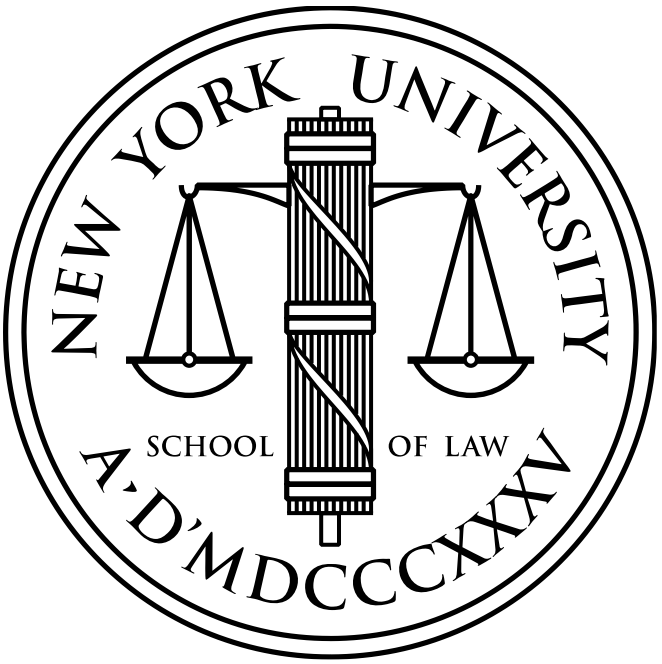
# JIPEL

NYU Journal of Intellectual Property
& Entertainment Law

VOLUME 11 NUMBER 2

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NEW YORK UNIVERSITY

JOURNAL OF INTELLECTUAL PROPERTY AND ENTERTAINMENT LAW

VOLUME 11 FALL 2021 NUMBER 2

# DOES ANYBODY SEE WHAT I SEE?: ABANDONED PATENTS AND THEIR IMPACTS ON TECHNOLOGY DEVELOPMENT

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"Is anybody there? Does anybody care? Does anybody see what I see?"†

*Most patented advances are ultimately abandoned by their owners. Owners give up their patents apparently because the patented advances seem so worthless that the owners cannot justify paying modest maintenance fees needed to keep the patents in force. These voluntarily relinquished patents cover technological dead ends—advances of little interest to later innovators and commercial entities seeking marketable products that serve public interests. Abandoned patents are surprisingly common, comprising a majority of United States patents, and a largely overlooked feature of the United States patent system.*

*This article analyzes empirical evidence reflecting abandoned patents' roles in later technology development. The analysis relies on citations in later-issued patents to evaluate inventors' interest in advances covered by abandoned patents.*

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† SHERMAN EDWARDS, *Is Anybody There?*, *on* 1776 (1969), https://www.allmusicals.com/lyrics/1776/isanybodythere.htm.

*The results suggest that inventions described in abandoned patents have some influence on later technology development, but far less than their unabandoned counterparts. Citations per patent for unabandoned patents are over twice as high as for abandoned patents. Almost immediately after patent issuance, technologists see what patent owners take years to realize—that some patented advances are worthless, having very little potential as the basis for successful commercial products or as pointers toward future technology advances with commercial value. Later innovators appear to agree with owners that abandoned patents cover dead ends in technology development. Technologists avoid these dead ends by turning away from advances described in abandoned patents and pursuing other types of technology projects, leaving abandoned advances with few, if any, citations in later patents.*

## INTRODUCTION

When a patent is abandoned by its owner[1] and remains largely uncited in later patents, does the abandoned patent have an impact?[2] Are abandoned patents (and the associated administrative costs to the patent system and patent applicants) wastes of time and resources? Are these patents—despite their threatened restrictions on infringing conduct—meaningless constraints on commercial competition and technology development because the patents restrict technologies that no one is interested in and no infringement is likely? Do these patents provide valuable information to later researchers even if they have little value to their owners? These questions are important because abandoned patents are common in all areas of technology, yet their impacts (if any) on technology development are largely unstudied.[3]

### *A. Measuring the Impacts of Abandoned Patents*

This article analyzes empirical evidence of abandoned patents' roles in later technology development. It relies on citations in later-issued patents to measure inventors' interest in advances covered by abandoned patents. This evidence

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[1] "Abandoned patents" refer here to United States utility patents that are allowed to lapse by their owners before the end of the full available period of patent protection. This lapsing typically results from an owner's failure to pay patent maintenance fees due 4, 8, and 12 years after patent issuance. The failure to pay one of these fees causes the patent to lapse. *See* 35 U.S.C. § 41(b)(1)–(2).

[2] This question is a counterpart to the famous philosophical inquiry: "If a tree falls in a forest and no one is around to hear it, does it make a sound?" This inquiry—framed in terms of a falling tree and resulting sounds—invokes philosophical concerns regarding observation and perception. Key considerations include the possibility of unperceived existence, assumptions about the unobserved world, and the dissimilarities between perception and reality. *See generally If a Tree Falls in the Forest*, WIKIPEDIA, https://en.wikipedia.org/wiki/If_a_tree_falls_in_a_forest (last updated Dec. 21, 2021).

The parallel question about abandoned patents might be: "If a patent issues and no one notices, does the patent have an impact?" Key considerations about abandoned (and perhaps unnoticed) patents include how to measure the impacts of patents (including impacts on technology development and commercial product availability), assumptions about the unobserved impacts of patents, and potential disparities between the impacts of well-known patents covering highly valuable advances and other patents that are valueless, unenforced, and abandoned by their owners.

[3] A few studies have described the large numbers of patents abandoned in recent years but have not examined reasons why patent applicants seek so many ultimately abandoned patents or the impacts of abandoned patents on later technology development. *See, e.g.*, Dennis Crouch, *Maintenance Fees 2015*, PATENTLY-O (July 21, 2015), https://patentlyo.com/patent/2015/07/maintenance-fees-2015.html (describing the large number of United States utility patents abandoned in 2015).

suggests that inventions described in abandoned patents have some influence on later technology development, but far less than their unabandoned counterparts.[4] Almost immediately after patent issuance, technologists see what patent owners take years to realize—that some patented advances are worthless, having very little potential as the basis for successful commercial products or as pointers toward future technology advances with commercial value. The worthless patents cover dead ends in technology development. Technologists express their assessment of worthless patents by turning to other types of technology projects, leaving worthless advances with few, if any, citations in later patents.

The opposite is also true. Advances ultimately seen as valuable by patent owners (as indicated by the owners' willingness to pay maintenance fees needed to keep the patents alive for their full potential terms) are also seen as valuable from the outset by numerous technologists and cited at much higher levels than abandoned patents.[5] Citations per patent for valuable patents are over twice as high as for abandoned patents. This elevated citation level starts soon after patent issuance and holds true throughout the life of valuable patents. The technologists responsible for these citations are not just everyday innovators, but rather inventors with unusual talents and insights leading to patented advances. These inventors are typically highly trained engineers and scientists able to conceive and construct nonobvious additions to past technology designs and thereby qualify for patents. These exceptional inventors see value (or the lack of it) very quickly in the life of patented advances and shape their own innovation choices accordingly.

Inventors' interest in valuable innovations appears to be constrained somewhat by restrictive patent rights applicable to such innovations.[6] Differences in citations before and after valuable patents expire provide insights into the impacts of patent rights in deterring and suppressing related inquiries. While valuable patents are in force, advances similar to the valuable patents receive substantial interest by inventors (as evidenced by citation levels much higher than those for abandoned patents). However, after the patents expire, citations rise to even higher levels. This suggests that the threat of patent enforcement while rights are in force has a significant effect in suppressing surrounding technology development. Innovation levels related to valuable advances go up when the legal threat of patent enforcement is relieved through patent expiration

[4] *See infra* Section II(A).
[5] *See id.*
[6] *See infra* Section II(C)(4).

Conversely, changes in enforceable rights do not seem to impact interest in advances described in abandoned patents. Citation levels for abandoned patents remain relatively constant across periods—that is, across the thresholds when the rights emanating from the patents disappear. This is consistent with the view that rights concerning abandoned patents matter little in the first place. Rights limiting actions that no one is interested in pursuing are little different from no rights at all.

These results indicate that advances covered by valuable patents, unlike abandoned patents, serve as magnets for subsequent innovation. These advances attract citations while the cited patents are in force because technologists seek innovations in the vicinity of the cited advances, hoping to share in the significant value of the heavily cited advances. Valuable patents that have expired attract even more citations because innovations in their vicinity are both valuable and newly unconstrained. Additional related innovations (and related citations) result once restrictions and royalty costs for reuse of a patented advance are removed with patent expiration.

Both before and after patent expiration, citations capture crowdsourced information from subsequent innovators, identifying technology neighborhoods with strong innovator interest and probable future value. This article describes the remarkable congruence between the views of patent owners and subsequent innovators about the lack of value of advances covered by abandoned patents.[7] The article also suggests ways that innovator disinterest in patented advances (as evidenced by low citation levels) can identify worthless patents relatively early in patent life and shift attention of innovators, entrepreneurs, and persons allocating technology development resources away from wasteful commitments directed at projects mistakenly building on the false leads of abandoned patents.[8]

### *B. Viewing Patents as Markers for Speculative Testing of Uncertain Innovations*

Far from confirming the technological or commercial success of an advance, an issued patent is just an indicator of technological distinctiveness coupled with rights advancing market testing of the patented technology. The patent confirms that an advance is a technological outlier (as evidenced by the patent examiner's findings to this effect)[9] and potentially worthy of commercial testing (because the advance's

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[7] *See infra* Section II(C).

[8] *See infra* Section II(C)(2)(ii).

[9] United States patent laws require an invention to be "nonobvious" to a well-informed person of average skills in the field of the advance in order to qualify for a patent–in essence, a requirement that the advance be a technological outlier. *See* 35 U.S.C. § 103. Patent applications are reviewed

distinctive features may enable attractive consumer products and, if so, patent rights initially will reserve most of the resulting profits to the patent holder).[10] However, most patented advances fail commercial testing—either never being transformed into commercial products or failing in the marketplace because products incorporating the patented advance prove to be duds that are no better (and perhaps more costly) than non-patented substitutes.[11] Considering these often harsh results, an issued patent is only a speculative hunting license, indicating a market testing opportunity but hardly implying a likely success.[12] Indeed, the opposite is frequently the case—patented advances are more often losers than winners. Most patented inventions are found worthless by their owners[13] causing many related patents to be abandoned.

*1. Commercial Dreams Denied—The Debris of Abandoned Patents*

Abandoned patents corresponding to commercial failures of patented advances are surprisingly common. In recent years, more United States utility

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by patent examiners to determine if advances meet this and other patent law requirements; the issuance of a patent is confirmation that this requirement was met (at least in the eyes of the examiner). *See General Information Concerning Patents*, USPTO, https://www.uspto.gov/patents/basics/general-information-patents (last modified July 1, 2021, 9:13 AM) ("The examination of [a patent] application consists of a study of the application for compliance with the legal requirements and a search through U.S. patents, publications of patent applications, foreign patent documents, and available literature, to see if the claimed invention is new, useful and non-obvious and if the application meets the requirements of the patent statute and rules of practice. If the examiner's decision on patentability is favorable, a patent is granted.").

[10] A patent gives the owner the ability to control who is authorized to make, use, sell or import the patented invention. *See* 35 U.S.C. § 271. The resulting patent rights are commonly translated into profits by charging patent-mediated (that is, elevated) prices for patented items or by licensing other parties to make or sell such items and gaining profits through license royalties. *See, e.g.*, Ted Sichelman, *Commercializing Patents*, 62 STAN. L. REV. 341, 358 (2010) ("[T]he patent system . . . allow[s] an inventor to earn a return on his efforts either by selling a commercial embodiment of the invention at higher-than-normal prices or by licensing the invention to others for a fee.").

[11] *See* Sichelman, *supra* note 10, at 341 ("About half, probably more, of all patented inventions in the United States are never commercially exploited.").

[12] *Cf.* F.M. Scherer, *The Innovation Lottery*, *in* EXPANDING THE BOUNDARIES OF INTELLECTUAL PROPERTY 3 (Rochelle Dreyfuss et al. eds., 2001) (analogizing the patent system to a giant lottery with an individual patent having the features of a lottery ticket: generally worthless but highly valuable in the rare cases where it pays off).

[13] *See* Jonathan A. Barney, *A Study of Patent Mortality Rates: Using Statistical Survival Analysis to Rate and Value Patent Assets*, 30 AIPLA Q.J. 317, 329 (2002) ("A relatively large number of patents appear to be worth little or nothing while a relatively small number appear to be worth a great deal.").

patents have been abandoned by their owners than have been maintained for their full terms.[14] Inventors (or the organizations that back them) invest large sums in research[15] and additional amounts in patent applications,[16] presumably with the expectation that the future potential of the patented advances merits these investments in gaining intellectual property. Yet, within a period as short as four years after patent issuance, some patent owners lose faith in their patents and abandon them as worthless.[17] Most inventions receiving United States patents in recent years have produced similar disillusionment. The high rates of patent abandonment reflect one of the hard lessons of the patent system: patents are speculative investments in technology development and most such investments fail.[18]

*2. Patents Reflect Bets on Unproved Invention Value*

Separating valuable from worthless patents at patent issuance or even soon after is, unfortunately, highly difficult. The patent system encourages speed in seeking patents rather than care before applying to determine whether particular advances are likely to produce commercial successes.[19] Once innovators produce research results covering the minimum information needed to qualify for patents,

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[14] *See, e.g.*, Crouch, *supra* note 3 (showing that in 2015, owners of only about 45% of United States patents paid the third maintenance fee required for their patents at 12 years after patent issuance).

[15] In some fields, the research costs to produce a patented advance are staggeringly large. For example, developing a new prescription medicine that gains marketing approval is estimated to cost drugmakers $2.6 billion, according to a report by the Tufts Center for the Study of Drug Development. *See* Thomas Sullivan, *A Tough Road*, POL'Y & MED., https://www.policymed.com/2014/12/a-tough-road-cost-to-develop-one-new-drug-is-26-billion-approval-rate-for-drugs-entering-clinical-de.html (last updated Mar. 21, 2019).

[16] *See* Gene Quinn, *The Cost of Obtaining a Patent in the US*, IPWATCHDOG (Apr. 4, 2015), https://www.ipwatchdog.com/2015/04/04/the-cost-of-obtaining-a-patent-in-the-us/id=56485/ (estimating that typical costs for obtaining patents range from $12,000 to $20,000).

[17] A substantial fraction of patents lapse at the 4-year point. For example, in 2015, 15% of patents issued four years before lapsed due to nonpayment of maintenance fees. *See* Crouch, *supra* note 3.

[18] *See* Robert G. Cooper & Elko J. Kleinschmidt, *An Investigation into the New Product Process: Steps, Deficiencies, and Impact*, 3 J. PROD. INNOVATION MGMT. 71, 71 (1986) ("[P]roduct innovation is plagued by high risks [due to] both the large amounts at stake and the high probability of failure.").

[19] Patents are frequently sought and granted for inventions "at the initial stages of conception" when the minimum operative features of the invention are barely understood (and, in some cases, not yet even reduced to a working prototype). *See* Sichelman, *supra* note 10, at 351; *see also* Christopher A. Cotropia, *The Folly of Early Filing in Patent Law*, 61 HASTINGS L.J. 65, 72-75 (2009).

they frequently submit patent applications describing operative but superficially understood inventions.[20] These applications are based on hope and speculation regarding the commercial value of the inventions described. Patent applicants frequently lack information on a broad range of commercial factors affecting the value of their advances.[21] Applicants seek patents at early stages of invention development to secure their bets on the potential future value of the patented advances—ensuring that they, and not others, will reap the early-stage gains from products incorporating the patented advances.[22] The payoffs on their bets are only ascertained much later through market forces reflecting commercial success (if any) while the patents are in force. Relevant valuation information is typically gained after patent applications are filed, including insights into the full features of patented advances (both good and bad), the best ways to implement the advances to produce maximum functionality, the types of products or services that can be developed from these advances, and consumer interest in these products or services.[23]

The large number of patents abandoned as worthless by patent owners reflects how little these owners know about their patented advances when patents are issued. Patent applications are simply poorly informed bets on patent value. The inability of innovators (and the organizations that back their research and gain associated

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[20] *See* Robert P. Merges, *Commercial Success and Patent Standards: Economic Perspectives on Innovation*, 76 CAL. L. REV. 805, 807 (1988) ("[A commercial product resulting from a patented invention] will in all likelihood be different in significant respects from the [patented] invention due to the changes necessary to turn the invention into a commercial product."); Dennis Crouch, *The Trade Secret Value of Early Patent Filing*, PATENTLY-O (Oct. 23, 2008), http://www.patentlyo.com/patent/2008/10/the-trade-secre.html ("[M]any if not most patent applications are filed well before the associated product or method is ready for public consumption—before the inventor knows the best *commercially viable* mode.").

[21] For an overview of the information gathering problems facing patent holders seeking to commercialize their advances, see Sichelman, *supra* note 10, at 348-54.

[22] One of the main purposes of granting patent rights to inventors is to ensure that "free riders" are not able to reap the benefits of a patented advance without compensating those parties (holding patents) who have made the advances and borne associated research costs. *See Innovation and Intellectual Property*, WIPO, https://www.wipo.int/ip-outreach/en/ipday/2017/innovation_and_intellectual_property.html (last visited Jan. 2, 2022) (noting that a key advantage of extending patent protection to an inventor is that "[a] patent can help stop unscrupulous third parties from free riding on the efforts of the inventor."); *see also* Sichelman, *supra* note 10, at 358 ("The reward theory [of patent law] justifies patents as necessary to induce the invention and disclosure of new and non-obvious knowledge, which inventors would otherwise be reluctant to do in the fear that others may free ride off their efforts.").

[23] *See* Sichelman, *supra* note 10, at 351-54 (describing typical product development and market testing steps undertaken in attempts to commercialize patented advances and the types of new information acquired by patent owners after patent issuance).

patents) to accurately predict the value of advances at early stages of innovation development and commercialization produces many inefficiencies. The following subsection highlights the uncertainties that may account for these valuation errors and lead to large numbers of patent filings that patent owners ultimately see as mistakes, warranting patent abandonment.[24]

### *C. Unknowns Potentially Undercutting Patent Value*

Innovators and others attempting to value patented advances often lack information about many factors affecting the practical uses of the advances. The impediments to fully understanding (and correctly valuing) a patented advance stem from what Ted Sichelman describes as the difference between an "invention" and an "innovation".[25] The former is an early-stage technology design which—if sufficiently new, distinctively different from past technical designs, and otherwise in compliance with patent law requirements—can qualify for a United States utility patent. An "innovation", by contrast, is a problem-solving device or process produced by learning about and expanding upon an invention through commercialization processes. As Sichelman notes, extensive information gathering and design improvements are often needed to transform an invention into an innovation:

> Although "innovation" includes the act of invention, it is not so limited; rather, innovation encompasses the entire process of identifying a problem to [be] solved; conceiving a solution to the problem; identifying a market; building a prototype; testing the prototype;

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[24] A number of commentators have concluded (based on patent abandonment data and other empirical evidence such as low patent licensing rates (estimated at 5%) and litigation rates (estimated at 2%)) that "most [patented] technologies will not be economically viable or commercially successful." Robert P. Merges, *As Many as Six Impossible Patents Before Breakfast: Property Rights for Business Concepts and Patent System Reform*, 14 BERKELEY TECH. L.J. 577, 603 (1999); *see also* Michael Abramowicz, *The Danger of Underdeveloped Patent Prospects*, 92 CORNELL L. REV. 1065, 1074 (2007) ("[M]any patents go unlicensed and thus appear to be worthless.").

Patent owners' assessments that patented advances are worthless may be temporary, leading to later revivals of interest in advances covered by abandoned patents. Ted Sichelman suggests that some abandoned patents reflect patented advances that were not capable of successful commercialization while patent rights were in force–leading to patent abandonment–but were shown to be valuable advances in later periods. Sichelman, *supra* note 10, at 372.

[25] Sichelman, *supra* note 10, at 365-66.

> making a commercial product embodying the invention; marketing, selling, and distributing the product; and improving upon that product.[26]

An invention may lack value (and fail in attempts at commercialization) based on problems at any one of the steps along the path toward commercialization. For example, an invention may be relatively valueless because it never works well and its functionality is limited no matter how much effort is spent on improvements.[27] Or an advance may be valueless because, once incorporated into products, the products function no better than already available substitutes. Or a patented advance may be prohibitively expensive to make and distribute at scale, making the overall value of the advance very low. Or consumers may perceive difficulties in using the advance (or other adverse features of the advance) leading to a rejection of products incorporating the advance and low invention value. These problems correspond to information gaps that must be filled to accurately project the value of patented advances.

Foreseeing many of these problems and their impacts on the commercial value of an invention may be impossible when a patent is sought. Errors in estimating the outcome of the various steps toward commercialization may mean large errors in estimating value. Given the many factors involved and the substantial range of information and unknowns affecting valuation results, it is hardly surprising that inventors (or the organizations that back them) often make valuation errors and mistakenly project high value for patented advances when in fact the advances are worthless.

### *D. Filling the Valuation Gap: The Slow Path Toward Understanding Invention Value*

Several features of patented inventions make early-stage valuations challenging. Patented designs embody technological insights departing from conventional wisdom and prior lines of technology development. They are screened in patent application processes for technological distinctiveness, not superior commercial value. Patented inventions are often poorly understood when patents are

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[26] *See id.* at 366-67; see *also* Jan Fagerberg, *Innovation: A Guide to the Literature*, *in* THE OXFORD HANDBOOK OF INNOVATION 3, 4 (Jan Fagerberg et al. eds., 2005) ("Invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice.").

[27] An invention qualifies for a United States patent if it has *some* modicum of utility (in addition to meeting other patent law requirements). *See* 35 U.S.C. § 101. No particularly high or distinctive type of utility must be shown. The ability of patented advances to gain consumer acceptance over prior tools or devices for the same purpose is left to competition in the marketplace.

sought because the inventions depart materially from earlier knowledge and related frames of reference and analysis. Their distinctiveness and often unproven qualities make patented advances especially hard to translate into commercial products and to value in light of both the features and acceptance of these products. These invention features impeding the early-stage valuation of patented advances are summarized in this subsection.

### *1. The Starting Point: New Technological Outliers with Unexpected Features and Unproven Applications*

#### i. Selection for Speed: Patent Law Pressures for Quick Application Filings on Poorly Understood Innovations

United States patent laws strongly encourage speed in pursuing patent applications and thereby promote initial ignorance about invention value at the time applications are filed. Patent laws encourage an inventor (or an entity backing the inventor) to promptly file a patent application following completion of an invention lest someone else develop the same advance and snap up the opportunity for a patent.[28] This need for speedy filing cuts off pre-application factfinding about the attributes and value of an advance. Inventors are strongly pressured—at the threat of completely losing their patenting opportunities—to file patent applications with little or no information about invention value.[29]

Valuation gaps follow because valuation information is not needed to obtain a patent. The minimum invention information needed to qualify for a patent involves no more than bare bones findings about a few functional aspects of an invention. Patent applicants must understand all of the features of their advances that are needed

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[28] A second, subsequent inventor producing the same advance can undercut a patent opportunity for the first inventor in either one of two ways. If both of the inventors' advances are not publicly revealed, the first to file for a patent will cut off the ability of the second to file regardless of who was first to invent. Alternatively, if a second inventor produces and discloses an advance before the first inventor of an advance files for a patent, the first inventor's opportunity to gain a patent for the advance will be lost. The only way for an inventor to be sure of avoiding these problems is to be the first to file a patent application for a given advance. The pressure to do this and to beat other possible inventors in the race to the patent office (even if such other inventors are merely phantoms in the minds of innovators and do not really exist) accounts for the strong pressures on inventors to seek patents promptly.

[29] *See* Sichelman, *supra* note 10, at 367 ("For patent law to promote innovation, it must rely on a variety of activities that occur only after an inventor has completed the work necessary for patenting."); Mark A. Lemley, *Ex Ante Versus Ex Post Justifications for Intellectual Property*, 71 U. CHI. L. REV. 129, 137 (2004) ("Creators are often terrible managers. They frequently misunderstand the significance of their own invention and the uses to which it can be put.").

to produce functional results, and these results must have some modest practical impacts.[30] They must include this minimum information in patent applications[31] and convince patent examiners that they have sufficiently described this required information in their applications.[32] If examiners are so convinced, the applicants will receive issued patents; little (if any) information bearing on the likely commercial value of advances needs to be gathered or submitted to the United States Patent and Trademark Office (USPTO) to gain patents.

Because speed is important and detailed knowledge about invention value is not, the net pressures of patent laws make it rational for many parties to defer valuation assessments and submit patent applications on inventions with highly indeterminate value. Haste in applying is needed if patents are not to be lost; greater knowledge of an invention's value is of little initial consequence and can be left for later. In short, extensive ignorance of an invention's value is commercially rational at the time key decisions about submitting a patent application are made by many applicants.

ii. Selection for Distinctive Features Instead of Commercial Success

Beyond promoting speed in patent application filings, additional patent law features encourage selective development and patenting of advances that emphasize new and distinctively different technology designs with hopes that the commercial value of these advances will later emerge. This is a case of "seeing what you look for." Innovators seeking patentable advances aim for advances that will meet substantive patent law tests; these generally require that a patentable advance include new and distinctively different features in comparison with prior technologies with

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[30] To qualify for a patent, a party must invent a "new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof." 35 U.S.C. § 101. The requirement that an invention be "useful" implies both that all of its components needed to produce a functional result are specified and that this result provides some practical benefit to users (although this benefit need not be superior to that from other items used for the same purpose). *See generally* Brenner v. Manson, 383 U.S. 519 (1966).

[31] As part of a valid patent application, an applicant must provide a "written description" of his or her invention. U.S. PATENT & TRADEMARK OFFICE, MANUAL OF PATENT EXAMINING PROCEDURE § 2162 (9th ed. 2020). "The 'written description' requirement implements the principle that a patent must describe the technology that is sought to be patented; the requirement serves both to satisfy the inventor's obligation to disclose the technologic knowledge upon which the patent is based, and to demonstrate that the patentee was in possession of the invention that is claimed." Capon v. Eshhar, 418 F.3d 1349, 1357 (Fed. Cir. 2005).

[32] Patent examiners working for the United States Patent and Trademark Office review patent applications to determine if inventions and the patent applications describing them meet patent law requirements. *See* 35 U.S.C. § 131.

similar functions.[33] Innovators (or the organizations that back them) look carefully for distinctively new technologies that produce functional results because advances with these features can qualify for patents; they do not—at least prior to the patent application filing—generally explore the full commercial implications of their discoveries.

Patented advances are accordingly selectively developed to emphasize technological distinctiveness and to stake out new design directions. The resulting advances are evaluated for patenting along this same dimension of technological distinctiveness. At least three filtering processes ensure that most patented advances involve poorly understood outlier technologies. First, innovators, lured by patent rewards, may selectively direct their research toward work on distinctively new technologies that will qualify for patents. These research targeting choices skew the outputs of their research (and patents resulting from the research) toward distinctively new results.[34] Second, where innovators seek and produce a range of advances in the course of research, they may still select only the distinctively new advances for submission in patent applications.[35] This filter, applied in targeting and preparing patent applications, also tends to ensure that only distinctively new advances are described in issued patents. Third, if innovators submit patent applications that do not describe departures from earlier technologies, patent

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[33] *See* 35 U.S.C. §§ 101, 103.

[34] One of the key goals of the patent system is to shift research investments toward new levels and types of research that would not occur absent the lure of patent rewards. *See, e.g.*, Heidi L. Williams, *How Do Patents Affect Research Investments?*, 9 ANN. REV. ECON. 441, 442 (2017). Several empirical studies have confirmed that patent protections materially affect the types of research that certain firms pursue, with especially high impacts on research in particular industries such as pharmaceutical drug development and chemical research. *See, e.g.*, Edwin Mansfield, *Patents and Innovation: An Empirical Study*, 32 MGMT. SCI. 173-75, 177, 180 (1986) (stating that company managers reported as many as 60% of company innovations in certain industries would not have been pursued without patent protections); *see also* C.T. TAYLOR & Z.A. SILBERSTON, THE ECONOMIC IMPACT OF THE PATENT SYSTEM (Cambridge Univ. Press 1973) (reporting similar results based on a smaller study); Edwin Mansfield, Mark Schwartz & Samuel Wagner, *Imitation Costs and Patents: An Empirical Study*, 91 ECON. J., 907 (1981) (reporting similar results based on smaller studies).

[35] A patent application will be a futile waste of resources (and, hence, generally not pursued) if an invention fails to meet patent law requirements because it involves no more than an adjustment to prior technology that, for most persons of average skill in the relevant field, would seem obvious to pursue. This will be the case if there "was motivation in the prior art to do what the inventor has done, or if there is some reasonable expectation that the combination of elements [in the invention] would achieve a successful result." *See* Gene Quinn, *Patentability: The Nonobviousness Requirement of 35 U.S.C. 103*, IPWATCHDOG (June 17, 2017), https://www.ipwatchdog.com/2017/06/17/patentability-nonobviousness-35-usc-103/id=84716/.

examiners are charged with rejecting the applications as failing to meet patent law requirements.[36] In the face of such a rejection, an applicant will typically have the choice of withdrawing their patent application or rephrasing it to describe the distinctively new features of their advance. Either way, reviews by patent examiners tend to limit successful patent applications to those describing distinctively new advances. As a result, the patented designs are outliers in their respective fields.

The processes leading to issued patents emphasize technological novelty and distinctiveness, but not necessarily the commercial superiority of the inventions. Inventors are technological risk-takers who explore and develop unproven technologies. Their endeavors are risky because they must often expend extensive time and resources on directions of study with few grounds in past technologies to expect success. Sometimes, their work proceeds in the face of traditional knowledge indicating that their projects will probably fail. Inventors are often single-minded in pursuit of technological solutions, consumed by their most important task—determining whether a new, untried, and somewhat unpredictable technology can be made to produce functionally desirable results. They often fail to produce working advances many times before they succeed.[37]

Amidst the numerous burdens of producing a new technology in basic, workable form, detailed commercial assessments are ignored.[38] Patent application processes—including reviews by patent examiners—do not create additional pressures for commercial assessments. An applicant will qualify for a patent with a

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[36] Patent examiners are required to reject patent applications that fail to describe inventions meeting patent law requirements—including the requirement that an invention incorporate nonobvious differences from prior technology designs. Inventions lacking such departures from prior technology are thereby filtered out of issued patents. *See* 35 U.S.C. §§ 103, 131.

[37] The tendency of inventors to fail in attempts to produce workable advances are rooted in human imagination processes that cause parties to imperfectly project future events including the features and operations of imagined inventions. *See* Richard S. Gruner, *Imagination, Invention, and Patent Incentives: The Psychology of Patent Law*, 2017 U. ILL. J.L. TECH. & POL'Y 375, 424 (2017).

[38] Beyond just a lack of time and resources to undertake commercial analyses while minimally workable advances are still in development, the deferral of commercial studies until a working advance is on hand ensures that commercialization analyses are on point—that is, that they address actual features of realized advances. Efforts to assess commercial characteristics of partially completed advances may waste time evaluating speculative ideas about what a (hypothetical and not yet realized) advance might look like and what the commercial implications of the advance might be. Commercial evaluations are best deferred until a concrete advance is on hand; earlier assessments might evaluate the wrong features (not present in the final version of the advance) and overlook features that are present in a final design but that were not yet understood at earlier stages when speculative commercialization analyses were completed.

minimally functional technology that is distinct from past designs in some unexpected way even if there is no evidence of any commercial potential for the application.[39] The resulting patent does not indicate that the patented advance is superior to other similarly functional items or that it has other desirable commercial characteristics. Rather, patent requirements ensure only that a patented advance has some minimal practical results.[40] Questions of functional superiority and commercial success are left to later market tests.[41]

Inventions presented for patenting often possess unappreciated features that will ensure their commercial failure. These features are rarely caught before filing patent applications because no one is looking for them. Patented advances are analogous to hits in a baseball game: they have the distance to be home runs but are aimed without regard to foul lines. Patents are awarded for technological outliers without regard to commercial value—they go the distance of a home run, but whether the hits are in the right direction to be commercially successful is yet to be determined. While costly research efforts to develop patentable advances (and further costly efforts to apply for patents) are typically not undertaken without some expectation of positive commercial returns from the inventions involved, these expectations are often no more than unconfirmed hopes. The very newness and distinctively different characteristics required to meet patent law standards mean that patented advances serving as starting points for commercial products and services frequently incorporate many technological and commercial unknowns.

*2. Missing Accounts of Commercial Products Derived from Patented Advances*

The outlier features embedded in patented advances often make these advances hard to transform into new products and services and, accordingly, hard to value in terms of projected products and services. Patented advances distinctively departing from past technologies will often have characteristics and functions that are hard to assess and extend using existing technical knowledge and engineering frameworks. The operation of the new advances and how they should be incorporated in commercial products may be difficult to project because normal analytic tools based on past technologies are insufficient to account for and interpret

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[39] *See* 35 U.S.C. §§ 101, 103.

[40] *See generally* Brenner v. Manson, 383 U.S. 519 (1966).

[41] A market test involves designing useful products based on a patented design, producing numerous units of the products, and marketing the products to gauge consumer interest. Many patented technologies are not seen as having enough commercial value to justify the creation of related commercial products and the submission of the technologies to market tests. Others fail in the tests, lacking sufficient consumer interest to produce profits. *See, e.g.*, Sichelman, *supra* note 10, at 351-52.

the distinctively new advances. The distinctiveness that ensures advances can qualify for patents also ensures that the advances exist somewhat apart from past technical knowledge and are, accordingly, hard to evaluate and extend with analytic tools that depend on past technical understanding.

Projecting the ultimate commercial value of a minimally functioning prototype may also be difficult because innovators and other analysts are unable to accurately imagine future invention capabilities and problems with operation. Imagining the altered and perfected versions of advances embedded in commercial products may be especially hard for patented advances.[42] Patented advances—as inventions distinctively different from past technologies in some way—may lead to commercial products with features that are unusually hard to imagine. The more inventions depart from past technology designs, the more parties projecting the features and uses of related commercial products must imagine rather than rely on past knowledge. The more they must imagine, the more mistakes they are likely to make, and the more their valuation estimates may err.

When parties imagine future products based on patented technologies, they may stumble due to weaknesses in human cognitive abilities.[43] These weaknesses impair all human efforts to imagine the future. Errors in projecting the future features and value of applications built on new technologies stem from at least three types of weaknesses in imagination: (1) assumptions in imagining future activities that the activities will be like similar ones today, leading to imagined future invention usage and results that are too much like counterparts in the present (that is, unfounded presentism); (2) a tendency to treat imagined circumstances and events like real ones, leading to insufficient doubt about the accuracy of imagined ideas of future invention use and results and inadequate testing of the veracity of these imagined visions (that is, excessive realism); and (3) difficulties in projecting human reactions to future invention use and results even when parties imagine such use accurately (that is, inaccurate rationalization).[44] All of these types of imagination errors directly impact the accuracy in projecting future invention uses and undercut the accuracy of invention valuations based on the projected uses.

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[42] I have written previously on the features of human cognition—particularly our abilities to project future actions, values, and circumstances—that make the imagination of successful inventions difficult. *See* Gruner, *supra* note 37, at 391-421. Even when a minimally functional invention is imagined and patented, imagining commercially successful implementations of these advances will still be impaired by weaknesses in the processes for imagining future events. *See id.*

[43] *See id.*

[44] *See id.*

*3. Missing Valuation Tools*

Even if future commercial products based on distinctively new advances are accurately imagined, the value of the projected products may be difficult to measure. The necessary valuation tools may not be available. Old valuation frameworks and criteria may be irrelevant or incomplete for assessing fundamentally new technologies. The very differences from past technologies that qualify advances for patents may make them difficult to value.

Valuation problems may arise because the special value of patented advances—relative to prior items or processes for accomplishing the same ends—is linked to the distinctively new features of the advances. But, as distinctively new departures from past technologies, these new features may have functional and practical implications that are unfamiliar and thus hard to fully value using past experience and valuation methods.

Past experience may be of little use in interpreting the value of distinctively new features of patented inventions. If past experience or well-known methods for extrapolating technological characteristics were sufficient to predict and understand the functionality of the new elements of an advance, the new elements would likely be deemed obvious variations of old technologies and, as such, the advance would not qualify for a patent. Patented advances are inventions that have cleared this hurdle—that is, advances that parties in the relevant field could not easily design with commonly used analytic tools and methods.[45] These same commonly used analytic tools and methods may therefore be insufficient to understand and project invention value. Interpreting patented invention use and the resulting value may only be possible when actual products are realized and placed in widespread use after which the net value of the inventions can be measured concretely. Until then, the unfamiliarity of the patented advances and the lack of trusted methods to understand and project the features of the advances when placed in products may make the early-stage valuation of patented advances highly problematic.

*4. Biases Undercutting Invention Valuations*

Beyond problems resulting from commercialization uncertainties, parties owning patents may be highly biased in making post-innovation valuation assessments, leaning toward overly high estimates of patented invention value.[46] As they learn about the strengths and weaknesses of an advance as a commercial

[45] *See* 35 U.S.C. § 103; Graham v. John Deere Co., 383 U.S. 1, 17 (1966).
[46] *See* Gruner, *supra* note 37, at 391-421.

vehicle, patent owners will tend to be unduly optimistic about the value of raw advances resulting from their discoveries.[47]

Pride may foster unsupported estimates of high invention value.[48] Inventors of a patented invention may be proud of their discovery of an outlier advance that was beyond the capabilities of most of their peers and distinctively different from past technologies. Alternatively, they may be proud that their advance qualified for a patent and assume (often wrongly) that the distinctive features of the patented advance will directly translate to significant commercial value. Pride in their advances may encourage estimates of high commercial value even if there is little or no evidence supporting that value.

Other factors may also bias valuation assessments by inventors or their backers. These stakeholders may be highly selective in information they seek and evaluate, emphasizing (or even exclusively considering) information that supports a desired conclusion (such as a finding of high value in a hard-won invention) and blinding themselves to contrary information about the limitations of an advance.[49] Or they may become attached through ownership to a patent and suffer from unappreciated "endowment effects" in valuing the patent; endowment effects cause parties possessing an asset to assign a higher value than a neutral non-owner would give to the same asset.[50] Endowment effects tend to cause inventors and backing organizations to overvalue owned patents early in commercialization processes.

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[47] "[D]esigners [including inventors] are human beings first and as such are . . . subject to the failings of the species, including complacency, overconfidence, and unwarranted optimism." HENRY PETROSKI, SUCCESS THROUGH FAILURE 194-95 (Princeton Univ. Press 2006).

[48] Pride is a feeling that typically tracks how much others in a person's local world value the actions of an individual. *See* Andrea Estrada, *The Value of Pride*, SCIENCEDAILY (Aug. 6, 2018), https://www.sciencedaily.com/releases/2018/08/180806175957.htm. For inventors, pride may increase following the discovery of inventions that impress the inventors' scientific or engineering peers—perhaps because the inventions incorporate nonobvious features that others in the field were not able to formulate or appreciate. But technological insights, while furthering additional technology development and having design value (as measured by the esteem of peers), do not guarantee commercial value. Great pride in an invention may cause an inventor to conflate these two types of value and to project commercial value in a new advance even when there is little basis for anticipating favorable commercial results.

[49] *See* Gruner, *supra* note 37, at 401-05.

[50] Endowment effects arise where persons owning or "endowed" with assets tend to overvalue those assets and refuse to part with the items when offered purchase amounts determined through market processes. Christine Jolls, Cass R. Sunstein & Richard Thaler, *A Behavioral Approach to Law and Economics*, 50 STAN. L. REV. 1471, 1484 (1998). These effects are particularly strong where—as with many inventors of patented items (or organizations that have backed the inventors and gained associated patents)—the owner of an asset feels that he or she has "earned" ownership or that he or she particularly deserves it. *See id.* at 1498.

Indeed, optimism born of invention "possession"—and the associated endowment effects—may attach as early as the invention's discovery. The optimism of inventors (and others seeking patents) propels them to file for patents on many apparently valuable advances only to find later that their value estimates were biased and faulty.

Patent holders may also find it difficult to reconsider erroneous valuations once they have reached them. Patent applicants' initial commitments to the positive value of their advances—commitments reflected in large expenditures on costly patent applications—undercut neutrality in later evaluations of an invention's value. Parties making such commitments are loath to admit their mistakes. Given their initial conclusions that the advances have sufficient value to justify expensive patent applications, inventors and their backing organizations remain vested in this assessment and biased against contrary findings of an invention's worthlessness.[51] Carried forward by their biases, these parties are often slow to appreciate the information in front of them indicating low innovation value.

### *E. Consequences of Delayed Recognition of Worthless Inventions*

For the various reasons just summarized, most patent owners only gain an accurate idea of the value of their patented advances long after receiving their patents. They start the patent application process with early but largely unfounded enthusiasm and then learn the hard truth that most of their patents are valueless. The number of valueless patents is enormous but identifying which are worthless takes time.

The number of valueless patents in the United States patent system is staggering, in part due to the large number of patents issued in general. Hundreds of thousands of new utility patents are issued in the United States each year—354,507 new patents in 2019 alone.[52] Given these many patents (each corresponding to an outlier invention capable of qualifying for a patent but often imperfectly

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[51] This bias against recognizing a patent's worthlessness following an initial assessment of substantial value is a form of confirmation bias. Confirmation bias makes a person somewhat insensitive to adverse information and biased in favor of keeping an original conclusion rather than changing one's mind. *See* Univ. of Iowa, *See! I Was Right*, SCIENCEDAILY (Nov. 16, 2015), https://www.sciencedaily.com/releases/2015/11/151116143602.htm (noting research confirming that, once people reach a conclusion, they are not likely to change their minds, even when new information shows that their initial belief is likely wrong and that clinging to that belief has costly implications). In the context of invention valuation, early-stage projections of high invention values will bias patent owners against later realizations that their patents are worthless.

[52] Dennis Crouch, *How Many Patents Issued in 2019?*, PATENTLY-O (Dec. 31, 2019), https://patentlyo.com/patent/2019/12/many-patents-issued.html.

understood), numerous patent valuation errors and associated commercialization failures are to be expected.

What is surprising is the high percentage of patents that are apparently valueless. A majority of patent owners ultimately conclude that their patents are essentially worthless and refuse to pay modest maintenance fees to keep the patents in force. For example, in 2015, owners of only 45% of patents saw sufficient value to justify paying maintenance fees needed to extend their patents for their full potential duration.[53] The remainder of patents (55%) were treated by their owners as essentially worthless.[54]

The high levels of patent abandonment have significant implications for the patent system. Assuming that the abandonment rate in 2015 (55% of patents abandoned) holds true for recent patents issued in 2019,[55] about 194,979 of the patents issued in 2019 are probably worthless.[56] These worthless patents—likely to be abandoned by their owners—come at a high cost. Application costs for patents can vary widely but are typically large. One analyst has estimated that typical patent applications cost about $12,000 to $20,000 to prepare and pursue (with costs for particular applications depending on an invention's complexity and technology type).[57] These application costs are in addition to the costs of the underlying research producing the inventions being patented. Ignoring research costs and assuming just an average patent application cost at the low end of the range, the number of abandoned patents projected above for 2019 corresponds to about $2.34 trillion per year in wasted patent application costs (not counting the further costs to the government in processing patent applications on worthless inventions).

### *F. The Price of Patent Speculation: Recognizing Frequent Worthlessness Late and from Hard Experience*

Despite the enormity of these costs, bearing them may be a necessary evil in a patent system aimed at rewarding valuable inventions but operating in technology spaces where valuable and worthless advances are initially difficult to distinguish. The costs of patenting failed inventions may need to be paid to enable patent rewards

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[53] Crouch, *supra* note 3.

[54] *Cf.* Sichelman, *supra* note 10, at 362-63 ("[P]atentees fail to pay maintenance fees on more than 60% of patents within twelve years after issuance.").

[55] The percentage of maintenance fee payments has been decreasing, meaning that figures quoted in the text for payments related to 2003 patents may *understate* the percentage of 2019 patents that will be allowed to lapse prior to the end of their full patent terms. *See id.*

[56] This figure results from the following calculation: (Total Issued Patents) x (Fraction Abandoned) = 354507 x .55 = 194,979.

[57] Quinn, *supra* note 16.

for other advances that have substantial value. Losses for abandoned patents reflect a patent system in which patented invention wheat and chaff cannot be separated at patent issuance—that is, a system in which the future value of outlier inventions qualifying for patents cannot be determined without significant information only available after patent issuance.

Despite the obvious economic advantages to innovators and backing organizations of earlier invention value assessments (in making better research-initiation decisions and avoiding the costs of patent applications for ultimately abandoned inventions), patent owners generally can only identify worthless patents via additional invention, application, and market information gained over extended periods. This explains their significant delays in recognizing and abandoning worthless patents (in many cases, not abandoning their patents until 12 years after patent issuance). Oftentimes, the slow realization is that patent owners have made bad bets on worthless innovations.

Patent owners seem to accumulate more and more disillusioning information about low patent values over time, leading to increasing numbers of abandonment decisions as later and later maintenance fees come due. At each of the 4-, 9-, and 12-year fee due dates, patent owners must decide whether their patents appear valuable enough to justify paying the next maintenance fee. All of the fees at stake are relatively modest.[58] In 2015, approximately 85% of patent owners paid maintenance fees due 4 years after patent issuance (thereby retaining patents issued in 2011); approximately 66% of patent owners paid maintenance fees due 8 years after patent issuance (thereby retaining patents issued in 2007); and approximately 45% of patent owners paid maintenance fees due 12 years after patent issuance (thereby retaining patents issued in 2003).[59] This means—assuming similar maintenance fee payment percentages apply across recent years—that about 15% of patents were found

[58] The fees needed to keep patents in force vary with both the number of years from patent issuance and the size of the entity owning a patent. The highest fees apply to large organizational patent owners, which are defined as organizations with at least 500 employees. Vic Lin, *Small Entity vs. Large Entity USPTO Filing Fees*, PAT. TRADEMARK BLOG, https://www.patenttrademarkblog.com/small-entity-vs-large-entity-uspto-filing-fees/ (last visited Jan. 2, 2022). For such entities, the maintenance fees are: $2,000 due 4 years after patent issuance; $3,760 due 8 years after issuance; and $7,700 due 12 years after issuance. The amounts due from patent owners that are smaller organizations or individuals are less at every maintenance fee due date. *USPTO Fee Schedule*, USPTO, https://www.uspto.gov/learning-and-resources/fees-and-payment/uspto-fee-schedule#Patent%20Maintenance%20Fee (last updated Jan. 1, 2022).

[59] Crouch, *supra* note 3.

valueless and allowed to lapse after 4 years, another 19% after 8 years, and a further 21% after 12 years, for a total of 55% lapsed patents.[60]

This pattern suggests a growing body of adverse information—or increasing levels of disillusionment for other reasons—indicating low perceived value in more and more abandoned patents over time. Patent holders appear to have high initial hopes for many of their patented advances—as evidenced by their willingness to invest in application costs—but have less and less confidence in their patented advances over time. The growing fraction of advances abandoned at each successive maintenance fee due date reflects the hard lessons that many patent holders learn about the worthlessness of their advances through growing bodies of adverse information accumulated over time.[61]

### *G. The Residual Value of Abandoned Patents*

Even if valueless to its owner (and accordingly abandoned), an abandoned patent may have value in the development of further technologies. Information disclosed in abandoned patents may shape subsequent technology development in at least two ways. First, abandoned patents may disclose germs of ideas or design approaches that are more successfully implemented by later innovators. While the

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[60] *Id.*

[61] Beyond the effects of growing information about patent worthlessness, two other mechanisms may explain the growing fraction of patents abandoned at successive maintenance fee due dates.

First, the fees due at later deadlines are higher than earlier ones, meaning that a patent which was perceived as valuable enough to justify paying a low fee might not be seen as sufficiently valuable to justify paying a later, larger fee.

Second, earlier maintenance fee payments may gain patent owners more valuable options regarding patent enforcement than later payments, making owners more willing to make the earlier payments. Early payments keep the option of future enforcement available for longer periods than later payments. For example, payment of the fee due 4 years after patent issuance keeps open patent enforcement for the remainder of the life of a patent (assuming later maintenance fees are also paid). The full potential duration of patent rights is 20 years from patent application filing. Assuming a typical delay between patent application filing and patent issuance of about three years, patent rights will typically last a total of about 17 years from patent issuance if all maintenance fees are paid. A fee payment at 4 years from issuance therefore keeps open the option of about 13 more years of patent enforcement while a payment at the 12-year point only keeps the patent in force for about 5 more years. The option of retaining a longer period of potential enforcement—and a longer period to learn about actual patent value and to detect patent infringement—may be seen as worth more than a shorter period. Hence, a patent holder may perceive a patent as having enough commercial potential to warrant keeping enforcement open over 13 additional years but see the same patent as not having sufficient perceived value to justify a payment to keep enforcement open for only 5 additional years.

invention versions covered by abandoned patents may not be wanted by consumers, the advances disclosed in the patents might aid later innovators in producing related technology advances that modify or extend the abandoned inventions. Second, failed advances covered by abandoned patents may provide valuable guidance on where *not* to pursue new technologies, warding subsequent innovators away from what would have been wasteful innovation projects. Both of these potential sources of value are explored in this subsection, along with empirical evidence highlighting each of these types of abandoned patent value.

*1. Aiding More Successful Attempts in Similar Technological Directions*

Inventions covered by abandoned patents might advance technology development by providing jumping off points for later designs. Such might be the case, for example, if a patented advance reveals a new analytic insight or technology design potential but has applied that insight or potential in a poorly functioning way, or in a field where the insight or potential did not have much commercial importance. The same insight or potential applied somewhat differently elsewhere might produce a more useful and commercially significant result.

Empirical evidence suggests that abandoned patents rarely enhance future research in this way. If advances described in abandoned patents were frequently used as jumping off points for further designs, one would expect there to be a substantial upward jump in citations when abandoned patents lapsed (and the related legal constraints on using similar technologies were removed). As discussed in Section II of this article, there is no evidence of high citation counts for abandoned patents either before or after abandonment. Rather, citations to such patents are generally low and stay at the same low levels after patent abandonment.[62] It does not appear to be that subsequent inventors see much value in following technology design directions embedded in abandoned patents.

*2. Directing Research Away from Failed Technological Directions*

The residual value of patented advances once the relevant patents are abandoned may lie in increasing knowledge about what *not* to try—that is, about failed directions of technology development. Even failures have educational value. However, this value will be realized only if an understanding of abandoned inventions and how they failed informs later efforts to undertake similar inventions. Abandoned patents and the unwanted inventions they describe may have some value in forestalling wasteful efforts to pursue further projects that not only waste resources in duplicating the failed invention but that are likely to fail as well. In

[62] *See infra* Section II(C)(2).

effect, abandoned patents may warn future inventors where not to go in subsequent innovation efforts. The value in this type of warning would lie in research not undertaken and associated costs not incurred. The size of these savings is hard to measure, as is the mechanism (if any) whereby abandoned patents are assessed for information on how they failed to meet consumer needs.

There is evidence that subsequent innovators avoid further work on the technology and development directions described in abandoned patents. Abandoned patents are cited at much lower rates than valuable patents, suggesting that the advances described in the abandoned patents and closely-related innovations (which would have resulted in citations to the abandoned patents) are rarely of much interest to innovators.[63] However, there is no evidence that innovators' avoidance of these technologies occurs because the innovators are warded away from the technologies by knowledge of the abandoned inventions' failures.[64] More likely, later innovators make their own evaluations of the technologies described in abandoned patents (through independent research about those technologies without necessarily accessing the abandoned patents) and conclude that these technologies lack probable value.[65] Based on their separate but similar analyses, both patent owners and later innovators see the technology neighborhoods of abandoned inventions as essentially worthless.

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[63] *See id.*

[64] The problem in evaluating the implications of low citations to abandoned patents is a bit like analyzing why a dog at the scene of a crime did not bark: was the dog just ignoring relevant facts, or was it reacting to a familiar party who was the criminal? In the context of abandoned patents, low levels of citations can be interpreted in at least two ways. Subsequent technology innovators may have been aware of the abandoned inventions and been warded away from similar research projects, in which case the informative but abandoned patents would not be cited as there would be no line of citing patents resulting from inventions not produced. Or later innovators may just have made their own assessments of valuable research directions, been attracted to different directions than those pursued in abandoned patents, produced new advances in the new directions, and failed to cite the abandoned patents because they were not relevant to the new directions. This would also result in low citation counts for the abandoned patents. Which of these mechanisms was in play cannot be ascertained from low citation counts alone—that is, from the citation "dog" that did not bark.

[65] In general, inventors tend not to read patents, meaning that they are unlikely to be influenced by the content of abandoned patents and the negative technical design information (such as indications of technology directions not to pursue) that inspection of these patents might reveal. *See* Mark A. Lemley, *Ignoring Patents*, 2008 MICH. ST. L. REV. 19, 22 n.16 ("Empirical research suggests that scientists don't in fact gain much of their knowledge from patents, turning instead to other sources."); Wesley M. Cohen et al., *R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States*, 31 RSCH. POL'Y 1349, 1362-64 (2002).

# I
## THE PRESENT STUDY

The present study relies on forward citation data to track innovators' reactions to and interest in patented technologies.[66] The study uses forward citations as indicators of inventor interest and research intensity concerning technologies conceptually similar to the cited advances. Large numbers of forward citations indicate strong inventor interest in technologies like that in a cited patent. Large numbers of forward citations also confirm substantial invention follow-through in the technology neighborhoods of the cited patents. Because numbers of forward citations track inventor interest—and because inventors are under legal obligations to make these citations as part of their duties to provide full accounts of the background of their inventions—forward citations provide useful data on inventors' estimates of technology value and related shifts in technology development. Inventors convey their estimates of high technology value in their choices of innovation projects. They "follow the (perceived) money" and projected invention value in innovation targeting. Their aggregate value estimates are captured in forward citation counts reflecting crowdsourced information on projected invention value. Where a given advance attracts many forward citations, the cited advance reflects a technology domain with high estimated value in the minds of later innovators.

The following subsections describe the conceptual and methodological underpinnings of the present study. First, Subsection A explains why forward citations are useful metrics for evaluating inventor interest in particular technology domains (including descriptions of past studies using forward citations for this purpose). Second, Subsection B describes the data and methods used in the present study. Section II of this article presents the findings of the present study, including evidence of significant differences in the interest shown by subsequent inventors in owner-valued patents (that is, patents extended to their full term by their owners) as

[66] Forward citations are citations to a patent in later-issued patents. Inventors filing patent applications are required to describe the background of their inventions. One way to do this is to cite earlier patents that describe related inventions. These citations create "backward citations", so named because they cite patents that are *backward* in time from the citing patent. Once a patent issues, backward citations (along with additional citations added by patent examiners) appear in the patent and in databases recording the patent. Forward citations are backward citations looked at in the opposite direction; that is, a citation treated as a backward citation from the standpoint of a citing patent is treated as a forward citation from the standpoint of the cited patent. Forward citations are so labeled because the citing patents are issued later or *forward* in time from the cited patents. *See* Leonidas Aristodemou & Frank Tietze, *Citations as a Measure of Technological Impact: A Review of Forward Citation-Based Measures*, 53 WORLD PAT. INFO. 39, 40 (2018).

opposed to abandoned patents (that is, patents abandoned before their full term due to a failure to pay maintenance fees).

### *A. Forward Citations as Markers for Inventor Interest and Projected Invention Value*

#### *1. Forward Citations Reveal Technology Neighborhoods with High Inventor Interest and Projected Value*

A citation in a patent application to an earlier patent suggests that the inventor filing the application was working in the technology vicinity or "neighborhood" of the advance in the cited patent. While a forward citation provides no guarantee of direct intellectual dependence (in the sense that the inventor of the citing advance was aware of and influenced by the cited advance), a forward citation does imply an intellectual proximity and conceptual relationship between the advances in the citing and cited patents.

Citations to earlier patents in an inventor's patent application are sometimes mistakenly taken as evidence that an inventor read the cited patents and derived his or her work from the cited patents' inventions.[67] This is probably incorrect in most cases and not the meaning of a forward citation relied on here. For the most part, inventors neither read earlier patents nor write their own patent applications.[68] Patent attorneys or agents write most patent applications, and these parties—along with patent searchers and patent examiners—account for patent citations in patent applications.

A more accurate interpretation of a patent citation is as a marker for similarity in technology between a cited and citing patent. A patent citation in a patent application indicates that the citing party felt that there was such a key similarity to the cited invention and that understanding the cited invention was important for evaluating the new features of the citing invention.[69] The cited invention then can be

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[67] The assumption that patent contents are inspected by subsequent innovators and have direct impacts on later technology development is implicit in citation analyses that use citation counts as measures of the varying technology development "influence" of different patents. *See, e.g.*, *id.*, ("Forward citations are commonly used to measure the technological impact of innovation.").

[68] *See* Lemley, *supra* note 65, at 22 n.16.

[69] Most patent citations are made by patent applicants, although some are added by patent examiners as they review patent applications. Patent applicants (and persons aiding in the drafting and submission of patent applications, such as patent attorneys) have a duty to disclose information that is materially related to the patentability of an invention, insofar as such information is known when a patent application is submitted to the USPTO. The required information includes past technology designs that bear upon whether an advance covered by a patent application is new and

considered as part of the background technology baseline or "prior art" against which the new (and not new) features of the advance described in a citing patent can be evaluated.[70]

Interpreted this way, citations suggest that the inventions in cited and citing patents share a single technology neighborhood defined by the common features of the advances.[71] A single citation confirms only that there are two advances in the relevant neighborhood (the cited and citing advances). But a large number of citations to a particular patent indicates that subsequent innovators produced numerous advances in the same technology neighborhood as the cited advance. Forward citations grouped around cited advances thereby measure the magnitude and intensity of inventive activity in the conceptual vicinity of the cited patent.[72] Large numbers of forward citations point to areas of strong innovator interest.

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sufficiently different from past technologies to qualify for a patent. The disclosed information serves as a starting point for reviews of patent applications by patent examiners. *See* U.S. PATENT & TRADEMARK OFFICE, MANUAL OF PATENT EXAMINING PROCEDURE §§ 2001.05, 2001.06 (9th ed. 2020). Patent citations in a patent application are convenient ways to point to and disclose the contents of the cited patents to patent examiners. *See generally* Christopher A. Cotropia, Mark A. Lemley & Bhaven Sampat, *Do Applicant Patent Citations Matter?*, 42 RSCH. POL'Y 844 (2013) (describing patent examiners' consideration of cited patents as well as other prior art sources).

[70] Relevant prior art includes all types of publicly available information from which the novelty and nonobviousness of an advance covered by a patent application can be assessed. *See* U.S. PATENT & TRADEMARK OFFICE, MANUAL OF PATENT EXAMINING PROCEDURE §§ 2001.05, 2001.06 (9th ed. 2020). Common sources of prior art information include publicly available knowledge, products, and patent documents. Patent records provide particularly important prior art sources both because they present recent technological knowledge in organized ways and because they are indexed and therefore easily retrieved via computer-enhanced searching. Some worldwide patent databases contain 130 million documents, collected and indexed over many years by patent offices in many countries. *See What Is Prior Art?*, EUR. PAT. OFF., https://www.epo.org/learning/materials/inventors-handbook/novelty/prior-art.html (last updated Nov. 3, 2021).

[71] This approach uses inventors' self-evaluations (or the evaluations of parties aiding inventors in filing patent applications) to identify patents that share similar technology design neighborhoods. A citation implies that the citing inventor feels his or her advance is conceptually close to the cited advance and in the same neighborhood. Other parties have recognized that technology similarity defines neighborhoods of patented advances but have attempted to define the relevant neighborhoods in terms of pre-existing technology classification systems and to measure the adjacency of advances based on these externally imposed schemes. *See* Madeline K. Kneeland, Melissa A. Schilling & Barak S. Aharonson, *Exploring Uncharted Territory: Knowledge Search Processes in the Origination of Outlier Innovation*, 31 ORG. SCI. 535 (2020).

[72] Manuel Trajtenberg previously recognized this implication of numerous forward citations:

Citation counts are crowdsourced indicators of technology "hot spots"—technology domains with intense innovation interest and high-volume productivity. These indicators reflect the views of talented innovators capable of generating patented advances since only the work of these innovators result in patent citations. Their interest, in turn, tracks the innovators' beliefs (and those of their research backers) in the economic potential of further inventions within the heavily pursued and extensively cited areas of innovation.[73]

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> The very existence of [numerous citing] patents attests to the fact that the cited patents opened the way to a technologically successful line of innovation. Moreover, it presumably attests also to economic success (at least in expected value terms), since those subsequent patents are the result of costly innovational efforts undertaken mostly by profit-seeking agents . . . . [I]f citations keep coming, it must be that the innovation originating in the cited patent ha[s] indeed proven to be valuable.

*A Penny for Your Quotes: Patent Citations and the Value of Innovations*, 21 RAND J. ECON. 172, 174 (1990). According to this view, the meaning of later citations is that "a patent that has been revealed to be profitable will induce other firms to undertake research in technologically close but non-infringing areas, (probabilistically) resulting in citing patents." Bhaven N. Sampat & Arvids A. Ziedonis, *Patent Citations and the Economic Value of Patents: A Preliminary Assessment*, *in* HANDBOOK OF QUANTITATIVE SCIENCE AND TECHNOLOGY RESEARCH 277, 280-81 (Henk F. Moed et al. eds., 2004).

[73] *See* Trajtenberg, *supra* note 72, at 174. Recent empirical research suggests that numerous forward citations reflect strong market interest in (and perceived value of) technologies similar to those described in heavily cited patents. Based on studies of licensing of university patents (from Columbia University and the University of California) and related licensing revenues, Bhaven N. Sampat and Arvids A. Ziedonis concluded that high forward citation counts were good predictors that patents were licensed, but not good predictors of revenues gained once patents were licensed. Their preliminary interpretation of these results is that:

> [C]itations reflect market interest in areas in technological proximity to particular patents. Market interest induces innovative effort in particular technological areas, increasing the probability of later citations. At the same time market interest also increases the probability of licensing. However, as innovation and commercialisation are uncertain activities, the level of revenues ultimately earned by particular technologies may be influenced by factors other than market interest, including competition by competing technologies, licensees' commercialisation incentives, and R&D and marketing competencies.

Sampat & Ziedonis, *supra* note 72, at 295.

*2. Past Studies Confirming Forward Citations' Links to Inventor Interest and Commercial Success*

Past studies confirm that forward citations—particularly early-stage forward citations within three years of patent issuance (hereinafter "quick citations")—track innovator success in producing advances with high value. Researchers at the Massachusetts Institute of Technology (MIT) found that mean quick citations for different types of advances predicted approximately 64% of variations in value growth for diverse technologies.[74] They concluded that quick citations were markers for innovator interest, with areas of intense interest and active innovation efforts tending to produce the most commercially successful and valuable technologies.[75] Numerous early-stage citations point to attractive, fast-moving technology fields where many innovators (and supporting organizations drawn by the commercial potential of the fields) produce numerous advances with "immediate importance" in the further development of valuable technologies.[76]

Bronwyn H. Hall, Adam Jaffe, and Manuel Trajtenberg explained the link between forward citations and patent value as follows:

> There are reasons to believe that citations convey not just technological but also economically significant information: Patented innovations are for the most part the result of costly R&D conducted by profit-seeking organizations; if firms invest in further developing an innovation disclosed in a previous patent, then the resulting (citing) patents presumably signify that the cited innovation is economically valuable. Moreover, citations typically keep coming over the long run, giving plenty of time to dissipate the original uncertainty regarding both the technological viability and the commercial worth of the cited innovation. Thus, if we still observe citations years after the grant of

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[74] *See* Christopher L. Benson & Christopher L. Magee, *Quantitative Determination of Technological Improvement from Patent Data*, 11 PLOS ONE 1, 11 (2015).

[75] *See id.*

[76] While they did not provide detailed accounts of how advances achieved immediate importance in particular technology fields, the MIT researchers felt that immediate importance in technology development as measured by quick citations was consistent with the types of disruption and innovation redirection of technology fields noted by Clayton M. Christensen and the importance of technological discontinuities recognized by Philip Anderson and Michael L. Tushman. *See id.* (citing CLAYTON M. CHRISTENSEN, THE INNOVATOR'S DILEMMA: WHEN NEW TECHNOLOGIES CAUSE GREAT FIRMS TO FAIL (Harvard Bus. Review Press l997) and Philip Anderson & Michael L. Tushman, *Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change*, 35 ADMIN. SCI. Q. 604, 604-33 (1990)).

> the cited patent, it must be that the latter had indeed proven to be valuable.[77]

They note that forward citation counts provide useful information on inventive project commitments and the values of firms that hold patent rights to highly cited inventions:

> We think of the knowledge-creation process as a continuum going from R&D to patents to citations, which involves the sequential revelation of information about the value to the firm of the innovations generated along the way. That is, R&D reveals the commitment of a firm's resources to innovation, patents catalog the success in generating codifiable new knowledge that the firm can in principle appropriate, and citations indicate the extent to which those innovations turn out to be "important" and hence presumably more valuable to the firm.[78]

Hall, Jaffe, and Trajtenberg concluded that the market value of companies holding patents tracked the frequency of forward citations to company patents, with "[t]he value of high citation intensity . . . disproportionately concentrated in highly cited patents[. F]irms having two to three times the median number of citations per patent display a 35% value premium, and those with 20 citations and more command a staggering 54% market-value premium."[79]

Other researchers have shown that forward citation variations track invention valuation differences.[80] For example, Dietmar Harhoff, Francis Narin, F. M. Scherer, and Katrin Vopel established private values for patents by asking German holders of United States patents to estimate the price at which they would have been willing to sell a patent three years after filing. They found that the estimated prices were correlated with forward citation counts, with the most highly cited patents having very high estimated values.[81] Manuel Trajtenberg examined links between forward citations and invention value as measured from estimates of the social surplus resulting from improvements in computed tomography (CT) scanners. He found that citation-weighted patent counts were highly correlated with differences in estimated

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[77] *Market Value and Patent Citations*, 36 RAND J. ECON. 16, 19 (2005).

[78] *Id.* at 24.

[79] *Id.* at 17.

[80] Sampat & Ziedonis, *supra* note 72, at 280 (noting that, in empirical studies of the economics of innovation, patent citation counts have been used as proxies for the private value of patents).

[81] *See Citation Frequency and the Value of Patented Inventions*, 81 REV. ECON. & STAT. 511, 512-13 (1999).

surplus value (even though patent counts alone showed no such correlation).[82] John R. Allison, Mark A. Lemley, Kimberly A. Moore, and R. Derek Trunkey used patents involved in litigation as a sample of valuable patents and found that these valuable patents were cited significantly more often than unlitigated patents.[83] Again focusing on litigated patents as a subset of all valuable patents, Jean O. Lanjouw and Mark A. Schankerman found that forward citations predicted patent litigation likelihood (and hence, patent value) when citations were made by competitors of the patent holders.[84] Francis Narin, Anthony Breitzman, and Patrick Thomas found a strong association between the quality of companies' patent portfolios, as measured by patent citation indicators, and the companies' stock market value in the short- and long-term.[85] Examining the licensing of patents by universities, Bhaven N. Sampat and Arvids A. Ziedonis concluded that high forward citation counts were good predictors that patents were licensed (suggesting that the highly-cited inventions were viewed as the most valuable by licensees) but found that forward citations did not explain variations in licensing revenues among licensed patents (suggesting that factors other than surrounding innovator interest influenced the differences in licensing revenues among licensed patents).[86]

### *B. Additional Analyses in the Present Study*

#### *1. Evaluating Differences in Inventor Interest Across Valuable and Abandoned Patents*

The present research extends the studies just described by evaluating whether patent owners and subsequent innovators view patent value similarly. The study compares innovator interest in patented advances (as measured by forward citations after patent issuance) with patent owners' valuations of the same advances (as recorded in maintenance fee payments). Two major categories of patents are considered: valuable patents (defined as patents seen by owners as having sufficient value to warrant payment of all maintenance fees needed to keep the patents in force for their full terms) and relatively worthless patents (defined as patents that are

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[82] *See* Trajtenberg, *supra* note 72, at 172.

[83] *Valuable Patents*, 92 GEO. L.J. 435, 455 (2004) ("Patents that end up being litigated are much more likely to be cited as prior art by other issued U.S. patents than are non-litigated patents.").

[84] *See Characteristics of Patent Litigation: A Window on Competition*, 32 RAND J. ECON. 129 (2001).

[85] *Using Patent Citation Indicators to Manage a Stock Portfolio*, *in* HANDBOOK OF QUANTITATIVE SCIENCE & TECHNOLOGY RESEARCH 553, 553-54 (Henk F. Moed et al. eds., 2004).

[86] Sampat & Ziedonis, *supra* note 72, at 293.

abandoned by their owners due to non-payment of maintenance fees prior to the end of the patents' full terms).

Worthless patents are evaluated in three subgroups with varying ownership duration and valuation timing. The three subgroups include: (1) patents abandoned four years after issuance (reflecting relatively quick assessments of worthlessness); (2) patents abandoned eight years after issuance (reflecting more extended assessments of patent value before conclusions of worthlessness); and (3) patents abandoned twelve years after issuance (reflecting extensive fact finding and relatively late evaluations of patents still found to be worthless). One goal of this separation is to see if subsequent innovators show different interest in these subcategories of worthless patents. Citations to these three subcategories of patents illuminate whether inventors' interest in the different types track the diminishing uncertainties about invention value held by patent owners, reflected in delayed abandonment decisions.

Finally, for all four categories of patents (valuable patents and the three subcategories of worthless patents), additional comparisons are made of citation levels before and after patent abandonment (due to non-payment of maintenance fees) or expiration (due to completion of the full authorized patent term). The purpose here is to see if patent rights, while in force, are artificially suppressing innovation levels in the technological vicinity of the patented advances. If patent rights do suppress some innovation in this way, a jump upward in citation levels should occur upon the elimination of patent rights (whether through patent abandonment or through the natural expiration of a patent at the end of its full term).

*2. The Data Used*

The study examines patent abandonment decisions and inventors' forward citations concerning a random sample of 5,099 United States utility patents issued between January 1, 1995 and March 31, 1995. Information on these patents and related forward citations was obtained from two sources. Basic information on the patents, the advances they describe, and the inventors producing the patented advances was obtained from the AcclaimIP database service.[87] Additional information on patent characteristics and citations was obtained from PatentsView, a patent data project supported by the Office of the Chief Economist at the USPTO.[88]

[87] *See* ACCLAIMIP, http://www.acclaimip.com/ (last visited Jan. 2, 2022).
[88] *See* PATENTSVIEW, https://patentsview.org/ (last visited Jan. 2, 2022).

Diverse technologies were represented in the patent sample. The technology breakdown was as follows:[89]

**Figure 1: 1995 Patent Sample by National Bureau of Economic Research (NBER) Technology Sub-Category**

| Category | Name | Sub-Category | Technology | N | Percent | Cum. |
|---|---|---|---|---|---|---|
| | | | | | | |
| 1 | Chemical | 11 | Agriculture, food, textiles | 33 | 0.65 | 0.65 |
| | | 12 | Coating | 96 | 1.88 | 2.53 |
| | | 13 | Gas | 18 | 0.35 | 2.88 |
| | | 14 | Organic compounds | 170 | 3.33 | 6.22 |
| | | 15 | Resins | 166 | 3.26 | 9.47 |
| | | 19 | Misc. (chem.) | 490 | 9.61 | 19.08 |
| 2 | Computers & Communications | 21 | Communications | 256 | 5.02 | 24.10 |
| | | 22 | Computer hardware and software | 212 | 4.16 | 28.26 |
| | | 23 | Computer peripherals | 74 | 1.45 | 29.71 |
| | | 24 | Information storage | 157 | 3.08 | 32.79 |
| | | 25 | Electronic business methods and software | 24 | 0.47 | 33.26 |
| 3 | Drugs & Medical | 31 | Drugs | 234 | 4.59 | 37.85 |
| | | 32 | Surgery, medical instruments | 226 | 4.43 | 42.28 |
| | | 39 | Misc. (drugs & med.) | 23 | 0.45 | 42.73 |
| 4 | Electrical & Electronic | 41 | Electrical devices | 186 | 3.65 | 46.38 |
| | | 42 | Electrical lighting | 108 | 2.12 | 48.50 |
| | | 43 | Measuring, testing | 164 | 3.22 | 51.72 |
| | | 44 | Nuclear, X-rays | 76 | 1.49 | 53.21 |
| | | 45 | Power systems | 144 | 2.82 | 56.03 |
| | | 46 | Semiconductor devices | 177 | 3.47 | 59.50 |
| | | 49 | Misc. (elec.) | 165 | 3.24 | 62.74 |
| 5 | Mechanical | 51 | Materials processing & handling | 209 | 4.10 | 66.84 |
| | | 52 | Metal working | 129 | 2.53 | 69.37 |
| | | 53 | Motors, engines, parts | 165 | 3.24 | 72.60 |
| | | 54 | Optics | 49 | 0.96 | 73.56 |
| | | 55 | Transporation | 134 | 2.63 | 76.19 |
| | | 59 | Misc. ( mech.) | 224 | 4.39 | 80.58 |
| 6 | Others | 61 | Agriculture, husbandry, food | 88 | 1.73 | 82.31 |
| | | 62 | Amusement devices | 63 | 1.24 | 83.55 |
| | | 63 | Apparel & textile | 84 | 1.65 | 85.19 |
| | | 64 | Earth working & wells | 56 | 1.10 | 86.29 |
| | | 65 | Furniture, house fixtures | 112 | 2.20 | 88.49 |
| | | 66 | Heating | 41 | 0.80 | 89.29 |
| | | 67 | Pipes & joints | 41 | 0.80 | 90.10 |
| | | 68 | Receptacles | 101 | 1.98 | 92.08 |
| | | 69 | Misc. (others) | 404 | 7.92 | 100.00 |
| | | | | | | |
| | | Total | | 5,099 | 100.00 | |

[89] *See* Bronwyn H. Hall, Adam B. Jaffe & Manuel Trajtenberg, *The NBER Patent Citations Data File* (Nat'l Bureau of Econ. Rsch., Working Paper No. 8498, 2001), https://www.nber.org/papers/w8498.pdf (describing the technology categories and sub-categories defined by the National Bureau of Economic Research in its technology classification system); Alan C. Marco et al., *The USPTO Historical Patent Data Files* 25 (U.S. Pat. & Trademark Off., Working Paper No. 2015-1, 2015) (Table 2), https://www.uspto.gov/sites/default/files/documents/USPTO_economic_WP_2015-01_v2.pdf.

Owners of patents in the sample perceived their patents as having widely varying values (as reflected in their decisions to keep or abandon the patents). Patent abandonment decisions governing the sample patents are summarized in the following figure. Patented advances identified as "Extended to Full Term" were viewed by their owners as sufficiently valuable to warrant payment of fees required for the extension of the relevant patents to their full terms, while those listed as abandoned were allowed to lapse by their owners at the indicated times due to the non-payment of required maintenance fees:

**Figure 2: Patent Retention and Abandonment Breakdown**

| Retention/Abandonment | N | Percent | Cum. |
|---|---|---|---|
| | | | |
| Abandoned 4 Years After Issue | 806 | 15.81 | 15.81 |
| Abandoned 8 Years After Issue | 1,024 | 20.08 | 35.89 |
| Abandoned 12 Years After Issue | 957 | 18.77 | 54.66 |
| Extended to Full Term | 2,312 | 45.34 | 100 |
| | | | |
| Total | 5,099 | 100 | |

These figures indicate that only a minority of the patents in the sample (about 45%) were kept in force for their full term. The remaining 55% lapsed at various points after patent issuance, suggesting that owners of these lapsed patents eventually felt that the patents were essentially worthless—worth less than the modest fees needed to keep the patents in force. While the full-term retention rate of about 45% for patents in the sample may seem low, it is consistent with the retention rate for all patents issued in the same period. According to calculations by Dennis Crouch for the Patently-O Blog, the rate of third maintenance fee payment in 2007 (the year when this fee would be due for patents issued in 1995) was about 45%.[90] Thus, the patent retention and abandonment decisions for the patents in the present sample were similar to those reached for all contemporaneous patents.

Patents in the sample were cited a total of 135,236 times (through August 20, 2019, the cutoff date for citations considered in this study). Individual patents were cited at widely varying levels. The mean citation count was 26.52 citations per patent. The distribution of total forward citations to patents in the sample was as follows:

[90] Crouch, *supra* note 3.

**Figure 3: 1995 Patent Sample Forward Citation Breakdown**

| Forward Citations | N | Percent | Cum. Percent |
|---|---|---|---|
| | | | |
| 0 | 149 | 2.92 | 2.92 |
| 1 | 219 | 4.29 | 7.22 |
| 2 | 255 | 5.00 | 12.22 |
| 3 | 251 | 4.92 | 17.14 |
| 4 | 251 | 4.92 | 22.06 |
| 5 | 243 | 4.77 | 26.83 |
| 6 | 224 | 4.39 | 31.22 |
| 7 | 199 | 3.90 | 35.12 |
| 8 | 178 | 3.49 | 38.62 |
| 9 | 177 | 3.47 | 42.09 |
| 10 | 184 | 3.61 | 45.70 |
| 11 | 148 | 2.90 | 48.60 |
| 12 | 135 | 2.65 | 51.25 |
| 13 | 117 | 2.29 | 53.54 |
| 14 | 131 | 2.57 | 56.11 |
| 15 | 120 | 2.35 | 58.46 |
| 16 | 115 | 2.26 | 60.72 |
| 17 | 109 | 2.14 | 62.86 |
| 18 | 99 | 1.94 | 64.80 |
| 19 | 73 | 1.43 | 66.23 |
| 20 | 68 | 1.33 | 67.56 |
| 21 or more | 1,654 | 32.44 | 100.00 |
| | | | |
| Total | 5,099 | 100 | |

More than half of the patents in the sample had 12 or fewer forward citations during the more than 20 years covered by this study.[91] About 25% had 5 or fewer citations. Relatively few (only 149 or about 3% of the sample) had no citations. The top tiers of citations were as follows: top 10%—59 citations or more; top 5%—98 citations or more; and top 1%—248 citations or more.

[91] Citations were included in the study if made on or before August 20, 2019. Thus, the period for citations considered in the study extended from January to March 1995 (when the cited patents in the sample were issued) through August 20, 2019, or approximately 24 ½ years.

## II
## FINDINGS

### *A. Significant Differences in Citations Between Valuable and Worthless Patents*

Innovators' interest in patents within the sample tracked the value assessments of patent owners. Patents seen as valuable by their owners were highly cited (reflecting strong interest in developing further advances similar to the cited innovations), while abandoned patents were cited much less frequently (reflecting relatively low interest in advances similar to the ones found valueless by patent owners). The breakdown of mean citation levels by patent abandonment categories was as follows:

**Figure 4: Forward Citations Per Patent by Patent Retention Category**

| Retention/Abandonment | N | Mean Citations |
|---|---|---|
| | | |
| Abandoned 4 Years After Issue | 806 | 16.27 |
| Abandoned 8 Years After Issue | 1024 | 18.96 |
| Abandoned 12 Years After Issue | 957 | 21.95 |
| Extended to Full Term | 2312 | 35.34 |
| | | |
| Total | 5099 | 26.52 |

All three of the mean citation figures for abandoned patents were significantly different (at the $p<.01$ level of statistical significance) from the 35.34 mean citations per patent received by valuable patents extended to their full term. This difference indicates that innovators (who made the innovation-targeting choices resulting in later patent citations) apparently saw the same value indicators (or lack of them) as patent owners making patent abandonment decisions.

Furthermore, the value assessments by innovators and patent owners correlated across the three subcategories of abandoned patents. Patents abandoned the soonest (4 years after issuance) were cited the least, presumably because these patents covered inventions that were the most clearly worthless. Similarly, patents abandoned at 8 years were cited somewhat more than patents abandoned at 4 years, while those abandoned at 12 years were cited a bit more than those abandoned at 8 years. Both patent owners and innovators appear to have taken some time to reach the conclusion that these patents covered worthless inventions, but eventually resolved their uncertainties in similar ways and with similar gradations in invention interest. For all of these subcategories of inventions ultimately found worthless, innovator interest (as reflected in mean citations) was far below the interest shown in inventions covered by valuable patents extended to their full term.

### *B. Citation Differences Controlling for Technology Types and Invention Sources*

Some of the observed differences in citation levels for valuable and abandoned patents may reflect differences in the technology mixes for these two groups of patents and corresponding differences in citation patterns for different technologies. Similarly, factors such as research location and funding source may influence the analysis. To control for and remove differences caused by these variations, citation differences were evaluated using a negative binomial regression analysis.[92] In this analysis, the dependent variable was the total number of forward citations received by a patent and the independent variables were (1) a dummy variable recording whether a patent was a valuable patent (as perceived by its owner and indicated by a decision to pay maintenance fees necessary to extend the patent to its full term); (2) a series of dummy variables recording the NBER technology category of each patent (using the NBER technology category of mechanical advances as the base or "reference" category); (3) a dummy variable indicating whether a patent resulted from research conducted in the United States rather than overseas; and (4) an additional dummy variable indicating that a patented advance resulted from research conducted by an independent researcher (as opposed to a researcher supported by a corporation or university and resulting in an immediate assignment of the associated patent to the entity upon patent issuance). The regression results were as follows:

[92] Negative binomial regression analyses are appropriate for evaluating count data that is highly skewed toward numerous cases with low values. *See* Clay Ford, *Getting Started with Negative Binomial Regression Modeling*, U. VA. LIBR. (May 5, 2016), https://data.library.virginia.edu/getting-started-with-negative-binomial-regression-modeling/. In the present study, many of the patents had low citation counts.

**Figure 5: Negative Binomial Regression Analysis of Forward Citation Odds**

| Variable | Odds Ratio | Standard Error | Z | P>Z |
|---|---|---|---|---|
| | | | | |
| Valuable Patent | 1.65 | 0.08 | 10.16 | 0.00 |
| Chemical | 1.11 | 0.10 | 1.24 | 0.21 |
| Computers & Communications | 2.14 | 0.15 | 10.78 | 0.00 |
| Drugs & Medical | 2.83 | 0.24 | 12.03 | 0.00 |
| Electrical & Electronic | 1.54 | 0.11 | 6.05 | 0.00 |
| Other Technologies | 1.18 | 0.08 | 2.46 | 0.01 |
| US Source | 1.71 | 0.08 | 11.04 | 0.00 |
| Independent Inventor | 0.95 | 0.06 | -0.85 | 0.40 |
| | | | | |
| /lnalpha | 0.16 | 0.03 | | |
| alpha | 1.17 | 0.03 | | |

The reported odds ratios estimate the odds of receiving a forward citation for a patent having the feature represented by each independent variable relative to the odds for a patent lacking the feature. For example, a patent from a United States source was 1.71 times or about 71% more likely to attract a forward citation than an otherwise similar patent resulting from foreign research (with research locations determined from the location of the lead inventor listed in each patent). The odds ratios for different technology types reflect odds relative to patents in the reference category of mechanical advances. Thus, a patent involving a computer or communication innovation was 2.14 times or over twice as likely to obtain a citation than a mechanical engineering patent that was similar in all other respects. All of the odds ratio values were statistically significant at the $p<.01$ level except those for chemical advances, other technology advances,[93] and advances from independent inventors.[94]

*1. Significant Citation Variations with Patent Retention*

These results confirm the significant relationship between valuable patents and citation levels across diverse technology types. The estimated odds ratio of 1.65 means that a valuable patent retained to its full term was about 65% more likely to

[93] The lack of statistically significant odds ratios for chemical advances and other technologies means that forward citations for advances of these types were not significantly more or less likely than citations for mechanical advances.

[94] The lack of a statistically significant odds ratio for independent inventors means that citations for advances produced by independent inventors were not more or less likely than citations for advances from other sources, all else being equal.

receive a forward citation than a comparable abandoned patent (controlling for differences due to technology and the other factors reflected in the independent variables used in the analysis). This statistically significant[95] odds ratio indicates that there was a positive relationship across technologies between patent owners' value assessments (as reflected in their decisions to extend patents to their full term and recorded in the "Valuable Patent" dummy variable) and innovator interest in the patented advances (as reflected in increased forward citations). Patents that were highly valued by patent owners were also likely to be interesting to innovators, leading to high citation counts. The high citation counts for these patents also indicate that innovators felt that further technologies in the vicinity of the cited patents had positive development potential (warranting the initiation of further research projects) and probable value.

*2. Variations Across Technologies*

The technology-specific odds ratios in these results suggest that research programs (and related citation processes) were particularly intense for some technologies. Substantial variations were present across technologies in likelihoods of forward citations. Patented advances covering computers and communications inventions as well as drugs and medical innovations were particularly likely to be cited, indicating strong interest in advances within these fields. Forward citations were also significantly more likely for electrical and electronic advances than for inventions in the reference category of mechanical innovations but were not significantly more likely (at the $p<.01$ level of statistical significance) for chemical advances and other technology inventions (suggesting that innovation interest and citation patterns in these fields were no more intense than for mechanical advances, all else being equal).

*3. Domestic Versus Foreign Invention Sources*

Advances from the United States were more likely to gain forward citations than comparable advances from foreign sources. The odds ratio of 1.71 for an advance from a United States source suggests that an advance from a domestic source was about 71% more likely to be cited than a counterpart from a foreign source, all else being equal. Whether this reflects a higher quality of United States advances leading to more citations, greater knowledge of United States advances by later innovators making citations, or greater interest in United States advances for other reasons (perhaps due to better targeting of these advances toward areas of high

[95] This odds ratio was statistically significant at the $p<.01$ level.

commercial potential) cannot be ascertained from the data examined in the present study.

*4. Advances from Independent Inventors*

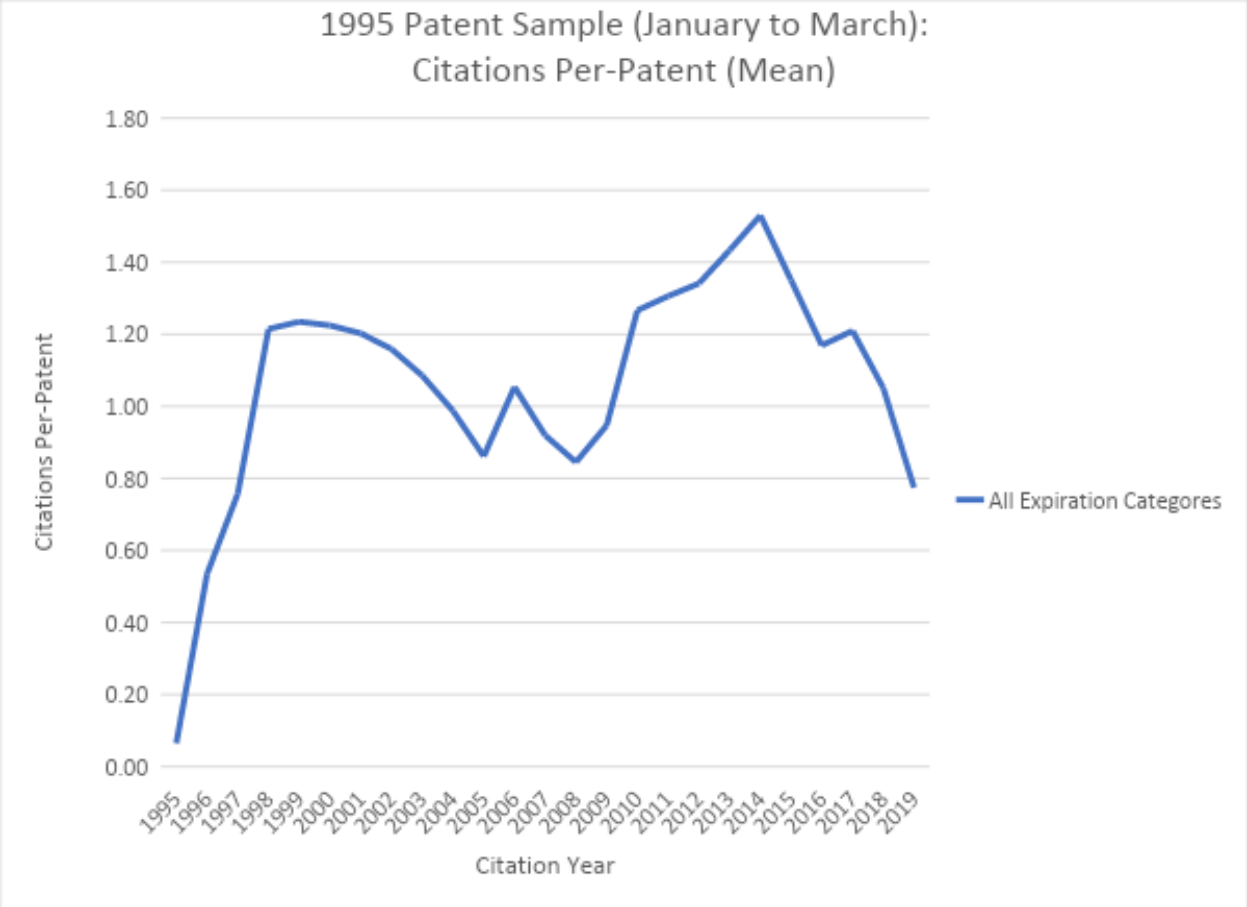
Interestingly, advances from independent inventors were no more or less likely to be cited than equivalent innovations from innovators working with institutional associations and support. The lack of a statistically significant odds ratio for citations to patents from independent inventors means that advances from independent inventors and similar advances from inventors working for organizations (such as corporations or universities) were equally likely to be of interest to later innovators and cited in later patents, all else being equal. This suggests that the content of patents drives innovator interest and later citations, not the institutional source of the patents. Patent citations are attracted by the technical content of a patent rather than the institutional associations of the party producing that content.

## *C. Citations Over Time*

*1. Variations in Citations Over the Life of Patents*

Patents in the sample (all issued in early 1995) were cited at varying annual levels between 1995 and 2019. The following figure summarizes the per-patent citation means over this period. For each year, the reported figure reflects the mean number of citations in that year to the patents in the sample.

**Figure 6**




Two aspects of this graph probably reflect no more than anomalous artifacts resulting from data truncation. As more completely described below, the limited availability of the patents in the sample produced the sharp upward slope at the left side of the graph concerning citations in 1995 and 1996. Incomplete data gathering covering only part of 2019 accounted for the sharp downward slope for citations in that year.

i. Early Stage Data Anomalies

The upward slope at the left side of the graph probably reflects the first public availability of the sample patents upon their issuance and publication in early 1995.[96]

[96] Patents issued in 1995 were not subject to present rules on pre-issuance publication of patent applications, which provide that most patent applications are published 18 months after the applications are filed. The only exceptions are applications that the applying parties certify will not form the basis for counterpart patent applications in foreign patent systems. The latter type of patent applications can be maintained confidentially until patent issuance. These rules providing for pre-issuance publication of most applications only took effect in 2000, meaning that patents

Their earlier unavailability produced low citation levels in 1995 and for a few years after. Their initial unavailability until published in early 1995 may have suppressed initial citations for at least three reasons.

First, patents issued in late 1995 (which were the only 1995 patents capable of citing the patents in the sample) constituted only a fraction of the total year's set of citing patents (a fraction roughly corresponding to the portion of patents issued after January to March of 1995, or about 9 out of 12 months). Citations from only a partial year of citing patents would tend to produce unusually low per-patent citation counts for 1995.

Second, delays in the drafting of citing patent applications may explain the sorts of ramping up of per-patent citations seen in the years after 1995. Patent applications are typically drafted several years before the relevant patents are issued. Thus, patent applications drafted before 1995 (when the sample patents were not available for citing) may have resulted in many patents issued in later years. For example, a patent issued in 1997 may have stemmed from an application prepared in 1994, at which point the sample patents were still confidential.[97] A typical delay from patent application submission to patent issuance is about three years.[98] Assuming that most patent applications drafted in 1995 (when information about the sample patents was fully available) resulted in issued patents about three years later in 1998, one would expect normal levels of citations to the 1995 sample patents to begin only around 1998. This is precisely what is seen in the data. Citations to the 1995 patents in the sample level off after 1998. The sharp increases in patent citations between 1995 and 1998 may reflect the fact that not all patent applications took three years to examine. For example, if a few (but not most) patent applications

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issued in 1995 (such as those in the sample) were only publicly available and capable of being cited as of their issuance in 1995. *See generally* U.S. PATENT & TRADEMARK OFFICE, MANUAL OF PATENT EXAMINING PROCEDURE § 1120 (9th ed. 2020).

[97] Although it would be possible for a patent applicant filing an application in 1994 to amend the pending application in 1995 to include one of the recently published and publicly available patents in the sample, the patent applicant's legal obligation to make a full disclosure of relevant prior art applies only to the prior art known at the application's submission and would thus not include any obligation to make such an amendment. Indeed, a desire to avoid changes that might slow the consideration of an application by patent examiners might discourage such a legally optional amendment.

[98] *See How Long Does It Take to Get a Patent?*, ERICKSON LAW GROUP, http://www.ericksonlawgroup.com/law/patents/patentfaq/how-long-does-it-take-to-get-a-patent/ (last visited Jan. 2, 2022) ("The average time it takes to obtain a patent from the [USPTO] is about 32 months or a little under 3 years.").

drafted in 1996 and citing the 1995 patents emerged in 1997, this would have resulted in an intermediate level of per-patent citations for 1997, as seen in the data.

Third, the low but growing numbers of citations to the patents in the early years after their issuance in 1995 may reflect initially slow progress in further research concerning the distinctively new technologies described in the cited patents. If the distinctive originality of the advances patented in 1995 meant that researchers needed time to react to the new features and did not undertake many related research projects for a substantial period, the resulting delay in related research would produce a lag in the rise of citations. If related research was delayed, few initial citations to the 1995 advances would be made over the period of the delay. As related research increased with greater understanding and appreciation of the value of the advances patented in 1995, citations to the 1995 patents would slowly increase in parallel. Hence, learning about and reacting to the distinctively original advances described in the 1995 patents may explain delays in follow-on research and related delays in the rise of citations as seen in the data.

ii. Late Stage Data Anomalies

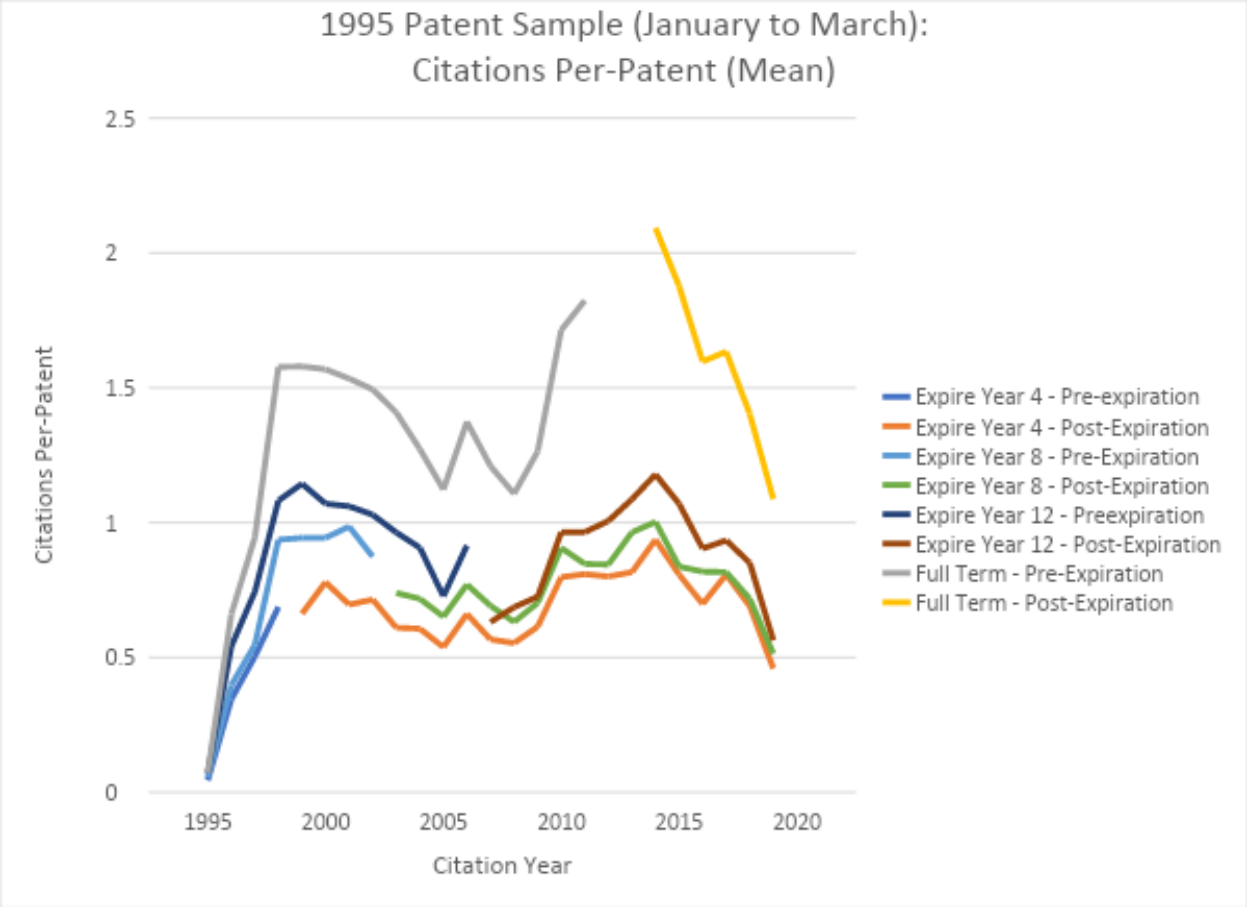
A different feature probably accounts for the low citation counts seen for 2019. The study considered citing patents issued through August 20, 2019. Since the data for 2019 only reflected a partial year of citing patents, the truncation of this data for 2019 produced an anomalously low per-patent citation figure in comparison with other years.

*2. Citation Variations Over Time*

i. Separating Citation Levels by Patent Value

The following figure summarizes the per-patent citations by year for the four types of patents considered in the study:

**Figure 7**




Each of the four categories of patents is represented by two lines—one reflecting per-patent citations before the patents in the category expired (due to either failure to pay maintenance fees or the completion of a full patent term) and a second line reflecting citations after the patent's expiration. For example, patents that were allowed to expire 4 years after patent issuance are represented by the dark blue line (for citations before expiration) and the dark orange line (for citations after expiration). Each pair of lines has a gap between them representing the year when the relevant patents ended and during which citation levels were anomalous (since the omitted years reflected partial periods split between patent enforceability and absence). For valuable patents extended to their full term, a two-year gap was included because the expiration dates of the patents included in the sample were spread over several years (resulting in several years of citation data influenced by both pre- and post-expiration patents).[99]

[99] The spreading of patent expirations over several years for full-term patents in the patent sample probably resulted from two patent law features. First, the full terms for patents in the

ii. Interpreting Citation Variations for Valuable and Worthless Patents

The results shown in Figure 7 reveal several interesting citation patterns. First, all four categories of patents exhibited changes in citations per patent that tracked overall differences in citation counts from year to year. This is apparent from the similar peaks and valleys in citation levels for all four categories of patents. For example, all four categories reflect a peak in per-patent citations in 2013-2014 corresponding to a surge in patent counts around this period (and a rise in related citations due to the increased number of citing patents).[100] These overall variations in total citation levels are evaluated more thoroughly in the next subsection of this article (where normalized assessments of per-patent citations are used to eliminate the effects of year-to-year changes in overall citations).[101]

Second, the ordering of citation levels from high citation levels for valuable patents downward to ever lower citation levels for the three categories of worthless patents is maintained throughout the terms of the cited patents. This ordering is present for every year from 1995 to 2019. Valuable patents are consistently the most frequently cited from early in their life, throughout their terms, and even after. Worthless patents are consistently cited at low levels early in their life, throughout their enforceability, and after lapsing. Apparently, innovators recognize valuable and worthless patents early and generally maintain their assessments throughout the life of the patents involved.

Innovators are arguably clearer eyed about patent value than patent owners. Patents that are ultimately but not initially abandoned by their owners (reflecting either denial by owners about the real worthlessness of their patents or initial gaps in information precluding owners from correctly identifying worthless patents) are seen by innovators very early in patent terms as having little research interest and

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sample were governed by two different legal standards. Some had durations limited to 17 years from patent issuance. Others benefitted from a change in the law that extended patent terms to 20 years from patent application filing (many patents already issued as of the change were given whichever of the new or old durations produced a longer patent term). This mixture of duration standards resulted in patent expirations of the sample patents distributed across multiple years. Second, additional patent term adjustments based on special circumstances—such as delays due to secrecy orders, interferences, or appellate review periods—meant that patent terms and expiration dates varied even further. *See generally Patent Term Calculator*, USPTO, https://www.uspto.gov/patent/laws-and-regulations/patent-term-calculator (last modified Dec. 30, 2021, 7:57 AM).

[100] United States utility patents jumped by about 33% between 2011 (108,622 issued) and 2014 (144,621 issued). *See U.S. Patent Statistics Chart: Calendar Years 1963 - 2020*, USPTO, https://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm (last updated May 2021).

[101] *See infra* Section II(C)(3).

are cited at relatively low levels accordingly. Innovators are willing (and perhaps compelled by resource limitations requiring them to make research choices carefully) to make patent value assessments promptly (and without the same attachment biases or other unwillingness to abandon costly innovations that may cause patent owners initially to overvalue their patented advances).

Of course, innovators are not perfect in recognizing worthless patents and moving their research to other areas. Some worthless patents are cited every year (both before and after patent lapsing). This indicates that innovators do not ignore abandoned patents altogether. Their citations to abandoned patents (roughly the same before and after patent expiration) probably reflect one or both of two processes.

First, these citations may result because worthless patents describe background elements of fields that still have research promise. The reasons why a specific patented advance is worthless and abandoned by its owner may leave some similar advances still worth pursuing (perhaps to correct the defects that rendered the abandoned innovation worthless). Hence, citations to abandoned patents may occur as some still promising research in related areas proceeds.

Second, citations to abandoned patents may result as patent applicants describe failed invention attempts to distinguish their later inventions and explain why these inventions are significantly different from the prior art in the relevant field of technology. The negative examples of worthless and abandoned inventions would provide a context and baseline for descriptive contrasts of inventions addressed in later patent documents. Used this way, citations of abandoned patents may characterize what has not worked and document how hard functionally meaningful innovation in the relevant field has been. Citations used for negative descriptive purposes may contribute to a "noise level" of citations to innovations that are known by the citing inventors to reflect unpromising but still descriptively relevant design directions.

The full reasons for the continuing noise level of citations to abandoned patents cannot be ascertained from this study. Further evaluations tracing the ways that citations to valuable and abandoned patents are relied on in citing patents (as well as whether the citations are predominantly made by patent applicants or by patent examiners) may reveal more about the role of abandoned patents in informing subsequent innovation and explain the lingering reasons for citations to patents recognized even by their owners as having little or no value for further technology development.

*3. Normalized Citations Over Time*

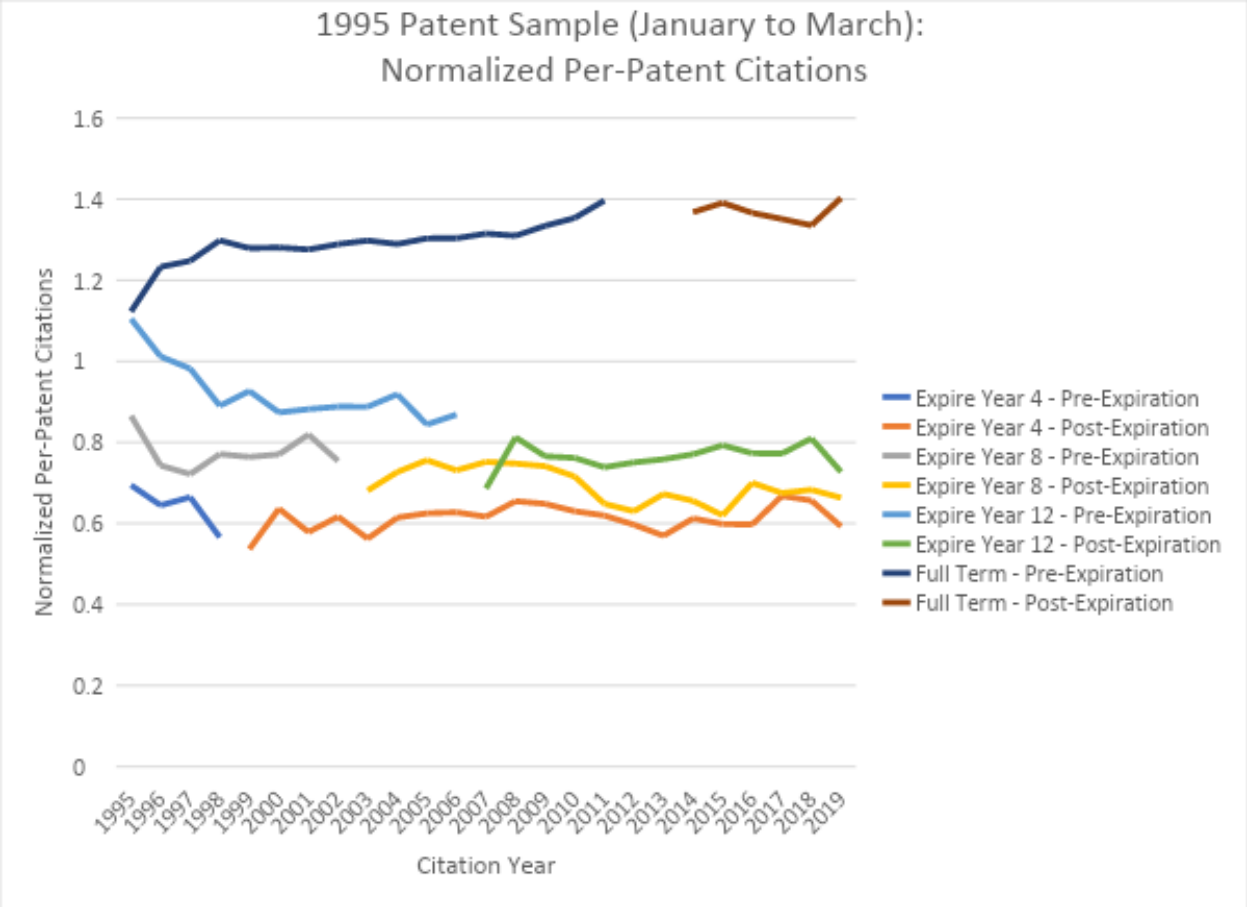
i. Computing Normalized Citation Counts

As previously mentioned, per-patent citation levels varied from year to year over the period of the study as the number of patents issued in various years changed. System-wide variations in per-patent citations—producing peaks and troughs in year-by-year citation figures—somewhat muddy the differences between patent value categories that are of interest in this study. It is difficult to know if the differences seen in the raw per-patent citation figures are due to changes in general citing levels or differences between citing levels for the four value categories.

To eliminate the effects of system-wide changes in citation volumes from year to year, normalized citation levels were computed to estimate citation levels for the four types of patents under study independent of overall changes in total citations. For each year and patent abandonment category, a normalized citation mean was computed that was equal to the mean per-patent citations for that year and category divided by the overall per-patent citations for the same year. The resulting normalized figures reflect the citations that would be expected for valuable and abandoned patents if the same number of citations per patent were made in every year considered in the study.

The resulting normalized per-patent citations are summarized in the following figure (as before, each of the four categories of valuable and abandoned patents is represented by two lines corresponding to citations in the category before and after patent expiration):

**Figure 8**




ii. Interpreting Normalized Citation Patterns

The normalized citation patterns—having removed the confounding effects of overall changes in citation levels—reveal the differences in citation patterns across patent value categories more clearly. This subsection interprets the citation patterns reflected in Figure 8.

a. Consistent Ordering Over Time

The relative ordering of citations—at high levels for valuable patents and ever lower levels for patents abandoned earlier and earlier—holds true in the normalized data throughout the period of the study. That order is present in citations for every year from 1995 to 2019. Innovators' assessments of interest (as reflected in citations) track owners' evaluations of patent value (as reflected in abandonment/retention decisions).

b. Learning Effects

Data on the latest abandoned patents (abandoned 12 years after patent issuance) provide insights into the parallel learning processes influencing valuation assessments of innovators making citations and patent owners. The initially high but rapidly diminishing interest of innovators in patented advances within this category (as reflected in the light blue line in Figure 8) indicates that innovators felt that advances in this group had promise but (as the diminishing line in later years indicates) were ultimately convinced otherwise. High initial interest by innovators in the latest abandoned patents produced initial citation levels that almost matched the high levels of citations for valuable patents. However, interest diminished year by year, ultimately reaching about the same low interest and low citation counts seen for other worthless patents abandoned at earlier points. This learning process, moving from initial promise to adverse findings, probably tracked the impressions of patent owners who maintained their belief in the value of their advances in this category for a long period (12 years) only to reach the long-delayed conclusion that their advances were worthless and should be abandoned. The reasons for this shift from apparent promise to identified worthlessness cannot be ascertained from the data in this study, but the learning path of innovators and patent owners about inventions covered by late-abandoned patents appears to have produced the same increasing disillusionment about innovation value.

c. Consistently Low Interest in Most Worthless Patents

Patents abandoned at 4 and 8 years after issuance—the patents most clearly and promptly ascertainable as worthless—described advances that were generally of low interest to innovators from the issuance of the patents. Citation levels for these patents started low and stayed there. There were few learning effects of the sort just discussed, and citation levels were consistently well below (approximately half) the levels seen for valuable patents. There was essentially no change in citation levels before and after patent expiration (due to the lapsing of patents at the 4- and 8-year points). This lack of change is consistent with the interpretation that innovators were just not interested in research in the vicinity of these patents and that, therefore, the enforceability of related patent rights had no impact. Such rights were not suppressing anything. Removing the rights made no difference.

d. Evidence of Patent Rights' Impacts on Later Research

In contrast to the absence of an increase in research levels upon the expiration of worthless patents, research levels and associated citation levels did increase for valuable patents after those patents expired. This suggests that some projects that would have incorporated the valuable patented technologies (and would have

involved actionable patent infringement accordingly) were suppressed during the period when patent rights applied but proceeded when those rights were relieved through patent expiration.

This provides further confirmation that innovators and patent owners evaluated invention value similarly before and after patent expiration, but innovators were further influenced (and forced to curtail some innovation projects) by the threat of, and value reduction implicit in, potential patent infringement litigation. The increase in research related to valuable patents after patent expiration (as evidenced by the corresponding jump in citation levels) is a confirmation of a basic feature of the patent bargain—that is, the release into the public domain of the valuable elements of a patented advance upon patent expiration makes those elements freely available for new research and product development. The citation pattern seen here suggests that there is a meaningful enhancement of research following patent expiration, at least for valuable patents recognized as such by their owners and retained to their full patent term. These patents release the most valuable and interesting technologies for further use upon patent expiration and consequently spur the largest increase in research once their patent rights disappear.

*4. Quantifying Patent Rights' Impacts*

To estimate the size of the impact of altered patent rights on citation levels, per-patent citation means with and without patent rights were compared through several regression analyses. For each year and patent abandonment category, a per-patent citation mean was computed.[102] These annual per-patent citation means were combined to create a set of panel data. In the panel data, each panel corresponded to one of the four patent abandonment categories, and the year a citation was made was the timing variable.[103] The regression analyses used mean per-patent citations as the dependent variable, and a dummy variable corresponding to patent expiration (or lapsing) as the independent predictor variable. The panel regressions employed a random effects model that controlled for factors not otherwise included in the regression analysis (including year-to-year variations in total volumes of citations). An initial panel regression analysis was performed using all of the data. This analysis

[102] The resulting annual citation figures were the same as those plotted in Figure 7.

[103] Two portions of yearly citation data were excluded from the regression analyses because they reflected abnormal and unrepresentative citation processes. First, data on citations in the years 1995 and 1996 were excluded because the patents in the sample (issued in early 1995) may not have been publicly available when most patent applications resulting in patents issued in 1995 and 1996 were drafted (thereby precluding citations to patents in the sample). Second, data from 2019 was excluded because citations from only a portion of that year were considered in this study (the cutoff date for citations considered in this study was August 20, 2019).

was supplemented with four further panel regression analyses addressing changes in portions of the citation data upon patent expiration—one study using just the data for valuable patents (those extended to their full term) and three more using data on the three subcategories of abandoned patents.

i. Overall Impacts of Patent Expiration on Citations

Relying on data covering all 100 yearly citation means (25 for each of the four categories of patents), a panel regression analysis estimated the overall impact of removing patent rights on related citations. The results were as follows:

**Figure 9: Overall Impact of Patent Expiration on Citations Per Patent**

| Mean Citations Per Patent | Coef. | Std. Err. | z | P>z | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| | | | | | | |
| Expiration Impact | 0.1659 | 0.0620 | 2.68 | 0.0070 | 0.0444 | 0.2874 |
| Constant | 0.8290 | 0.1670 | 4.96 | 0.0000 | 0.5017 | 1.1562 |
| | | | | | | |
| /sigma_u | 0.3214 | 0.1177 | | | 0.1568 | 0.6588 |
| /sigma_e | 0.2770 | 0.0200 | | | 0.2405 | 0.3192 |
| rho | 0.5737 | 0.1828 | | | 0.2333 | 0.8643 |
| | | | | | | |
| Likelihood-ratiotest of sigma_u=0: chibar2(01) = 61.55; Prob>=chibar2 = 0.000 | | | | | | |
| LR chi2(1) = 6.84 | | | | | | |
| Log likelihood = -20.627651; Prob > chi2 = 0.0089 | | | | | | |

The statistically significant coefficient for the dummy variable corresponding to the ending of patent rights (due to completion of full patent terms or patent lapsing following non-payment of maintenance fees) indicates that the release of patent rights tended to produce a corresponding increase in per-patent citations. This is consistent with the view that patent rights, while in force, were a constraint on some research projects that proceeded in greater numbers once those rights were terminated. It is logical to infer that similar levels of projects in these technology vicinities would have proceeded in the period of active patent rights if those rights were not present and constraining research.

The amount of constraint from patent rights is suggested by comparing the estimated per-patent citations with and without patent rights. The citations with such rights—corresponding to the mean citation level in the period before patent expiration—are estimated by the constant in Figure 9. This indicates that the estimated or typical annual citation count per patent before patent expiration was about .8290 annual citations per patent or just above 1 citation every 14 months.

After patent expiration, this increased by about .1659 (the coefficient for the dummy variable representing patent expiration) to about .9949. This represents about a 20% increase over the pre-expiration citation level.

Assessing the overall impact of patent expiration in this way masks the possible differences between impacts of valuable and worthless patents. As already explained, removals of patent rights due to expirations of valuable patents were expected to have greater impacts on research than expirations of rights related to abandoned patents. Research interest in technologies like those covered by valuable patents was much greater (and therefore much more likely to be restricted by active patent rights generated by valuable patents) than the lesser levels (if any) of research interest related to abandoned patents. Conversely, research related to abandoned patents was expected to change little in the presence or absence of patent rights. To see if this was the case, separate assessments of valuable and abandoned patent expirations were needed.

ii. Patent Expiration Impacts by Patent Categories

To reveal these differences, a set of four regression analyses was performed, each using the data on just one of the four patent expiration categories under scrutiny (valuable patents extended to their full term plus the three subcategories of abandoned patents). The results were as follows:

**Figure 10: Impacts of Patent Expiration on Yearly Per-Patent Citation Means**

| Patent Category | Expiration Impact | Standard Error | z | P>z | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| | | | | | | |
| Expire Year 4 | 0.1159 | 0.0769 | 1.51 | 0.132 | -0.0348 | 0.2667 |
| Expire Year 8 | -0.0740 | 0.0565 | -1.31 | 0.190 | -0.1847 | 0.0367 |
| Expire Year 12 | -0.0366 | 0.0600 | -0.61 | 0.542 | -0.1543 | 0.0810 |
| Full Term | 0.3431 | 0.1218 | 2.82 | 0.005 | 0.1044 | 0.5817 |

These results confirm the substantial differences in the impacts of patent expiration on the citations made to valuable and worthless patents. For valuable patents extended to their full term, the impact of terminating patent rights appears substantial. The removal of patent rights in this category resulted in a statistically significant rise in per-patent citations.[104] The regression coefficient reported in Figure 10 indicates that the annual per-patent citations for valuable patents went up from a mean of about 1.4301 citations before patent expiration to about 1.7732

[104] This impact was statistically significant at the $p<.01$ level.

citations after patent expiration.[105] For the 2,312 valuable patents included in the patent sample, this jump in citations reflects about 793 additional citing advances each year following patent expiration in comparison to the citations to the same patents in the period before patent expiration.

In contrast, there was no significant impact from terminating patent rights on citation levels for any of the three categories of worthless patents. None of the regression coefficients for these three categories of abandoned patents were significantly different than 1.0, meaning that there was no meaningful difference found in per-patent citation means before and after patent expiration. Patent rights appear to have had little impact before they expired; once they were gone due to patent expiration, they continued to not have an impact. Rights constraining unwanted activities have the same practical impacts as no rights at all.

Applying this last insight at a higher policy level, the constant (and generally low) citation levels for worthless and ultimately abandoned patents suggests that a large fraction of issued patents probably have few impacts on continuing research choices and directions. Even while worthless and ultimately abandoned patents are in force, innovators make roughly the same decisions about research directions as they do in later periods when rights related to the patents are not a factor. The decisions before and after patent expiration are as if these patents did not exist. This insight about minimal patent impacts—applicable to a majority of issued patents in recent years since a majority of patents are regularly abandoned—casts doubt on frequently voiced concerns about the extensive limitations on research resulting from the vast numbers of patents issued in the United States.[106]

By contrast, valuable patents—those extended to their full terms by their owners—do appear to constrain related research choices, but these patents represent less than half of the United States patents. Policy discussions and possible reforms should focus on this minority of patents with meaningful research impacts and not be distracted and misdirected by a concern over the vast numbers of worthless and abandoned patents with little or no innovation consequences.

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[105] These before and after figures were both estimated by the regression analyses of yearly citation means—the figure for pre-expiration means reflects the estimate recorded in the constant of the analysis, and the post-expiration figure reflects the constant plus the estimated coefficient of the dummy variable corresponding to patent expiration.

[106] These arguments are sometimes posed as complaints about the "thickets" that issued patents are asserted to place in the way of productive research. *See, e.g.*, *Too Many Patents*, PAT. PROGRESS, https://www.patentprogress.org/systemic-problems/too-many-patents/ (last visited on Jan. 2, 2022).

## CONCLUSION

Patent owners' assessments of the value of their patented inventions (as reflected in decisions to either abandon patents or extend the patents to their full patent terms) track later interest by technology developers. Patents with high perceived private value (as determined by their owners) are interesting to numerous later innovators (as evidenced by high levels of citations to the valuable patents).

High patent values perceived by patent owners and strong interest shown by subsequent innovators point to distinct technology subfields with intense development and rapid advancement. Such subfields—exemplified by the highly-cited innovations at their core—are the heartlands of valuable technology development.

Conversely, patents perceived by owners as having little commercial promise (and abandoned accordingly) describe technology with little interest to innovators as they decide where to focus further technology development. The technologies addressed in abandoned patents are often "dead ends" in technology progress that are rarely explored by later technologists (resulting in few later citations).

Patents that are abandoned and rarely cited describe technology development hinterlands—subfields with little interest for further technology development. They describe technology explorations and findings with little if any influence on later technology and product development. While the inventions described in these abandoned patents are functionally complete, distinctive in some design features, and capable of producing minimally useful results—all features needed to gain a patent—patented but abandoned inventions may have few technological offspring. Rather, these abandoned patents may be most useful in technology development as pointers to technological "negative space"[107]—that is, technology-development attempts that failed to contribute advantageous functionality to innovation users and that are accordingly of little interest to subsequent innovators.

[107] In art, "negative space" is an empty void that carries a message due to its shape or other characteristics. *See* Sara Barnes, *How Artists Use Negative Space to Say A Lot with Nothing*, MY MOD. MET (June 21, 2019), https://mymodernmet.com/negative-space-definition/.