some evidence that the doctrinal differences were practically meaningful.

¹⁰² See *Graham v. John Deere Co.*, 383 U.S. 1 (1966).

majority and concurring opinions of the Court. . . . Further, the emphasis on *Hotchkiss v. Greenwood* tended to support a view that the Court had returned to a relatively mild test of patentability perceived by some persons as part of the “good old days.”

But other language in the *Graham v. Deere* opinion pointed in a different direction. The Court emphasized the strict standard of unobviousness, and made unkind comments on the Patent Office performance. The Court stressed its view that the level of patentability was not lowered by Section 103. . . . These and other aspects of the opinion suggest that the Court was not casting aside all of the views expressed in recent opinions on “invention” and that it continued to view the standard (however expressed) as quite severe.¹⁰³

In practice, the opinion seemed to apply a somewhat less rigorous standard than that found in pre-1952 cases. Yet, in the years after *Graham*, the Supreme Court issued several opinions that seemed to diverge from the *Graham* approach and instead return to aspects of the pre-1952 framework.¹⁰⁴ And, more generally, during these decades, the Supreme Court’s interest in supervising the circuit courts’ patent jurisprudence waned.¹⁰⁵ The Court rarely granted certiorari in patent cases, and seemed to give something less than its full attention to the cases it did take, issuing opinions that were “poorly reasoned and inconsistent.”¹⁰⁶

Absent useful guidance from the Supreme Court, the circuit courts were left to their own devices, and the split persisted, with some circuits applying a stricter regime, and others a distinctly more lenient regime. Robert L. Harmon, a then-practicing patent lawyer and later the author of an influential patent law treatise, described this period as follows:

When this author broke into the business, and for many years thereafter, it was quite clear that there was no such thing as a valid

¹⁰³ George E. Frost, *Does Section 103 Apply to “Combination” Patents?*, 5 APLA Q.J. 117, 117 (1977) (footnote omitted).

¹⁰⁴ See Herbert H. Mintz, *The Standard of Patentability in the United States—Another Point of View*, 1977 DET. COLL. L. REV. 755, 785 (arguing that *Graham* and subsequent cases created a doctrinal “[m]orass”).

¹⁰⁵ See John F. Duffy, *The Festo Decision and the Return of the Supreme Court to the Bar of Patents*, 2002 SUP. CT. REV. 273, 275.

¹⁰⁶ Jaffe & Lerner, *supra* note 7, at 99–100 (“[I]mportant differences persisted because the Supreme Court rarely heard patent-related cases. The justices were reluctant to devote their time to what they saw as banal commercial disputes. For instance, one of the few patent cases that was heard by the ‘Supremes’ during the 1970s involved a dispute over a system to flush cow manure from the floor of dairy barns. Who would get the duty of writing the opinion for this ‘cow shit case’ was a matter of considerable controversy—ultimately, it was assigned to Justice William Brennan because he had antagonized the Chief Justice with his acrid dissents in other cases. Perhaps not surprisingly, the decision that resulted in this case was poorly reasoned and inconsistent with the Supreme Court’s own earlier rulings.” (footnotes omitted)).

patent in the Eighth Circuit, and the climate in the Ninth Circuit was not much more hospitable. In the Seventh Circuit, on the other hand, patent infringement could get a client into big trouble. Each of the other circuits occupied its own bad in the enforcement spectrum.¹⁰⁷

Again, there are signs that these doctrinal differences were practically meaningful—empirical studies report that large differences in patent-validity decisions across the circuit courts persisted throughout the 1970s.¹⁰⁸

E. The Federal Circuit's "Suggestion" Test

These divisions were ultimately resolved by Congress's 1982 creation of the U.S. Court of Appeals for the Federal Circuit, a specialized court of appeals for patent cases to replace the regional circuits.¹⁰⁹ Congress was motivated by growing fears in the 1970s that divisions between the circuits and weak patent rights had undermined incentives for innovation.¹¹⁰ The new court was intended both to unify patent law by resolving disputes that the Supreme Court had left to linger, and to strengthen patent rights by selecting rules that would make patents easier to obtain and enforce.¹¹¹ Judge Newman (appointed to the Federal Circuit in 1984) described the feeling on the new court this way:

Practitioners from an earlier era well recall the adverse impact on industrial innovation when patents were not a reliable support for commercial investment, based in part on the judicial belief that patents and their practice were seriously flawed. With invalidation of most of the patents that reached the courthouse, the contribution of a diminished patent incentive to the weakening of technology-based investment was a serious national concern, and the impact on the nation's commercial vigor was recognized by government as well as by the industrial and scientific communities. The formation of the Federal Circuit Court of Appeals was part of the nation's program to restore technology-based leadership with the aid of an effective patent system.¹¹²

The Federal Circuit's first opinion, *South Corp. v. United*

¹⁰⁷ Robert L. Harmon, *Seven New Rules of Thumb: How the Federal Circuit Has Changed the Way Patent Lawyers Advise Clients*, 14 GEO. MASON U. L. REV. 573, 574 (1992).

¹⁰⁸ See Matthew D. Henry & John L. Turner, *The Court of Appeals for the Federal Circuit's Impact on Patent Litigation*, 35 J. LEGAL STUD. 85, 99–103 (2006).

¹⁰⁹ See Federal Circuit Improvements Act of 1982, Pub. L. No. 97-164, 96 Stat. 25 (codified as amended in scattered sections of 28 U.S.C.).

¹¹⁰ See Rochelle Cooper Dreyfuss, *The Federal Circuit: A Case Study in Specialized Courts*, 64 N.Y.U. L. REV. 1, 6–7 (1989).

¹¹¹ *Id.*; see also Lemley, *supra* note 1, at 7 (“[T]he Federal Circuit was created in 1982 with a mission to strengthen patent rights.”).

¹¹² *Ferring B.V. v. Barr Lab'ys, Inc.*, 437 F.3d 1181, 1195–96 (2006) (Newman, J., dissenting) (citation omitted).

States, adopted as precedent the body of opinions that had been issued by the Court of Customs and Patent Appeals (CCPA), the specialized court that previously heard appeals from the PTO (a duty taken over by the Federal Circuit).¹¹³ The CCPA had always been a pro-patent venue, which arguably never followed *Cuno* in the first place, and certainly had not done so after the 1952 Act.¹¹⁴ *South Corp.* therefore rejected a “strict” standard of invention in the Federal Circuit, a message reinforced by early opinions that were sharply critical of the Supreme Court’s patent jurisprudence.¹¹⁵

The Federal Circuit then gradually developed a new rule of evidence—known as the “suggestion” test or the “teaching-suggestion-motivation” test—that further lowered the effective standard of invention.¹¹⁶ In obviousness cases, the defendant typically argues that the patented invention is a *combination* of elements that are found separately in the prior art, and a key question is accordingly whether combining these elements to form the invention would have been an obvious idea. The “suggestion” test limits the evidence that can be used to answer this question. In particular, it emphasizes the need for written materials—like patents or published technical articles—dated before the discovery of the invention, that “suggest[]” (or “teach[]” or “motivate[]”) the combination.¹¹⁷ And by the same token, it limits arguments based on non-written evidence, such as testimony about the general knowledge and common sense of technical workers in the field or the commercial incentives that existed at the time of the invention.

Like many rules of evidence, the “suggestion” test comes with a tradeoff.¹¹⁸ On the one hand, it reduces the danger of “hindsight bias,” that is, the chance that a judge or jury will incorrectly conclude that the invention was obvious.¹¹⁹ On the other hand, it demands evidence that may not exist in some cases. This is

¹¹³ *South Corp. v. United States*, 690 F.2d 1368 (Fed. Cir. 1982) (en banc).

¹¹⁴ See Keating, *supra* note 97, at 262–63 (“*A & P* and *Cuno* are not even suggested by this court.”).

¹¹⁵ See, e.g., *Union Carbide Corp. v. Am. Can Co.*, 724 F.2d 1567, 1574 n.4 (Fed. Cir. 1984) (referring to Supreme Court patent doctrines as “cliché[s] which this court has rejected”).

¹¹⁶ Duffy, *supra* note 16, at 62–65; see also Robert W. Harris, *Prospects for Supreme Court Review of the Federal Circuit Standards for Obviousness of Inventions Combining Old Elements*, 68 J. PAT. & TRADEMARK OFF. SOC’Y 66, 71–74 (1986) [hereinafter Harris, *Prospects for Supreme Court Review*]; Robert W. Harris, *Critique of the Federal Circuit’s Suggestion Test for Obviousness*, 72 J. PAT. & TRADEMARK OFF. SOC’Y 990, 991 (1990) [hereinafter Harris, *Critique of the Federal Circuit’s Suggestion Test*].

¹¹⁷ *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 419 (2007) (noting that the test emphasized “published articles and the explicit content of issued patents”).

¹¹⁸ See Duffy, *supra* note 16, at 63–65.

¹¹⁹ See *id.* at 64–65.

particularly likely to be true in fast-moving areas of new technology, where obvious ideas “in the air” have not yet been reduced to writing, and inventors instead exploit new opportunities by following common sense and commercial incentives.

Much like earlier changes in the law, the “suggestion” test was established incrementally through a series of cases. It was first mentioned in Federal Circuit opinions issued in 1983.¹²⁰ The test was then applied and developed in a series of cases throughout the 1980s, and by the end of the decade, commenters were prepared to recognize that it had crystallized into a new rule of “general applicability” in patent cases that represented a “more liberal, pro-patentee” approach.¹²¹ The “suggestion” test remained the governing rule through the early 2000s (although some commenters have argued that different Federal Circuit opinions seemed to take different positions on just how strictly the test should be applied).¹²²

F. *KSR International Co. v. Teleflex Inc.*

The sixth (and final) era of invention doctrine was inaugurated by renewed fears and complaints in the late 1990s and early 2000s that strong patent rights once again seemed to be hindering, rather than promoting, innovation. Lemley gives the following account:

These complaints shared a worry that two decades of strengthening patents had led to a wave of bad patents approved by the PTO in the 1990s and asserted in the 2000s; to a pervasive problem of patent holdup as companies faced hundreds of suits, each with the potential to shut down its core product; and to a flood of suits by nonpracticing entities (NPEs), or “patent trolls,” that took advantage of plaintiff-friendly rules to extract more money than they deserved.¹²³

¹²⁰ See Harris, *Prospects for Supreme Court Review*, *supra* note 116, at 72.

¹²¹ Harris, *Critique of the Federal Circuit’s Suggestion Test*, *supra* note 116; see also Harmon, *supra* note 107, at 575 (“[T]he task facing the patent challenger has been made even more difficult by the court’s insistence, in a dozen or more cases, that there must be something in the prior art as a whole to suggest the desirability, and thus the obviousness, of making a combination of prior art references. It is impossible for a patent lawyer of reasonable experience to read these cases without concluding that obviousness is a much more problematic defense than it was a decade ago.” (footnote omitted)); Dreyfuss, *supra* note 110, at 16 (commenting, in 1989, that the Federal Circuit had begun to apply a new “teaching, suggestion, or inference” test).

¹²² See, e.g., Joshua McGuire, *Nonobviousness: Limitations on Evidentiary Support*, 18 BERKELEY TECH. L.J. 175, 179 (2003); Rebecca S. Eisenberg, *Obvious to Whom? Evaluating Inventions from the Perspective of PHOSITA*, 19 BERKELEY TECH. L.J. 885, 894–96 (2004).

¹²³ Lemley, *supra* note 1, at 9–10 (footnotes omitted).

These concerns were captured in a pair of reports—one from the Federal Trade Commission in 2003,¹²⁴ and another from the National Research Council in 2004¹²⁵—both of which called for the Federal Circuit’s “suggestion” test to be struck down.

Three years later, the Supreme Court acted. Its 2007 opinion, *KSR International Co. v. Teleflex Inc.*, reversed the “suggestion” test, reasoning that “[t]he obviousness analysis cannot be confined by a formalistic conception of the words teaching, suggestion, and motivation, or by overemphasis on the importance of published articles and the explicit content of issued patents,” and that “[g]ranting patent protection to advances that would occur in the ordinary course without real innovation retards progress.”¹²⁶

The impact of this decision was largely to unwind the Federal Circuit’s case law of the 1980s, and return patent law to its pre-“suggestion” (and pre-“genius”) focus on simple “nonobviousness.”¹²⁷ In the early twenty-first century, patent law asked largely the same question that had been asked by the original late nineteenth- and early twentieth-century “nonobviousness” cases: whether an invention involves “something more than what is obvious to persons skilled in the art to which it relates.”¹²⁸

III. TECHNOLOGICAL THEORY

A. Literature

The technological theory is that these shifts in the standard of invention are explained by underlying changes in the “pace of technological advance.”¹²⁹ This section explains the technology theory, as it has been presented in the existing literature.

The first account of this theory seems to be the one found in Judge William K. Townsend’s 1901 history of U.S. patent law in

¹²⁴ FED. TRADE COMM’N, TO PROMOTE INNOVATION: THE PROPER BALANCE OF COMPETITION AND PATENT LAW AND POLICY (2003), <https://www.ftc.gov/sites/default/files/documents/reports/promote-innovation-proper-balance-competition-and-patent-law-and-policy/innovationrpt.pdf> [<https://perma.cc/5VAZ-3DNN>].

¹²⁵ NAT’L RSCH. COUNCIL, A PATENT SYSTEM FOR THE 21ST CENTURY (Stephen A. Merrill et al. eds., 2004).

¹²⁶ *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 419 (2007).

¹²⁷ Duffy, *supra* note 16, at 68.

¹²⁸ *Id.* at 41 (quoting *Pearce v. Mulford*, 102 U.S. 112, 118 (1880)) (noting that the most common late nineteenth- and early twentieth-century formulations were “quite similar to the modern standard,” “nearly identical to the modern statute,” and “very close to the modern nonobviousness test”).

¹²⁹ Kitch, *supra* note 16, at 304.

the eighteenth and nineteenth centuries.¹³⁰ Townsend himself served as a federal district judge in Connecticut during the late nineteenth century (and had experience with patent cases),¹³¹ and his goal was to explain the rise of the new “nonobviousness” regime in the post-Civil War period. Townsend’s account of the rise of this doctrine is so interesting (and remains unsurpassed as a firsthand description of these events), that it is worth quoting at length:

[O]ur courts . . . and the inventor have grown wiser by reason of the lessons of the latter half of the nineteenth century.

Coincident with the development of our industries came the great inventions of the century just closed, steam-power, cotton-gins, looms, manufacturing machinery, india-rubber, mowing-machines, reapers, telegraphs, telephones, electric motors and lights; each primary invention opening up a vast field of undeveloped possibilities. . . .

Then after each principal pioneer invention followed a great host of minor improvements. . . . [I]n this lesser field of minor inventions, artisans, by means of patents for mere modifications, prevented others from making or using obvious improvements on existing devices. . . .

At length, when the inventive field became so crowded with secondary patents that there was no standing room for an inventor, and no pathway open for forward progress to the workman or the public, the courts undertook to find a remedy for this evil. They began to hold that the mere production of something shown not to have been made before did not of itself furnish consideration for a monopoly, but that such production must have required invention in order to entitle it to the protection of the patent law

Between the years 1880 and 1890, the Supreme Court repeatedly asserted this doctrine, applying it in the case of new forms of manufacture and new combinations of existing devices having superior utility but not requiring inventive conception.¹³²

The essence of Townsend’s theory is that the problems in the patent system of the late nineteenth century—a “crowded” field of overlapping patents that blocked innovation—were traceable to the new technological opportunities opened up by the “primary invention[s]” of the nineteenth century.¹³³ In a period of slow progress, like the early nineteenth century, when new ideas were scarce, the patent system could afford to grant patents freely on

¹³⁰ TOWNSEND, *supra* note 16.

¹³¹ Indeed, a Townsend opinion is cited by the famous Walker patent law treatise as a leading application of the new nonobviousness doctrine. WALKER, *supra* note 66 (“Judge Townsend has said that an electrical patent should be stripped of the dazzling halo which conventionally adorns appliances designed to deal with that mysterious agent, electricity; when a court is called on to decide the question of the presence or absence of invention, in an electrical patent.”).

¹³² TOWNSEND, *supra* note 16, at 395–96.

¹³³ *Id.*

almost any new device. However, the conditions of technological ferment and rapid technological progress in the late nineteenth century demanded a stricter approach, and the courts reacted.

Certainly, there seemed to be no shortage of complaints about conflicting patent rights in the late nineteenth century. Railroads complained that train cars had become covered by so many overlapping, conflicting patents (on the components of the engines, the brakes, the wheels, and so on) that it was impossible to clear the rights.¹³⁴ Farmers complained that the same situation prevailed with the new agricultural machinery—no one could plow a field without the fear of patent infringement, and ruthless “patent sharks” exploited the situation by filing vexatious patent infringement lawsuits against farmers.¹³⁵ And, more generally, the new industries of the late nineteenth century (railroads, rubber, electricity, and others) fought a series of protracted “patent wars” in these decades.¹³⁶

At least three later histories of this period seem to have independently come to similar conclusions as Townsend. Kitch’s 1966 history of the “nonobviousness” doctrine argues that the adoption of this doctrine in the late nineteenth century could only be explained by the “non-legal forces at work in the country after the Civil War,” and pointed to the “quickenning pace of technological advance, particularly after the Civil War,” reasoning that “as the pace of obsolescence in a society quickens, the standard of invention must be raised lest every common product be the subject of a patent monopoly.”¹³⁷ B. Zorina Khan’s 2004 history of changes in patent institutions during the nineteenth century contends that “[t]he heightened [obviousness] standards likely functioned as a more effective filter in view of the great increase in patenting rates and technical qualifications among the population during the postbellum period.”¹³⁸ And, lastly, Duffy’s

¹³⁴ *E.g.*, Steven W. Usselman, *Patents Purloined: Railroads, Inventors, and the Diffusion of Innovation in 19th-Century America*, 32 *TECH. & CULTURE* 1047, 1063 (1991) (“[T]he Patent Office had created a complex web of claims that would baffle attorneys for decades.”); STEVEN W. USSELMAN, *REGULATING RAILROAD INNOVATION: BUSINESS, TECHNOLOGY, AND POLITICS IN AMERICA, 1840–1920*, at 104–10 (2002); Christopher Beauchamp, *The First Patent Litigation Explosion*, 125 *YALE L.J.* 848, 929–30 (2016).

¹³⁵ *E.g.*, Earl W. Hayter, *The Patent System and Agrarian Discontent, 1875–1888*, 34 *MISS. VALLEY HIST. REV.* 59, 62–66 (1947) (“The farmers had neither the time, money, nor skill ‘to wade through this vast labyrinth of inventions.’”); Beauchamp, *supra* note 134, at 925–26.

¹³⁶ B. Zorina Khan, *Trolls and Other Patent Inventions: Economic History and the Patent Controversy in the Twenty-First Century*, 21 *GEO. MASON L. REV.* 825, 841 (2014).

¹³⁷ Kitch, *supra* note 16, at 304–05, 320.

¹³⁸ Khan, *supra* note 16, at 16–17.

2007 history asserts that “[t]he obviousness doctrine will be least important in societies where: (1) patent rights are expensive to obtain and to enforce, (2) the pace of social change is relatively slow, (3) few inventors are likely to be working on similar projects, and (4) patent rights are kept relatively narrow,” and that, as social and technological conditions changed during the nineteenth century, the need for this doctrine grew more dire.¹³⁹

These accounts are focused on the late nineteenth century, but other evidence suggests that the same dynamics—major technological breakthroughs followed by periods of concern about conflicting rights in the patent system—have occurred in the twentieth and twenty-first centuries as well. For example, economic historians David Mowery and Nathan Rosenberg argue that technological progress during the middle decades of the twentieth century was driven in substantial part by three “central clusters” of basic innovations: “the internal combustion engine, electricity (including electronics), and chemistry.”¹⁴⁰ Contemporary sources reported similar intellectual-property conflicts in these industries, and drew similar lessons. For example, Sylvester Petro, after describing intractable patent conflicts in the new chemicals industry,¹⁴¹ concluded: “In a developing technology there may be hundreds of important patents to be reckoned with,” and “[i]t is often impossible to tell which patents are the key patents in a complex and rapidly growing art. . . .”¹⁴² The result is that “the holder of any patent, if he has weight and swings it properly, may block a whole line of development; and even if no conscious attempt at frustration is made, the mere presence of conflicting, legally enforceable rights makes for confusion and obstruction.”¹⁴³

¹³⁹ Duffy, *supra* note 16, at 17–18.

¹⁴⁰ David Mowery & Nathan Rosenberg, *Twentieth-Century Technological Change*, in 3 THE CAMBRIDGE ECONOMIC HISTORY OF THE UNITED STATES: THE TWENTIETH CENTURY 803, 807 (Stanley L. Engerman & Robert E. Gallman eds., 2000); see also Alexander J. Field, *The Most Technologically Progressive Decade of the Century*, 93 AM. ECON. REV. 1399, 1399 (2003); *Investigation of Concentration of Economic Power: Hearings Before the Temp. Nat'l Econ. Comm.*, 76th Cong. 16207 (1940) (statement of Joseph O'Mahoney, Chairman, Temp. Nat'l Econ. Comm.) (“[T]he 10 years since the crash of 1929 have probably seen the establishment of more new industries and greater technological gains in old industries than any decade since the human race first began to measure time.”).

¹⁴¹ Sylvester Petro, *Patents: Judicial Developments and Legislative Proposals*, 12 U. CHI. L. REV. 352, 388 (1945) (“The foregoing situation was simple and innocuous in comparison with the one recently prevailing in the synthetic rubber field.”).

¹⁴² *Id.* at 390.

¹⁴³ *Id.*

Similarly, today's revolutionary advances have been concentrated in computers and biotechnology.¹⁴⁴ And modern accounts of problems in the patent system have once again focused on very similar concerns in these industries—"thickets"¹⁴⁵ or "anticommons" of conflicting patent rights that block innovation.¹⁴⁶

More broadly, historians of technology have often argued that technological progress is driven by major breakthroughs ("macroinventions" or "general purpose technologies") that temporarily open up new opportunities for rapid sequences of cumulative invention.¹⁴⁷ For example, Joel Mokyr argues that "[t]he chief importance of radical inventions is that they raise the marginal product of effort in development, and thus lead to a sequence of further improvements," and "[a]n implication of this theory is that, in periods of radical inventions, we observe an intensification of smaller inventions as well."¹⁴⁸ Eventually, the opportunities created by a basic breakthrough run into diminishing returns, and progress slows, until the next breakthroughs come along to restock the larder. Accordingly, over time, the opportunities for innovation, and the pace of technological progress, tend to fluctuate, driven by the "randomness associated with the discovery of great inventions."¹⁴⁹ The claim of the technological theory is that these underlying movements in technological conditions lie behind the recurring cycles in patent law.

B. Model

The goal of this section is to present a model that captures the essential empirical claim of the technological theory—changes in the standard of invention have consistently followed behind

¹⁴⁴ *E.g.*, ALFRED D. CHANDLER JR., *INVENTING THE ELECTRONIC CENTURY* 132–76 (2001) (describing the "microprocessor revolution"); Klaus Buchholz & John Collins, *The Roots—A Short History of Industrial Microbiology and Biotechnology*, 97 *APPLIED MICROBIO. & BIOTECH.* 3747, 3757 (2013) ("[A] large number of significant scientific breakthrough events as well as technological progress provided a new basis for [biotechnology].").

¹⁴⁵ Carl Shapiro, *Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting*, in 1 *INNOVATION POLICY AND THE ECONOMY* 119, 119 (Adam B. Jaffe, Josh Lerner & Scott Stern eds., 2001).

¹⁴⁶ Michael A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 *SCI.* 698, 698 (1998).

¹⁴⁷ *E.g.*, Mokyr, *supra* note 17, at 351–52; Bresnahan & Trajtenberg, *supra* note 17, at 84; *see also, e.g.*, Zvi Griliches, William D. Nordhaus & F. M. Scherer, *Patents: Recent Trends and Puzzles*, 1989 *BROOKINGS PAPERS ECON. ACTIVITY: MICROECON.* 291, 324–25 (Nordhaus comments); Nathan Rosenberg, *Technological Interdependence in the American Economy*, 20 *TECH. & CULTURE* 25, 26–32 (1979).

¹⁴⁸ Mokyr, *supra* note 17, at 352.

¹⁴⁹ *See* Griliches, *supra* note 147.

underlying changes in the pace of technological progress. There are two key features of the legal history, as described in the prior section,¹⁵⁰ that any adequate model of this claim would need to capture:

1. **The Role of Precedent.** The theory is that the standard of invention has been influenced by the rate of technological progress. However, changes in the rate of technological progress have not *instantaneously* translated into legal change. Instead, the legal standard has evolved gradually, through a common-law-like legal process, where judges are influenced by the existing body of precedent.¹⁵¹ In other words, in each year, judges give some weight to established precedents and only gradually and incrementally depart from them as new conditions require. For example, Townsend tells us that, in the late nineteenth century, the standard of invention did eventually rise under the pressure of new technological conditions, but only “[a]t length.”¹⁵² Accordingly, the legal standard applied in a particular year is generally not independent of the law in the prior year. Instead, the legal standard applied by judges in any given year will generally be a *mixture* of both: (a) the standard established by prior cases (which carry the force of precedent), and (b) current technological conditions (which may push the law in new directions).
2. **The Available Observations of Legal Change.** Although the law has evolved through a series of small, incremental steps, which gradually raise or lower the legal standard, a challenge is that it is not generally possible to precisely quantify the incremental change in the law in each year, i.e., to say that the standard of invention in 1872 was precisely X increments higher than the standard in 1871.¹⁵³ Instead, the available “observations” of legal change are the broader judgments made by doctrinal commenters about when the process of gradual legal change has gone far enough to qualify as a change in regime. In other words, these commenters watch the development of the law and report when the doctrine has departed sufficiently far from the old baseline to enter a new regime; for example, in the late nineteenth century,

¹⁵⁰ See *supra* Part II.

¹⁵¹ See *supra* Part II.

¹⁵² See Townsend, *supra* note 16, at 396.

¹⁵³ See *supra* Part II.

the law transitioned from the “substantial novelty” regime to the “nonobviousness” regime. And the property these reported regimes have is a *relative* ranking as stricter or more lenient.

A natural framework, capable of capturing both of these features, is the dynamic ordered probit.¹⁵⁴ This framework was originally introduced by Barry Eichengreen, Mark Watson, and Richard Grossman to study the influence of economic conditions on central-bank policy decisions and has been extended by a number of other papers.¹⁵⁵ It has never been used to model the evolution of a legal standard. However, the key features of the problems are relevantly similar. In particular, as applied here, the model has three essential parts.

The first is the actual standard of invention applied by courts in year t , which can vary continuously over time. In other words, if a patent lawsuit were filed, and a judge (or jury) had to decide whether the asserted patent was valid, this is the standard that would be applied. This standard (y_t^*) is defined as follows:

$$y_t^* = \theta y_{t-1}^* + \beta R_t + \varepsilon_t, \quad \varepsilon_t \sim N(0,1), i. i. d.$$

The definition says that the legal standard applied in each year is a function of three things: (1) the legal standard applied in the prior year (y_{t-1}^*), whose precedential force is determined by the coefficient θ (theta), (2) the current rate of technological progress (R_t), whose influence on the law is determined by the coefficient β (beta), and (3) a random error (ε_t) (epsilon). This definition captures the process of common-law legal change—it allows movements in the rate of technological progress to gradually influence the direction in which the doctrine evolves over time. As a stationarity condition (and realistic description of the force of precedent), $\theta < 1$.

The second part of the model is the legal regime reported by doctrinal commenters in year t (Y_t). Commenters have used three core legal regimes to describe the evolution of the standard of invention: (1) “substantial novelty” (lowest standard); (2) “nonobviousness” (intermediate standard); and (3) “genius”

¹⁵⁴ See Eichengreen, Watson & Grossman, *supra* note 30, at 733–35.

¹⁵⁵ See *id.*; see also Michael Dueker, *Conditional Heteroscedasticity in Qualitative Response Models of Time Series: A Gibbs-Sampling Approach to the Bank Prime Rate*, 17 J. BUS. & ECON. STAT. 466, 466–69 (1999); Marcelle Chauvet & Simon Potter, *Forecasting Recessions Using the Yield Curve*, 24 J. FORECASTING 77, 77–85 (2005); Sebastian Fossati, *Dating U.S. Business Cycles with Macro Factors*, 20 STUD. NONLINEAR DYNAMICS & ECONOMETRICS 529, 534 (2016).

(highest standard).¹⁵⁶ However, as the earlier historical discussion also illustrated, these three categories are not quite a rich enough language to capture the judgments made by doctrinal commenters.¹⁵⁷ In particular, commenters have often described the law as spending extended periods of time *in between* these regimes—for example, the period of gradual transition from “substantial novelty” to “nonobviousness” in the late nineteenth century, or the period of division between the circuits following the passage of the Patent Act of 1952. Accordingly, the model will use five categories to represent the legal judgments made by doctrinal commenters about the state of the law in each year (labeled 1–5), which allow the doctrine to be in one of three core legal regimes or between them:

1 = “substantial novelty”

2 = in between “substantial novelty” and “nonobviousness”

3 = “nonobviousness”

4 = in between “nonobviousness” and “genius”

5 = “genius”

Finally, there is a set of four cutpoints (c_1, c_2, c_3, c_4) that map the exact legal standard applied by courts in each year (y_t^*) to the legal regime reported by doctrinal commenters (Y_t):

$Y_t = 1$ if $y_t^* < c_1$

$Y_t = 2$ if $c_1 \leq y_t^* < c_2$

$Y_t = 3$ if $c_2 \leq y_t^* < c_3$

$Y_t = 4$ if $c_3 \leq y_t^* < c_4$

$Y_t = 5$ if $c_4 \leq y_t^*$

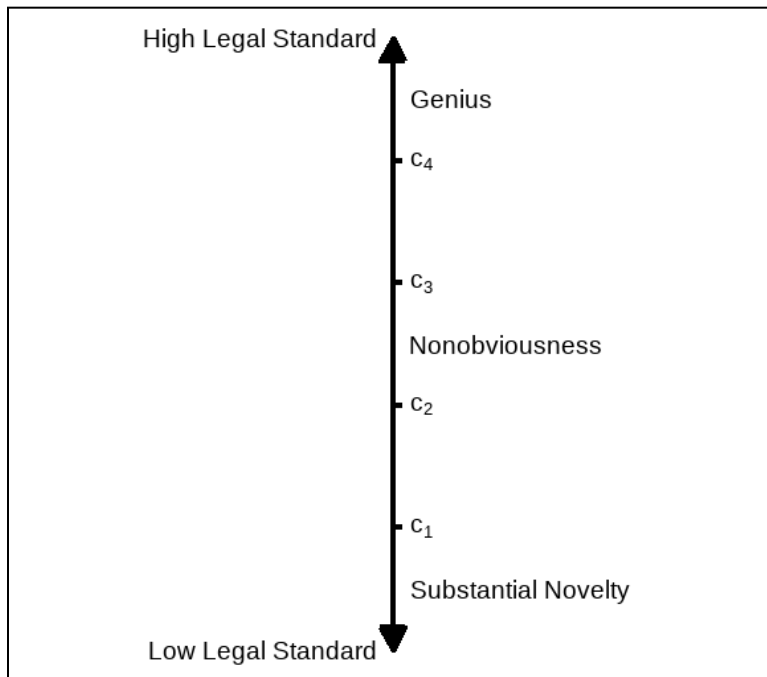
Figure 1 (below) represents these cutpoints visually. The cutpoints capture the nature of the observation process. Doctrinal commenters observe the evolution of the legal standard over time and classify the law in each year as falling into a particular legal regime based on the strictness of the standard applied by courts.¹⁵⁸ In so doing, commenters distinguish between “minor” fluctuations in the legal standard, which are not large enough to qualify as a regime change, and “major” movements, which do qualify as a jump into a new regime.¹⁵⁹ The cutpoints define *how much* movement in the underlying legal standard (y_t^*) is enough to qualify as a change in regime (Y_t).

¹⁵⁶ See *supra* Part II.

¹⁵⁷ See *supra* Part II.

¹⁵⁸ See *supra* Part II.

¹⁵⁹ See, e.g., Prager, *supra* note 64, at 81.

Figure 1: Cutpoints

Within this modeling framework, the data are: (1) the rate of technological progress in each year (R_t), and (2) the legal regime reported by doctrinal commenters in each year (Y_t). And the parameters to estimate are the coefficient on the rate of technological progress (β), the coefficient on the prior legal standard (θ), and the cutpoints (c_1 , c_2 , c_3 , c_4).

V. DATA

A. Rate of Technological Progress

To measure the rate of technological progress in each year (R_t), this Article relies on the two “traditional,”¹⁶⁰ “standard”¹⁶¹ long-run, quantitative measures of technological progress that have been developed by economic historians: (1) rate of productivity growth, and (2) number of technologically significant patents issued by the USPTO.

¹⁶⁰ See ROBERT J. GORDON, *THE RISE AND FALL OF AMERICAN GROWTH* 537 (2016) (noting that productivity growth is the “traditional” general-purpose measure of the pace of technological progress).

¹⁶¹ See Moser, *supra* note 2, at 23–24 (“[P]atent counts have become the standard measure of innovation.”).

The rate of productivity growth measures changes in the efficiency of the economy over time, which is a measure of better technology in the broad sense.¹⁶² And each invention issued by the USPTO represents, at least in theory, a new technology. Of course, not all patents are created equal—some are important, most are irrelevant. The standard measure of technological significance among patents is citation count (more highly cited patents are likely to be more technologically central).¹⁶³ A challenge is that citation data is only available for recent decades. However, a new line of work measures technological significance in a new way, using high-dimensional text analysis to identify patents that introduce new, influential, technical terms.¹⁶⁴ For example, by this metric, the first patent to introduce the term “alternating current” would score highly—the term is both novel (not used in prior patents) and influential (used in many future patents)—which captures basic new ideas entering the patent system. This measure (dubbed “breakthrough patents”)¹⁶⁵ is available over the long term, reaching back to the mid-nineteenth century. And the number of these patents in force in each year plausibly captures the mechanism of the technological theory—clusters of “primary invention[s]” that create new technological opportunities.¹⁶⁶

In particular, the two measures of technological progress the Article will use are:

1. The rate of productivity growth in each year
2. The number of “breakthrough patents” in force in each year (scaled per capita)

The merits of productivity growth and patenting as measures of technological progress have been much debated, and neither measure is perfect.¹⁶⁷ For example, productivity growth likely captures a somewhat broader notion of technology than the universe of merely *patentable* technology. And text-based measures of technological significance need to account for complex changes in the way language has been used across a two-century patent corpus. However, reassuringly, the two measures are

¹⁶² See Nicholas Crafts & Pieter Woltjer, *Growth Accounting in Economic History: Findings, Lessons and New Directions*, 35 J. ECON. SURVS. 670, 672 (2021) (“[Total Factor Productivity] is usually interpreted as a measure of technology, summarizing how intensively and efficiently inputs are used in production.”).

¹⁶³ See Moser, *supra* note 2, at 23–24.

¹⁶⁴ Bryan Kelly et al., *Measuring Technological Innovation over the Long Run*, 3 AM. ECON. REV.: INSIGHTS 303, 303 (2021).

¹⁶⁵ *Id.* at 305.

¹⁶⁶ Townsend, *supra* note 16, at 395; see *supra* Section III.A.

¹⁶⁷ See *generally* Crafts & Woltjer, *supra* note 162, at 670–71; Moser, *supra* note 2, at 23–24.

positively correlated—a higher number of technologically significant patents predicts higher productivity growth.¹⁶⁸ To the extent these measures agree, it is plausible that they are picking up a shared notion of technological progress that is both economically meaningful and relevant to the patent system.

The full details of the data are described in Appendix A. Productivity data for the nineteenth century is available from Abramovitz,¹⁶⁹ and productivity data for the twentieth century is available from three sources: (1) Alexander J. Field,¹⁷⁰ (2) Robert J. Gordon,¹⁷¹ and (3) Gerben Bakker, Nicholas Crafts, and Pieter Woltjer.¹⁷² Accordingly, there are three potential productivity series available for the entire period, using the Abramovitz data for the nineteenth century and one of three possible sources for the twentieth century:

1. Abramovitz + Field
2. Abramovitz + Gordon
3. Abramovitz + Bakker

In total, each series covers the period 1800–2007. For the reasons described in Appendix A, the Field data is the best fit for the Article’s analysis. However, the Article will estimate model with the other series as robustness checks. Data for “breakthrough patents” is available from Kelly et al.¹⁷³ The series for the number of “breakthrough patents” in force runs from 1856–2002.

B. Doctrinal Coding

To measure the legal regime in each year (Y_t), the Article codes the law in each year as falling into one of the five categories of the model:

- 1 = “substantial novelty”
- 2 = between “substantial novelty” and “nonobviousness”
- 3 = “nonobviousness”
- 4 = between “nonobviousness” and “genius”
- 5 = “genius”

¹⁶⁸ See Kelly et al., *supra* note 164.

¹⁶⁹ Moses Abramovitz, *The Search for the Sources of Growth: Areas of Ignorance, Old and New*, 53 J. ECON. HIST. 217, 228 tbl.2 (1993).

¹⁷⁰ ALEXANDER J. FIELD, A GREAT LEAP FORWARD 149 tbl.6.1 (2011).

¹⁷¹ Robert J. Gordon, *Revisiting U.S. Productivity Growth over the Past Century with a View of the Future* 44 tbl.8 (Nat’l Bureau of Econ. Rsch., Working Paper No. 15834, 2010).

¹⁷² Gerben Bakker, Nicholas Crafts & Pieter Woltjer, *The Sources of Growth in a Technologically Progressive Economy: The United States, 1899–1941*, 129 ECON. J. 2267, 2280 tbl.4 (2019).

¹⁷³ Kelly et al., *supra* note 164, at 315 fig.4.

To carry out the coding, the Article relies on the judgments of doctrinal commenters about the state of the law in each year, which were described in the history section above.¹⁷⁴ Based on that history, most coding decisions are straightforward. However, three questions deserve special comment. This section will discuss each one, then present the coding scheme as a whole.

1. Transition Dates

One challenge is that many of the transitions between legal regimes were gradual, incremental processes accomplished through a series of cases.¹⁷⁵ Accordingly, there is sometimes room for reasonable disagreement about the precise beginning or ending dates of these transitions. In particular, there are four such transition dates where the record of doctrinal commentary leaves open a range of possible views:

- The beginning of the transition to “nonobviousness” in the late nineteenth century might have occurred as early as 1870 or as late as 1875.¹⁷⁶
- The end of the transition to “nonobviousness” in the late nineteenth century might have occurred as early as 1880 or as late as 1885.¹⁷⁷
- The beginning of the transition to “genius” in the early twentieth century is most commonly described as occurring around 1930 but has been dated as early as 1925 or as late as 1939.¹⁷⁸
- The Federal Circuit’s “suggestion” test first appeared in cases in 1983, was then gradually developed through a series of cases, and had clearly ripened into a new “general” rule by the end of the 1980s—and therefore might be regarded as established at any point in between 1983 and 1990.¹⁷⁹

This Article’s approach to these timing questions is the following. First, it creates a “main” coding scheme, using the central values of the ranges identified by doctrinal commentary. For example, the beginning of the nineteenth-century transition to “nonobviousness” is coded as occurring in 1873 (between 1870

¹⁷⁴ See *supra* Part II.

¹⁷⁵ See *supra* Part II.

¹⁷⁶ See *supra* Section II.B.

¹⁷⁷ See *supra* Section II.B.

¹⁷⁸ See *supra* Section II.C.

¹⁷⁹ See *supra* Section II.E.

and 1875). Second, the Article then creates pairs of “alternative” coding choices for each date, capturing the outer boundaries of uncertainty. For example, the beginning of the nineteenth century transition to “nonobviousness” is coded as occurring in either 1870 or 1875—the earliest and latest dates identified by commentary.

2. Post-1952 Circuit Divisions

A second question is how to code the decades following the enactment of the Patent Act of 1952. The key feature of this period was persistent division between the circuit courts of appeal.¹⁸⁰ Some circuits subscribed to the view that the 1952 Act had overturned the strict Supreme Court precedents of the prior decades and wound the clock back to the pre-1930 era (Category 3 in Table 1, located at the end of this section), while other circuits held that this legislation had instead largely codified the strict legal standard of the 1940s (Category 5). And litigants might face different legal rules depending on the circuit in which their case was filed.

This Article’s approach is to code these years as Category 4, placing them somewhere between Category 3 and Category 5. This coding choice captures the “average” or “expected” state of the law. In these years, litigants competed to get cases filed in their favored circuits but had some chance of encountering either regime.

3. The Federal Circuit’s “Suggestion” Test

The final question is where to place the Federal Circuit’s “suggestion” test in the coding scheme. The source of uncertainty here is simply thin commentary. This test is generally described as a lenient, “pro-patentee” version of “nonobviousness.”¹⁸¹ However, to the author’s knowledge, no commentary tries to comprehensively rank and compare it to the other standards. For example, Duffy’s commentary contains a table setting forth and ranking the core legal regimes used by courts, but the “suggestion” test does not have its own entry in this table.¹⁸²

This Article’s approach is the following. First, by far the most natural coding choice is to place the “suggestion” test in Category 2, i.e., somewhere between “substantial novelty” (Category 1) and “nonobviousness” (Category 3). This coding choice captures the idea that the “suggestion” test is a more lenient, pro-patentee

¹⁸⁰ See *supra* Section II.C.

¹⁸¹ E.g., Harris, *Critique of the Federal Circuit’s Suggestion Test*, *supra* note 116.

¹⁸² Duffy, *supra* note 16, at 18.

version of the “nonobviousness” regime, but does not go so far as to overturn the “nonobviousness” regime altogether. The Article uses this coding choice for the main coding scheme.

However, as alternatives, it also considers Category 1 and Category 3. At one end of the spectrum, perhaps it could be argued that the “suggestion” test was so extreme, and limited the available evidence of “nonobviousness” so extensively, as to be effectively indistinguishable from the “substantial novelty” regime of the early nineteenth century (and is therefore properly coded as Category 1). Or, at the other end of the spectrum, perhaps it could be argued that the “suggestion” test had little practical importance—it was a mere rule of evidence—and was therefore hardly distinguishable from normal “nonobviousness” (and is properly coded as Category 3). To be clear, in this author’s view, neither choice seems like a plausible judgment about the doctrinal history. The “suggestion” test is stricter than normal “nonobviousness,” but still maintains the core requirement for originality (unlike “substantial novelty”). However, the alternate coding choice makes it possible to check what the implications of other judgments would be.

4. Coding Scheme

The main coding scheme is shown in Table 1 below. It covers the years 1800–2007, since that is the time period for which technological data is available.¹⁸³

Additionally, there are five total pairs of potential alternative coding choices¹⁸⁴:

- The beginning of the nineteenth century transition to “nonobviousness” could be coded as occurring in 1870 or 1875.
- The end of the nineteenth century transition to “nonobviousness” could be coded as occurring in either 1880 or 1885.
- The beginning of the twentieth century transition to “genius” could be coded as occurring in either 1925 or 1939.
- The Federal Circuit’s “suggestion” test could be coded as established in either 1983 or 1990.
- The Federal Circuit’s “suggestion” test could be coded as either Category 1 or Category 3.

¹⁸³ See *supra* Section IV.A.

¹⁸⁴ See *supra* Section IV.B.1–3.

One wrinkle is that the results could be insensitive to any *individual* alternative coding choice but would be sensitive to *combinations* of them. Accordingly, this Article checks the combinations. The set of combinations is listed in Appendix A.

Table 1: Main Coding Scheme

Time Period	Category	Comments
1800 – 1872	1	“Substantial Novelty” Era
1873 – 1882	2	Transition to “Nonobviousness”
1883 – 1929	3	“Nonobviousness” Era
1930 – 1940	4	Transition to “Genius”
1941 – 1951	5	“Genius” Era
1952 – 1981	4	Post-1952 Division Between the Circuits
1982 – 1986	3	Transition to the “Suggestion” Test
1987 – 2006	2	Federal Circuit’s “Suggestion” Era
2007	3	Return to “Nonobviousness” with <i>KSR</i>

V. ANALYSIS

This section reports the results. Estimation of the model is carried out using the Bayesian, Gibbs-sampler approach for a dynamic probit.¹⁸⁵ The details can be found in Appendix B. The analysis below reports the central estimate and the ninety-five percent confidence interval for each parameter of interest.

In particular, Section V.A presents results where the rate of productivity growth is used as the measure of the rate of technological progress (R_t), and Section V.B

¹⁸⁵ See Dueker, *supra* note 155, at 471–72; Chauvet & Potter, *supra* note 155 at 85–87, 101–02; Fossati, *supra* note 155, app. A.

presents results where the number of technologically significant patents in force is taken as the measure of the rate of technological progress.

A. Productivity Growth

Table 2 presents results where the model is estimated using the two main series: (a) the Field + Abramovitz productivity series to measure R_t , and (b) the main coding scheme shown in Table 1 to measure Y_t . The estimates show that the legal standard has been positively correlated both with its own past state (central coefficient estimate = 0.957) and with the current rate of technological progress (central coefficient estimate = 0.590).

Table 2: Abramovitz + Field

Parameter	Central Estimate	95% Confidence Interval
β	0.590	0.262 – 0.940
θ	0.957	0.933 – 0.982
c_1	6.0	1.6 – 11.5
c_2	13.3	7.7 – 19.8
c_3	20.3	13.7 – 28.5
c_4	29.3	20.7 – 39.5

As discussed above, the model is intended to capture a process of gradual legal change.¹⁸⁶ When the long-term rate of technological progress rises, it slowly pushes the legal standard upward. Eventually, over time, the standard reaches a new equilibrium, and the difference between the old and new standards may (or may not) be large enough to qualify as a change in legal regime.

The coefficient estimates in Table 2 determine these equilibria, which represent the long-run effect of a change in the

¹⁸⁶ See *supra* Section III.B.

rate of technological progress. In particular, each equilibrium is a pair of points—a prevailing legal standard (y_{t-1}^*) and a rate of technological progress (R_t)—such that the expected change in the legal standard is zero, i.e.:

$$E(y_t^*) = \theta y_{t-1}^* + \beta R_t = y_{t-1}^*$$

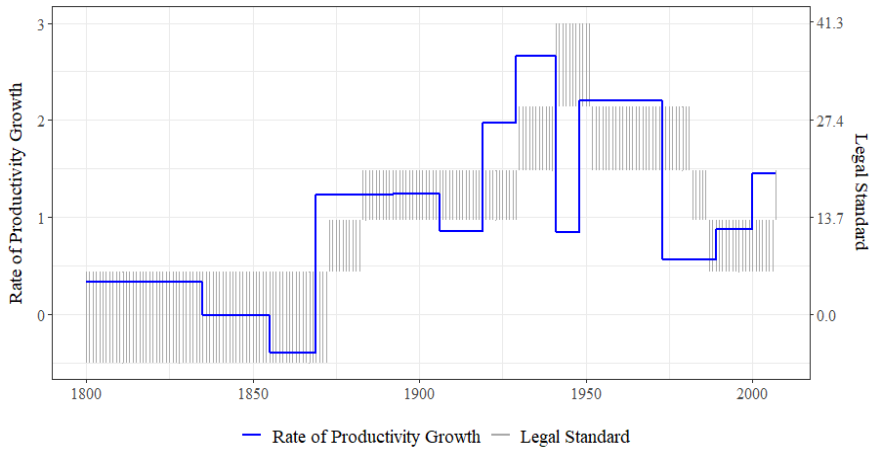
A little algebra shows that these equilibrium pairs are:

$$y_{t-1}^* = \frac{\beta}{1 - \theta} R_t = 13.7 R_t$$

In other words, a one-percent rise in the rate of productivity growth is associated with an increase in the legal standard of 13.7. Of course, that value by itself is not meaningful—it is mapped to observable changes in the legal regime by the cutpoint estimates. As Table 2 shows, the average distance between any pair of estimated cutpoints is 7.8, and the maximum distance between any pair of estimated cutpoints is 9. So, over the long run, a one-percent rise in the rate of productivity growth is associated with (at least) one step upward in the legal regime, but often two.

Using the results in Table 2, Figure 2 plots the rate of productivity growth against the legal standard in each year. Specifically, it takes advantage of the estimated cutpoints to represent the legal standard. The cutpoints indicate that, given the observed legal regime, the exact legal standard must at least lie within certain bounds. For example, if the observed legal regime is “nonobviousness” ($Y_t = 3$), then the exact legal standard must be between c_2 (13.3) and c_3 (20.3). Figure 2 plots these bounds for each year. The ratio between the two axes (13.7) is the equilibrium ratio.

As Figure 2 illustrates, the key implication of the estimates in Table 2 is that changes in the standard of invention have broadly tracked the rate of productivity growth throughout substantially the entire two-century-plus history of the U.S. patent system. In each historical era, legal actors have switched to a stricter legal regime after the rate of productivity growth rose, and vice versa, at a lag of roughly a decade.

Figure 2: Abramovitz + Field

These conclusions are largely insensitive to the alternative estimates of productivity growth and the alternative doctrinal coding schemes. To begin, Tables 3 and 4 (on the next page) present results where the model is estimated using the alternative productivity series: (1) Abramovitz + Gordon, and (2) Abramovitz + Bakker. The results are largely unchanged, along all relevant dimensions. In particular, the equilibrium effect of a one-percent change in the rate of technological progress ($\frac{\beta}{1-\theta}$) remains similar—slightly less than twice the average cutpoint distance, and larger than the maximum cutpoint distance:

Abramovitz + Gordon: $\frac{\beta}{1-\theta} = 24.8$, $avg_c = 13.0$, $max_c = 18.8$

Abramovitz + Bakker: $\frac{\beta}{1-\theta} = 24.8$, $avg_c = 7.8$, $max_c = 9.1$

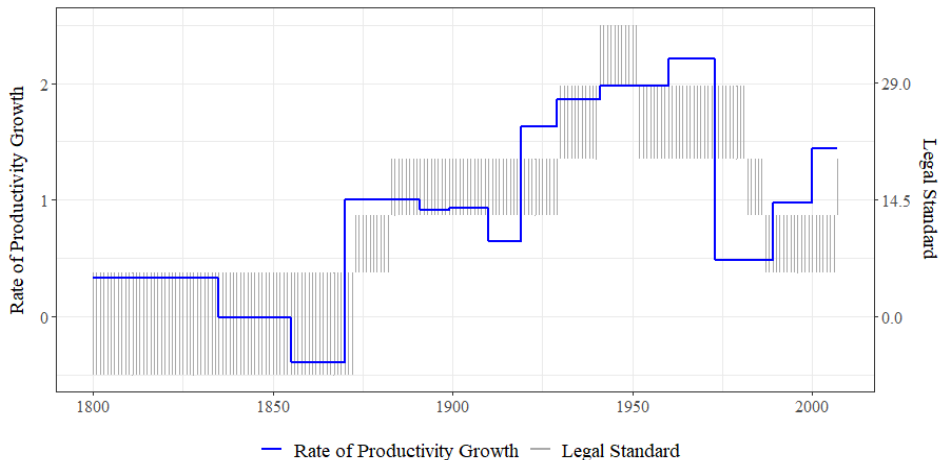
Figures 3 and 4 create plots analogous to Figure 1 for each series, plotting the rate of productivity growth against the legal standard in each year by using the estimates in Tables 3 and 4. In each case, the broad shape of the doctrinal history similarly tracks long-run changes in the rate of productivity growth.

Table 3: Abramovitz + Gordon

Parameter	Central Estimate	95% Confidence Interval
β	1.64	1.40 – 2.38
θ	0.934	0.914 – 0.953
c_1	7.3	3.5 – 11.7
c_2	18.8	12.0 – 27.3
c_3	27.4	18.9 – 38.0
c_4	46.3	31.6 – 64.8

Table 4: Abramovitz + Bakker

Parameter	Central Estimate	95% Confidence Interval
β	0.868	0.401 – 1.38
θ	0.940	0.908 – 0.972
c_1	5.4	1.7 – 9.9
c_2	12.5	7.4 – 18.4
c_3	19.6	13.4 – 26.7
c_4	28.7	20.5 – 38.2

Figure 3: Abramovitz + Gordon**Figure 4: Abramovitz + Bakker**

Finally, Table 7 (available in Appendix C, Supplemental Tables) presents results where the model is estimated using the alternative doctrinal-history coding schemes and the main Abramovitz + Field series to measure R_t . As the Table shows, the parameter estimates are largely insensitive to the (small) margins of disagreement among doctrinal commenters.

B. Technologically Significant Patents

Table 5 presents results where the model is estimated using: (a) the number of “breakthrough patents” in force (per 5,000 people) to measure R_t , and (b) the main coding scheme presented in Table 1 to measure Y_t . Again, the estimates show that the legal standard has been positively correlated both with its own past state (central coefficient estimate = 0.980) and with the current rate of technological progress (central coefficient estimate = 0.180).

Table 5: Breakthrough Patents

Parameter	Central Estimate	95% Confidence Interval
β	0.180	0.031 – 0.344
θ	0.980	0.959 – 0.997
c_1	4.8	0.0 – 10.9
c_2	11.2	5.3 – 18.4
c_3	17.2	10.8 – 24.7
c_4	24.6	17.1 – 33.1

The long-run equilibrium ratio is given below:

$$y_{t-1}^* = \frac{\beta}{1-\theta} R_t = 9 R_t$$

It shows that one additional breakthrough patent in force per 5,000 people has been associated, over the long-run, with an increase in the legal standard of 9. As Table 5 shows, the average distance between any pair of estimated cutpoints is 6.6, and the maximum distance between any pair of estimated cutpoints is 7.4. Accordingly, over the long run, one additional breakthrough patent in force per 5,000 people has been associated with at least one step upward in the legal regime, and sometimes two.

Figure 5 creates the analogous plot for this series, using the estimates in Table 5. As the Figure illustrates, there are two key points. First, the two measures of technological change—productivity growth and technologically significant patents—closely track each

other (and the doctrine) for most of the history, from the middle of the nineteenth century to the middle of the twentieth century. Second, these two measures then diverge somewhat in the closing decades of the twentieth century (1980s to 2000s). In these decades, the two measures disagree about the size of the most recent wave of technological progress—the productivity data shows a smaller wave, while the patenting data shows a much larger wave. The productivity data is a better match for the doctrine in these decades.

Figure 5: Technologically Significant Patents

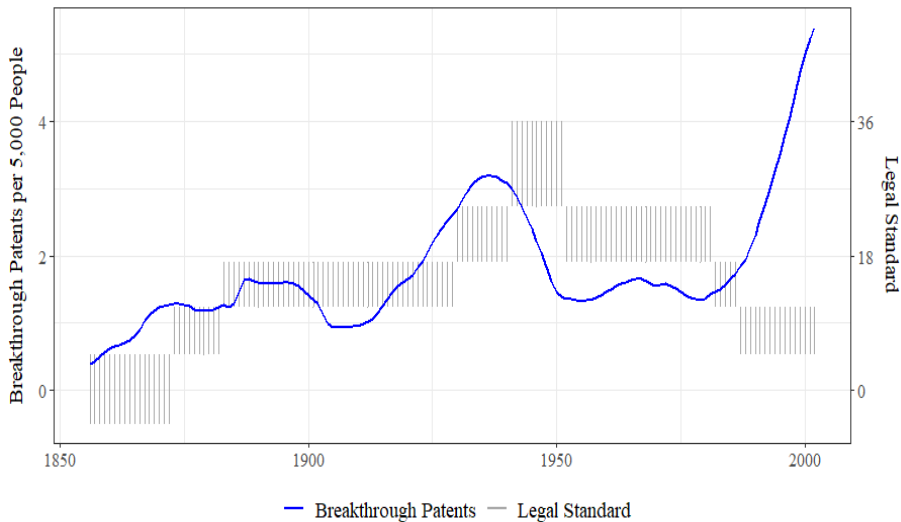


Table 8 (available in Appendix C, Supplemental Tables) presents results where the model is estimated using the alternative doctrinal-history coding schemes. Again, there are two key points. First, the results are largely insensitive to the robustness checks regarding the *timing* of the transitions between regimes (recodings 1–16). Second, relative to the productivity data, the results are much more sensitive to the robustness checks regarding the coding of the Federal Circuit’s “suggestion” test (which was the governing test from the 1980s to the early 2000s). In the main coding scheme (Table 1), the “suggestion” test is coded as category 2 (in between “substantial novelty” and “nonobviousness”). However, (a) if the “suggestion” test is coded as category 1 (lower legal standard, recodings 17–32), then the estimated coefficient on the rate of technological progress falls by

roughly a factor of two (average value = 0.0992), and the ninety-five percent confidence interval includes zero; but (b) if the “suggestion” test is coded as category 3 (higher legal standard, recodings 33–40), then the coefficient on the rate of technological progress increases by roughly a factor of two (average value = 0.338). In short, the patenting data is a substantially better fit for the doctrinal history if the history is coded as involving a higher legal standard during the 1980s, 1990s, and early 2000s (when the patenting data shows a larger wave of technological progress).

At present, it remains somewhat unclear why the two measures of technological progress (productivity growth and breakthrough patents) have recently diverged or what lesson should be drawn from this fact. Part of the reason is simply that textual analysis of patents is a relatively new method. Economic historians have refined estimates of productivity growth over the last six decades.¹⁸⁷ By contrast, there is currently only one published, long-run estimate of the number of technologically significant patents using a text-based method.¹⁸⁸ Recent results suggest that it is possible that the divergence between the two measures will eventually be narrowed or even eliminated.¹⁸⁹ And future work may shed more light on these questions.

V. CONCLUSION

In sum, this Article makes two main contributions. First, it draws a missing link between the history of patent rights and the ways that economic historians have thought about measuring long-term technological progress. It shows that a central legal standard in patent law has tracked these measures of technological progress for nearly two centuries. Second, this connection sheds new light on a longstanding puzzle in patent law. The Article’s results provide stronger reason to believe that the infamous cycles in patent law are explained by courts acting as responsible stewards of the patent system, reacting to changes in technology and adopting legal regimes that best encourage technological progress in different social conditions.

¹⁸⁷ See Crafts & Woltjer, *supra* note 162, at 670–91.

¹⁸⁸ Kelly et al., *supra* note 164, at 303–18.

¹⁸⁹ For example, a recent working paper estimates the number of technologically significant patents using a new, text-based metric (“creative patents”) and arrives at conclusions that track the productivity data (and the doctrine) much more closely. See Aakash Kalyani, *The Creativity Decline: Evidence from US Patents 21–23* & fig.6 (Fed. Rsrv. Bank of St. Louis, Working Paper No. 2024-008A, 2024).

APPENDIX A: DATA

This appendix provides details on the three data sources: (1) productivity growth, (2) technologically significant patents, and (3) doctrinal coding.

A. Rate of Productivity Growth

Long-term historical productivity data is available from several sources. By convention, all report average rates of productivity growth between peaks of the business cycle to filter out short-run business cycle fluctuations.¹⁹⁰

For the early to mid-nineteenth century, data is available from Abramovitz, who reports productivity figures for the period 1800–1890, sliced in two ways:

1. A “long” frame, containing average rates of productivity growth during two long historical intervals: 1800–1855 and 1855–1890.
2. A “short” frame, containing average rates of productivity growth during four shorter historical intervals: 1800–1835, 1835–1855, 1855–1870, and 1870–1890.¹⁹¹

This Article will use the “short” frame for two reasons. First, the “long” frame slices the data in a way that is not granular enough for this Article’s needs. In particular, it merges the decades dominated by the Civil War (1855–1871) with the post-war decades at the end of the nineteenth century (1871–1890). However, the 1870s contained a critical doctrinal transition (the rise of “nonobviousness”).¹⁹² This Article therefore requires a frame that is at least fine-grained enough to separate these two periods (1855–1871 vs. 1871–1890). Second, as Field argues, the “short” frame is also the one that is the most consistent with the values reported by the Kendrick data¹⁹³ for the period of history where the two series overlap (the post-Civil War years).¹⁹⁴

¹⁹⁰ See Bakker, Crafts & Woltjer, *supra* note 172; Alexander Field, The Impact of World War II on the Growth of U.S. Potential Output 13–14 (Apr. 16, 2018) (unpublished working paper), <https://www.researchgate.net/profile/Alexander-Field-3/publication/324546656> [<https://perma.cc/UX7L-PV2D>].

¹⁹¹ Abramovitz, *supra* note 169, at 223 tbl.1, 228 tbl.2.

¹⁹² See *supra* Part II.

¹⁹³ See generally JOHN W. KENDRICK, PRODUCTIVITY TRENDS IN THE UNITED STATES (1961) (foundational study).

¹⁹⁴ FIELD, *supra* note 170, at 148.

For later years, three recent series are available, compiled by different economic historians (all building on data originally reported by Kendrick, which runs back to 1869):

1. Field¹⁹⁵: private domestic economy, 1869–2007
2. Gordon¹⁹⁶: private, non-farm domestic economy, 1891–2007
3. Bakker et al.¹⁹⁷: private, non-farm domestic economy 1899–2007

This Article will use the Field series as the main estimate for three reasons. First, Field is the series that is the most consistent with Abramovitz. Abramovitz reports productivity figures that include the farm sector, as does Field, while Gordon and Bakker et al. report non-farm figures. Second, including the farm sector is especially desirable for a study of patent rights—farms were not just a historically important area of technological innovation but also a central battleground for disputes over patent rights, in particular.¹⁹⁸ Third, Field argues that the reported values are broadly consistent with the “short” frame reported by Abramovitz.¹⁹⁹ For the period of overlap between the two series (1869–1890), this Article will use the most recent data from Field. Finally, as a check, this Article will also estimate the model using the other two series. Accordingly, in total, there are three historical productivity series:

1. Abramovitz + Field (Abramovitz [1800–1868] / Field [1869–2007])
2. Abramovitz + Gordon (Abramovitz [1800–1890] / Gordon [1891–2007])
3. Abramovitz + Bakker (Abramovitz [1800–1898] / Bakker [1899–2007])²⁰⁰

B. Breakthrough Patents

Kelly et al. report the number of “breakthrough patents” issued by the PTO for the period 1840–2002.²⁰¹ To obtain the

¹⁹⁵ *Id.* at 149 tbl.6.1.

¹⁹⁶ Gordon, *supra* note 171.

¹⁹⁷ Bakker, Crafts & Woltjer, *supra* note 172.

¹⁹⁸ Beauchamp, *supra* note 134, at 925–29.

¹⁹⁹ FIELD, *supra* note 170, at 146–65.

²⁰⁰ The Bakker et al. series begins in 1899, while the Abramovitz “short” frame runs to 1890. Abramovitz also reports estimates for the post-1890 period, drawing on the data from Kendrick. This Article uses those values for the years 1891–1898.

²⁰¹ Kelly et al., *supra* note 164, at 315 fig.4.

number of these patents in force in each year, this Article makes a simple assumption—each patent remained in force for 17 years.

That was the term for most of the relevant history.²⁰² To be clear, there are two issues that this assumption does not account for. First, in the early decades of the nineteenth century, there was a discretionary element to patent term.²⁰³ Specifically, between 1836 and 1861, the term of a patent was 14 years by default but could be extended (and many were) to 21 years by application to the USPTO on a showing of need. Eventually, in 1861, the term was standardized to an intermediate length (17 years). However, individual patents in the early nineteenth century were in force for either longer or shorter times. Second, a patent owner needs to pay maintenance fees to keep a patent in force. Some patents—although technologically significant—likely lapsed before the end of their terms. However, many of the records from the nineteenth century have been lost.²⁰⁴ And, more generally, it is infeasible to match the set of an estimated 600,000 breakthrough patents to these administrative outcomes. The Article uses a 17-year term as the best approximation.

Accordingly, the series of patents-in-force runs from 1856–2002. This series is also scaled per capita by the number of breakthrough patents in force per 5,000 people.

C. Doctrinal Coding

The main doctrinal coding scheme is presented in Table 1. Table 6 lists the combinations of alternative coding schemes.

Table 6: Alternative Coding Schemes

Number	Coding Decisions
1	1870 / 1880 / 1925 / 1983 / “Suggestion” = 2
2	1870 / 1880 / 1925 / 1990 / “Suggestion” = 2
3	1870 / 1880 / 1939 / 1983 / “Suggestion” = 2
4	1870 / 1880 / 1939 / 1990 / “Suggestion” = 2
5	1870 / 1885 / 1925 / 1983 / “Suggestion” = 2

²⁰² Simon Lester & Huan Zhu, *Rethinking the Length of Patent Terms*, 34 AM. UNIV. INT’L L. REV. 787, 791–793 (2019).

²⁰³ *See id.*

²⁰⁴ *Id.* at 793.

6	1870 / 1885 / 1925 / 1990 / "Suggestion" = 2
7	1870 / 1885 / 1939 / 1983 / "Suggestion" = 2
8	1870 / 1885 / 1939 / 1990 / "Suggestion" = 2
9	1875 / 1880 / 1925 / 1983 / "Suggestion" = 2
10	1875 / 1880 / 1925 / 1990 / "Suggestion" = 2
11	1875 / 1880 / 1939 / 1983 / "Suggestion" = 2
12	1875 / 1880 / 1939 / 1990 / "Suggestion" = 2
13	1875 / 1885 / 1925 / 1983 / "Suggestion" = 2
14	1875 / 1885 / 1925 / 1990 / "Suggestion" = 2
15	1875 / 1885 / 1939 / 1983 / "Suggestion" = 2
16	1875 / 1885 / 1939 / 1990 / "Suggestion" = 2
17	1870 / 1880 / 1925 / 1983 / "Suggestion" = 1
18	1870 / 1880 / 1925 / 1990 / "Suggestion" = 1
19	1870 / 1880 / 1939 / 1983 / "Suggestion" = 1
20	1870 / 1880 / 1939 / 1990 / "Suggestion" = 1
21	1870 / 1885 / 1925 / 1983 / "Suggestion" = 1
22	1870 / 1885 / 1925 / 1990 / "Suggestion" = 1
23	1870 / 1885 / 1939 / 1983 / "Suggestion" = 1
24	1870 / 1885 / 1939 / 1990 / "Suggestion" = 1
25	1875 / 1880 / 1925 / 1983 / "Suggestion" = 1
26	1875 / 1880 / 1925 / 1990 / "Suggestion" = 1
27	1875 / 1880 / 1939 / 1983 / "Suggestion" = 1
28	1875 / 1880 / 1939 / 1990 / "Suggestion" = 1
29	1875 / 1885 / 1925 / 1983 / "Suggestion" = 1
30	1875 / 1885 / 1925 / 1990 / "Suggestion" = 1

31	1875 / 1885 / 1939 / 1983 / "Suggestion" = 1
32	1875 / 1885 / 1939 / 1990 / "Suggestion" = 1
33	1870 / 1880 / 1925 / [N/A] / "Suggestion" = 3
34	1870 / 1880 / 1939 / [N/A] / "Suggestion" = 3
35	1870 / 1885 / 1925 / [N/A] / "Suggestion" = 3
36	1870 / 1885 / 1939 / [N/A] / "Suggestion" = 3
37	1875 / 1880 / 1925 / [N/A] / "Suggestion" = 3
38	1875 / 1880 / 1939 / [N/A] / "Suggestion" = 3
39	1875 / 1885 / 1925 / [N/A] / "Suggestion" = 3
40	1875 / 1885 / 1939 / [N/A] / "Suggestion" = 3

APPENDIX B: ESTIMATION

This appendix describes the estimation strategy. Estimation broadly follows the Bayesian, Gibbs-sampler approach for a dynamic probit.²⁰⁵ The details for each step are described below.

A. Draws of Latent Values

Call $y_1^{*(i)} \dots y_T^{*(i)}$ the i th draws of y_t^* , for $t = 1 \dots T$.

The initial draws $(y_t^{*(1)})$ are taken sequentially from $f(y_t^{*(1)} | y_{t-1}^{*(1)}) \sim N(\theta y_{t-1}^{*(1)} + \beta R_t, 1)$, starting with $t = 1$, and working upward to $t = T$. Draws are subject to the truncation that y_t^* lies between the cutpoints for Y_t . For example, if $Y_t = 3$, then $c_2 \leq y_t^* < c_3$. For simplicity, y_0^* is fixed at 0 (a realistic value in all cases).

Subsequent draws of y_t^* are taken according to the approach described below, following the path set out in Fossati.²⁰⁶ All draws remain subject to the same truncation, i.e., y_t^* lies between the cutpoints for Y_t .

First, a new draw of the last value ($t = T$) is taken from $f(y_T^{*(i+1)} | y_{T-1}^{*(i)}) \sim N(\theta y_{T-1}^{*(i)} + \beta R_T, 1)$.

Second, new draws for $t = T-1, \dots, 2$ are taken using the following property. Define:

$$A_t = E(y_t^*) = \sum_{n=0}^{t-1} \theta^n \beta R_{t-n} = \beta R_t + \theta A_{t-1}$$

$$B_t = Var(y_t^*) = \sum_{n=0}^{t-1} \theta^{2n} = 1 + \theta^2 B_{t-1}$$

²⁰⁵ See Dueker, *supra* note 155, at 471–72; see also Chauvet & Potter, *supra* note 155, at 85–87, 101–02; Fossati, *supra* note 155, app. A; James H. Albert & Siddhartha Chib, *Bayesian Analysis of Binary and Polychotomous Response Data*, 88 J. AM. STAT. ASS'N 669, 669–73 (1993).

²⁰⁶ See Fossati, *supra* note 155, app. A.

Then, $f(y_t^* | y_{t+1}^*, y_{t-1}^*) \sim N(\tilde{\mu}_t, \tilde{\Sigma}_t)$, where:

$$\tilde{\mu}_t = A_t + \theta \begin{pmatrix} B_t \\ B_{t-1} \end{pmatrix}' \begin{pmatrix} B_{t+1} & \theta^2 B_{t-1} \\ & B_{t-1} \end{pmatrix}^{-1} \begin{pmatrix} y_{t+1}^* - A_{t+1} \\ y_{t-1}^* - A_{t-1} \end{pmatrix}$$

$$\tilde{\Sigma}_t = B_t - \theta^2 \begin{pmatrix} B_t \\ B_{t-1} \end{pmatrix}' \begin{pmatrix} B_{t+1} & \theta^2 B_{t-1} \\ & B_{t-1} \end{pmatrix}^{-1} \begin{pmatrix} B_t \\ B_{t-1} \end{pmatrix}$$

Using this property, new draws are taken sequentially from $f(y_t^{*(i+1)} | y_{t+1}^{*(i+1)}, y_{t-1}^{*(i)})$ starting with $T = t-1$, and working downward to $t = 2$.

Finally, a new draw is taken for the first value ($t = 1$) from $f(y_1^{*(i+1)} | y_2^{*(i+1)}) \sim N(\tilde{\mu}_1, \tilde{\Sigma}_1)$, where:

$$\tilde{\mu}_1 = A_1 + \theta B_1 B_2^{-1} (y_2^* - A_2) = A_1 + \frac{\theta}{1 + \theta^2} (y_2^* - A_2)$$

$$\tilde{\Sigma}_1 = B_1 - \theta^2 B_1 B_2^{-1} B_1 = 1 - \frac{\theta^2}{1 + \theta^2}$$

B. Prior and Posterior for β

The initial value of β is set at the maximum likelihood estimate (MLE) for a static ordered probit ($y_t^* = \beta R_t + \varepsilon_t$), and a flat, uninformative prior is adopted for β (given that the MLE is not consistent in this context).²⁰⁷ The posterior distribution of β is then:

$$\beta \sim N(\hat{\beta}, (X'_\beta X_\beta)^{-1})$$

where:

$$\hat{\beta} = (X'_\beta X_\beta)^{-1} X'_\beta W_\beta \quad W_\beta = \begin{pmatrix} y_1^* - \beta R_1 \\ \dots \\ y_T^* - \beta R_T \end{pmatrix} \quad X_\beta = \begin{pmatrix} y_0^* \\ \dots \\ y_{t-1}^* \end{pmatrix}$$

All draws of θ are subject to the condition that $\theta < 1$.

C. Prior and Posterior for θ

The initial value of θ is set at 0.5, and a flat uninformative prior is adopted for θ (as the initial value does not contain useful

²⁰⁷ See Albert & Chib, *supra* note 205; Fossati, *supra* note 155, app. A.

information).²⁰⁸ The posterior distribution of θ is then:

$$\theta \sim N(\hat{\theta}, (X'_\theta X_\theta)^{-1})$$

where:

$$\hat{\theta} = (X'_\theta X_\theta)^{-1} X'_\theta W_\theta \quad W_\theta = \begin{pmatrix} y_1^* - \beta R_1 \\ \dots \\ y_T^* - \beta R_T \end{pmatrix} \quad X_\theta = \begin{pmatrix} y_0^* \\ \dots \\ y_{t-1}^* \end{pmatrix}$$

All draws of θ are subject to the condition that $\theta < 1$.

D. Prior and Posterior for c_1, c_2, c_3, c_4

A flat, uninformative prior is adopted for the cutpoints c_1, c_2, c_3, c_4 , and initial values are set at the MLE for a static ordered probit.²⁰⁹ The posterior distribution for cutpoint c_i is then uniform over the interval:

$$[\max\{\max\{y_t^*: Y_t = i\}, c_{i-1}\}, \min\{\min\{y_t^*: Y_t = i + 1\}, c_{i+1}\}]$$

E. Gibbs Sampler

To run the sampler, initial draws of y_t^* were first generated; draws were then taken in the following order: cutpoints, y_t^* , β , θ .

Following Gelman et al.,²¹⁰ two diagnostics were calculated for each run: (1) \hat{R} (a measure of convergence, using the split-chain approach of Gelman et al.), and (2) n_{eff} (a measure of effective sample size). Gelman et al. suggest the guidelines $\hat{R} < 1.1$ and $n_{eff} > 10$ per chain = 100. Here, for all runs, and all parameters, $\hat{R} < 1.05$ and $n_{eff} > 150$.

For each run, ten chains of 250,000 draws were used by default (with the first 50,000 draws reserved for warmup), and this was typically sufficient to achieve satisfactory convergence and sample-size diagnostics ($\hat{R} < 1.05$ and $n_{eff} > 150$). However, several of the doctrinal robustness checks required longer chains. In particular, these doctrinal robustness checks (chain-lengths) were:

- Productivity—Recoding 2 (300,000)
- Productivity—Recoding 3 (300,000)
- Productivity—Recoding 7 (350,000)

²⁰⁸ See Fossati, *supra* note 155, app. A.

²⁰⁹ Albert & Chib, *supra* note 205, at 673.

²¹⁰ ANDREW GELMAN ET AL., BAYESIAN DATA ANALYSIS 281–88 (3d ed. 2013) (ebook), <http://www.stat.columbia.edu/~gelman/book/BDA3.pdf> [<https://perma.cc/2V2H-S6D7>].

- Productivity—Recoding 19 (300,000)
- Productivity—Recoding 24 (300,000)
- Productivity—Recoding 26 (300,000)
- Productivity—Recoding 32 (350,000)
- Productivity—Recoding 33 (400,000)
- Productivity—Recoding 34 (400,000)
- Productivity—Recoding 35 (400,000)
- Productivity—Recoding 36 (500,000)
- Productivity—Recoding 37 (400,000)
- Productivity—Recoding 38 (600,000)
- Productivity—Recoding 39 (500,000)
- Productivity—Recoding 40 (800,000)
- Patenting—Recoding 33 (400,000)
- Patenting—Recoding 34 (500,000)
- Patenting—Recoding 35 (400,000)
- Patenting—Recoding 36 (500,000)
- Patenting—Recoding 37 (300,000)
- Patenting—Recoding 38 (500,000)
- Patenting—Recoding 39 (300,000)
- Patenting—Recoding 40 (600,000)

Following Gelman et al.,²¹¹ thinning was used to address memory issues created by long chains. In particular, for chains longer than 400,000, only every other draw was stored (and, accordingly, 25,000 draws were reserved for warmup).

For each parameter, the Article reports: (1) the mean of the posterior distribution (the “central estimate”); and (2) a 95% confidence interval, i.e., the 2.5% draw from the posterior distribution and the 97.5% draw from the posterior distribution.²¹²

²¹¹ *Id.* at 282–83.

²¹² *Id.* at 267.

APPENDIX C: SUPPLEMENTAL TABLES

This appendix reports estimates for the doctrinal robustness checks. In particular, for each check, it reports an estimate for the coefficient on the rate of technological progress, β . Table 7 presents estimates for productivity growth; Table 8 presents estimates for breakthrough patents.

Table 7: Productivity Growth – Recodings

Recoding	Central Estimate (β)	95% Confidence Interval (β)
1	0.494	0.170 – 0.838
2	0.505	0.174 – 0.859
3	0.334	0.086 – 0.601
4	0.363	0.109 – 0.634
5	0.512	0.181 – 0.864
6	0.513	0.177 – 0.878
7	0.333	0.085 – 0.601
8	0.369	0.111 – 0.644
9	0.583	0.237 – 0.950
10	0.607	0.250 – 0.992
11	0.376	0.118 – 0.650
12	0.410	0.144 – 0.692
13	0.615	0.257 – 0.995
14	0.617	0.259 – 1.01
15	0.381	0.121 – 0.656
16	0.421	0.149 – 0.711
17	0.352	0.0903 – 0.632
18	0.360	0.0974 – 0.643

19	0.271	0.0541 – 0.507
20	0.289	0.0688 – 0.526
21	0.355	0.0970 – 0.633
22	0.355	0.0946 – 0.634
23	0.269	0.0541 – 0.505
24	0.284	0.0647 – 0.520
25	0.454	0.151 – 0.783
26	0.468	0.161 – 0.801
27	0.326	0.0892 – 0.580
28	0.344	0.102 – 0.605
29	0.461	0.162 – 0.789
30	0.456	0.151 – 0.788
31	0.326	0.0902 – 0.582
32	0.344	0.100 – 0.607
33	0.506	0.162 – 0.890
34	0.449	0.159 – 0.766
35	0.497	0.158 – 0.873
36	0.454	0.162 – 0.767
37	0.628	0.241 – 1.06
38	0.513	0.203 – 0.843
39	0.622	0.243 – 1.04
40	0.517	0.208 – 0.850

Table 8: Breakthrough Patents – Recodings

Recoding	Central Estimate (β)	95% Confidence Interval (β)
1	0.185	0.0328 – 0.351
2	0.147	0.00634 – 0.305
3	0.169	0.0248 – 0.327
4	0.142	0.00636 – 0.293
5	0.196	0.0387 – 0.366
6	0.157	0.0114 – 0.320
7	0.178	0.0293 – 0.341
8	0.150	0.0103 – 0.305
9	0.179	0.0312 – 0.342
10	0.146	0.00851 – 0.302
11	0.163	0.0237 – 0.318
12	0.142	0.00884 – 0.291
13	0.192	0.0380 – 0.361
14	0.156	0.0133 – 0.317
15	0.175	0.0292 – 0.334
16	0.149	0.0118 – 0.303
17	0.109	-0.0238 – 0.258
18	0.0839	-0.0413 – 0.226
19	0.0998	-0.0286 – 0.242
20	0.0819	-0.0400 – 0.218
21	0.113	-0.0217 – 0.263
22	0.0841	-0.0407 – 0.226

23	0.102	-0.0267 – 0.244
24	0.0823	-0.0394 – 0.218
25	0.121	-0.0174 – 0.278
26	0.0928	-0.0356 – 0.240
27	0.111	-0.0216 – 0.260
28	0.0912	-0.0337 – 0.233
29	0.121	-0.0167 – 0.276
30	0.0919	-0.0352 – 0.237
31	0.110	-0.0215 – 0.257
32	0.0920	-0.0332 – 0.234
33	0.306	0.108 – 0.510
34	0.373	0.153 – 0.607
35	0.314	0.115 – 0.520
36	0.388	0.164 – 0.624
37	0.295	0.101 – 0.499
38	0.362	0.142 – 0.600
39	0.302	0.108 – 0.505
40	0.365	0.158 – 0.583