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FILTERING INNOVATION WHEAT FROM CHAFF: QUICK CITATIONS AS INDICATORS OF PATENTED INVENTION VALUE

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ABSTRACT

Quick citations – forward citations to a patent by later patents issued within three years of the cited patent – are remarkably good predictors of probable patent value, as well as identifiers of technology fields and geographic areas producing high percentages of valuable patents. These citations point to areas of strong innovator interest, likely commercial potential, and probable opportunities for further specialized innovators. Quick citations can also distinguish between technology development centers presently producing high and low value advances, thereby aiding in evaluating the success of centers in capitalizing on research investments and meeting consumer needs. These potential uses of quick citations – and empiric evidence validating their use in these contexts – are described in this article. The aim is to establish the foundation for future technology studies using quick citations as analytic tools.

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I. INTRODUCTION

Inventors currently receive staggering numbers of United States patents each year. In 2019 alone, the United States issued 354,507 new utility patents.[1] This large number of patents – and associated rights to control corresponding numbers of inventions – have raised concerns that patents are imposing broad restrictions on innovation and impeding technological progress. Related concerns have been raised about the potential for detrimental concentrations of technological and commercial power in the hands of a few large companies owning numerous patents.

While patents doubtless spur and limit innovation to some degree, the scope and settings of patents' impacts are poorly measured from sheer patent numbers. Many patents appear to restrict unwanted inventions, making the patents both worthless and unlikely to have meaningful impacts on technology advancement. Evidence that many of the vast numbers of issued patents are not threats to desired innovation and commercially significant advances comes from patent owners themselves. Most patents are ultimately seen by their owners as essentially worthless and, accordingly, allowed to lapse in the face of maintenance fees that must be paid to keep the patents active. For example, in 2015 only 45 percent of patent owners felt that their patents were worth paying maintenance fees needed to keep the patents active for their full term.[2]

Lapsed patents discount the net impacts of patents on innovation for at least two reasons: 1) lapsed patents convey no subsequent patent rights and therefore have no remaining legal impacts on innovation opportunities and 2) the lack of commercial potential perceived by patent owners who allow patents to lapse suggests that subsequent innovators and commercial product providers, perceiving the same lack of commercial potential, were unlikely to use or extend the patented inventions even when the patents were still in force. As restrictions on uninteresting advances (with

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

[2] *See* Dennis Crouch, *Maintenance Fees 2015,* PATENTLY-O (July 21, 2015), https://patentlyo.com/patent/2015/07/maintenance-fees-2015.html (as of 2015 owners of only about 45 percent of United States patents paid the third maintenance fee for their patents when due, meaning that the remainder of patents lapsed due to nonpayment of this or prior maintenance fees; the second maintenance fee was paid for approximately 66 percent of patents and the first fee was paid for approximately 85 percent of patents).

little perceived commercial potential in present or extended forms), lapsed patents probably hinder few if any otherwise attractive innovation efforts. Lapsed patents (in contrast to patents for which maintenance fees are paid) map out dead ends in commercial technology development, restricting innovation options in directions that no subsequent innovators were likely to go. A red light has no impact on car movements when it is on a street with no traffic.

This article describes empirical evidence of the relationship between lapsed patents and innovator interest. Using quick citations – that is, forward citations[3] to a patent in later patents issued within three years of the cited patent[4] – the article describes the statistically significant relationship between high quick citation levels and the payment of maintenance fees sufficient to ensure full patent terms. High quick citation levels (reflecting strong innovator interest in particular advances or similar technology areas) track high levels of maintenance fee payments. Low innovator interest (as reflected in low quick citation levels) points to patents that are frequently found worthless by owners and allowed to lapse. This significant relationship is shown to hold true across diverse types of technologies and innovation sources.

Evidence of low innovator interest in lapsed patents provides empiric reasons to discount the impact of many issued patents on subsequent technology development. Patents with few quick citations, while theoretically enforceable, are often meaningless. They describe and control technology outliers sufficient to qualify for patents, but the restrictions are themselves outliers with no practical impacts on technologically interesting directions and subsequent innovation attempts. Eventually, patent owners reach the same conclusion – that their rights control directions and products that no one wants – and allow their patents to lapse for lack of commercial potential and value.

Beyond aiding in the interpretation of lapsed patents and their impacts, the present research suggests that quick citations serve as useful measures of probable patent value. Previous researchers have noted the relationship between the willingness of patent owners to pay maintenance fees for continuation of patent rights and assessments by those owners of probable patent value. By validating the strong relationship between quick citations and maintenance fee payments, this study

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[3] Forward citations are generally citations to a patent (or a published patent application) that are later (or forward) in time from the cited patent. This study focuses exclusively on forward citations within three years of issuance of the cited patents. Forward citations to published patent applications are not considered here. The patents examined in this study – a sample of patents issued in 1995 – were not published before issuance, a practice that was first instituted for patent applications filed on or after November 29, 2000. *See* UNITED STATES PATENT AND TRADEMARK OFFICE, CHANGES TO IMPLEMENT EIGHTEEN-MONTH PUBLICATION OF PATENT APPLICATIONS 1 (Sept. 20, 2000), https://www.uspto.gov/sites/default/files/web/offices/dcom/olia/aipa/pgpfr.pdf. Because there were no pre-issuance publications of the relevant patents, there were no forward citations to the patents prior to issuance.

[4] The window of time for citation assessments in this article – three years from patent issuance – builds on prior research that suggests citations accumulated in this period are strongly related to patent value. *See* Christopher L. Benson & Christopher L. Magee, *Correction: Quantitative Determination of Technological Improvement from Patent Data*, 11(3) PLOS ONE (Mar. 21, 2016) (manuscript at 3), https://journals.plos.org/plosone/article/file?type=printable&id=10.1371/journal.pone.0151931. Citations measured over different periods may have equal or even greater value prediction capabilities. The efficacy of citation measurements over different periods is a topic for another project.

similarly confirms the relationship between quick citations and probable patent value. Quick citations have particularly important implications as indicators of patent value as such citations can be measured at relatively early stages in the life of patents. Findings described here suggest that quick citations are essentially as good predictors of patent value as full forward citations measured over the complete life of patents but without the need to wait for that full life to transpire.

To confirm the potential of quick citations as accurate measures of probable patent value, the article additionally describes the strong positive relationships between quick citations and two additional indicators of patent value – assertions of patents in litigation and numbers of patent claims.

II. USING QUICK CITATIONS TO MEASURE PATENT VALUE

A. *Past Analyses*

This study is not the first to use quick citations to evaluate probable patent value. Researchers at the Massachusetts Institute of Technology (MIT) found quick citations to be highly accurate indicators of technology value growth across diverse technologies.[5] Quick citations were robust predictors of variations in future technology value growth in widely disparate technology fields.[6] Variations in mean quick citations (coupled with adjustments for the average year of issuance of the citing patents) predicted 64 percent of variations in value growth across technologies.[7] Quick citations standing alone were able to predict about 58 percent of the differences in value growth across technologies.[8] Quick citations were good predictors of value growth for highly different types of technologies, ranging from advances in super conductivity, genome sequencing, and integrated circuits to optical information transmission, incandescent lighting, and 3-D printing.[9]

The MIT team found that quick citations predicted technology value growth more effectively than forward citations measured over the full life of patents.[10] Quick citations were also better predictors than several other invention and patent characteristics tested, including the average publication date of cited patents, the average age of citations, and the total mean publication date of backward citations.[11]

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[5] *See* Christopher L. Benson & Christopher L. Magee, *Quantitative Determination of Technological Improvement from Patent Data*, 10(4) PLOS ONE (April 15, 2015) (manuscript at 11), https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0121635.

[6] *Id.*

[7] *See* Benson & Magee, *supra* note 4, at 3.

[8] *See id.* at 2 (reporting a Pearson's correlation coefficient (r) between quick citations and technology value growth rates of .76, which corresponds to an r^2 of .5776 and indicates that quick citations are able to explain about .58 or 58 percent of the variation in technology value growth figures for various technologies).

[9] *See id.* at 2, fig.1 (including the specific technologies noted in parts (A), (B), and (C) of this figure).

[10] *See id.* at 3, tbl.4. A regression model based on the full number of forward citations only explained about 55 percent of the variation in value growth while quick citations (coupled with the average year of citing patents) were able to explain 64 percent of the variation.

[11] *See id.*

B. *Extensions of Past Research Here*

The present project expands upon past studies of quick citations by confirming the relationships between such citations and three types of patent value measures. The three patent value measures employed here have been commonly used as patent value proxies in past studies: patent maintenance decisions (reflecting decisions by patent owners to pay maintenance fees necessary to keep patents enforceable), 2) patent litigation initiation and rates for specific patents (reflecting the willingness of patent owners to face large litigation costs in expectation of even larger patent recoveries and value), and 3) numbers of claims in patents (serving as indicators of probable patent breadth and potential ranges of enforcement).[12] The research results reported here confirm that quick citations have significant positive relationships to all three of these measures of patent value.

These findings are important from at least three perspectives. First, they suggest that quick citations can identify some valuable patents at very early points in their patent terms, supplying important valuation information to both investors and commercial parties who may wish to produce or distribute products related to the valuable products. Second, using quick citations as indicators of rapidly developing and probably valuable technology fields (and communities with significant success in those fields), parties wishing to target skills development and employment opportunities can gain useful direction on likely high value and growth areas. Third, innovators and entrepreneurs can use evidence from quick citations to identify technology directions that recent innovators (and commercial backers that have supported them) have found highly promising, thereby focusing subsequent rounds of innovation and related investment towards recently intense (and hopefully still current) fields of technology change and commercial demand.

III. CONFIRMING QUICK CITATIONS AS INDICATORS OF PROBABLE PATENT VALUE

A. *The Data*

Four types of data were used in this study: 1) information on patent characteristics and quick citations for a sample of 15,000 patents issued in 1995, 2) maintenance payment information for the same patents indicating which of them survived to its full patent terms, 3) litigation information for the same patents indicating whether any district court litigation was based on each patent and, if so, how many times each patent was litigated, and 4) claim counts for each of the patents in the sample. These data (and their sources) are briefly described in this subsection.

[12] *See infra* Section II(A). Past research utilizing these patent value measures (and the logic behind their use as value measures) is summarized in Section II(A).

1. *Patent Characteristics and Quick Citations*

This study examined data on a randomly selected set of 15,000 United States utility patents issued in 1995.[13] Patents from 1995 were chosen to ensure the full potential term of the applicable patents was certain to have run (if applicable maintenance fees were paid) and that decisions to keep the patents in force over that full term could be studied.[14] The patents scrutinized described inventions produced by innovators around the world covering diverse technologies. The breakdown of the patent sample by technologies was as follows:

Figure 1
Technology Types in Patent Sample

NBER Category	N	Percent	Cum. Percent
1 -- Chemical	2,745	18.3	18.3
2 -- Computers & Communications	2,264	15.09	33.39
3 -- Drugs & Medical	1,532	10.21	43.61
4 -- Electrical & Electronic	2,909	19.39	63
5 -- Mechanical	2,647	17.65	80.65
6 -- Other	2,903	19.35	100
Total	15,000	100	

[13] Data concerning United States utility patents issued in 1995 were obtained from two sources. Basic demographic information regarding the patents and the features of the inventions the patents describe were obtained from the AcclaimIP database service. *See AcclaimIP Patent Search & Analytics Software,* http://www.acclaimip.com/. Additional information on patent features and the quick citations received by each patent was obtained from PatentsView, a patent data project supported by the Office of Chief Economist of the USPTO. *See What is PatentsView,* USPTO, https://patentsview.org/what-is-patentsview (last visited Apr. 9, 2021). Quick citations for each patent were calculated by determining the full set of forward citations for each patent from PatentsView and then counting those forward citations received within three years of the cited patent's issuance. The NBER technology classification for each patent (recorded in PatentsView) reflect technology groupings developed by Bronwyn H. Hall, Adam B. Jaffe, and Manuel Trajtenberg in conducting earlier patent research sponsored by the National Bureau of Economic Research (NBER). *See* Bronwyn H. Hall, Adam B. Jaffe & Manuel Trajtenberg, *The NBER Patent Citations Data File* 13, 41 app'x.1 (Nat'l Bureau of Econ. Rsch., Working Paper No. 8498, Oct. 2001), https://www.nber.org/papers/w8498.pdf.

[14] *See Patent Term Calculator*, USPTO, https://www.uspto.gov/patent/laws-and-regulations/patent-term-calculator (last visited Mar. 8, 2021). The applicable term for most patents issuing in 1995 was 17 years from patent issuance, although, due to a change in the law at about this time, some patents issued in this period may have had a term of 20 years from the date of the applicable patent application.

2. *Patent Renewals*

Patent renewals – as determined by payments of patent maintenance fees necessary to keep United States patents in force for their full potential terms – have been used by a number of researchers as proxies for private patent value.[15] These renewals reflect owner's perceptions of patent value. The evidence provided by renewals is mostly negative – that is, the failure to pay relatively modest maintenance fees provides evidence that patent owners saw little potential and value in the future enforcement of the patents allowed to elapse. Perceptions of limited patent value evolve as patent owners develop and analyze potential applications of patented advances and further scrutinize opportunities to commercialize such applications. Hence, the fraction of patents for which maintenance fees are paid 4, 8, and 12 years after patent issuance goes down as more and more patents are seen as worthless by ever better-informed patent owners.[16]

Information on maintenance fee payments was obtained from United States Patent and Trademark Office (USPTO) records.[17] The fractions of patents in the 1995 patent sample for which maintenance fees were paid was as follows:

Figure 2
Summary Statistics on Patent Renewals

1995 Sample N	Renewed at 4	Renewed at 8	Renewed at 12
15000	0.8411	0.6381	0.4648

These figures indicate that only about .4648 or 46.48 percent of the patents under scrutiny remained in force for their full term. The remainder lapsed (some at 4 years from issuance, some at 8 years, and some at 12 years) due to the failure to pay corresponding maintenance fees.

While these maintenance fee payment figures may seem low, they are in fact consistent with the low payment rates seen for all patents in this period. According to figures calculated by Dennis Crouch on behalf of the Patently-O Blog, the rate of third maintenance fee payment in 2007 (the year when this fee would be due for most patents issued in 1995) was about 45 percent.[18]

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[15] *See, e.g.*, D. Hegde & B. Sampat, *Examiner citations, applicant citations, and the private value of patents,* 105 ECONOMICS LETTERS 287, 287–89 (2009); J.O. Lanjouw, A. Pakes, & J. Putnam, *How to count patents and value intellectual property: uses of patent renewal and application data* 8–9 (Nat'l Bureau of Econ. Research, Working Paper No. W5741, (1996)), https://www.nber.org/papers/w5741.

[16] *See* Crouch, *supra* note 2 (For example, in 2015 patent owners paid maintenance fees for about 85 percent of patents four years after patent issuance in contrast to only 66 percent of patents 8 years after issuance and 45 percent of patents 12 years after issuance).

[17] *Patent Maintenance Fee Events*, USPTO, https://bulkdata.uspto.gov/ (last visited Mar. 31, 2021).

[18] *See* Crouch, *supra* note 2 (as of 2015 owners of only about 45 percent of United States patents paid the third maintenance fee for their patents when due, meaning that the remainder of patents lapsed due to nonpayment of this or prior maintenance fees; the second maintenance fee was paid for approximately 66 percent of patents and the first fee was paid for approximately 85 percent of patents).

3. *Patent Litigation*

The involvement of patents in litigation – and assertions of patents in multiple cases – have also been used by researchers as measures of perceived private patent value.[19] The high costs of patent litigation are not faced lightly. A decision to assert a patent is presumed to reflect the rational projection by the patent owner that the value to be gained in litigation – coupled perhaps with additional profits from patent licensing or commercial sales realized by confirming the scope of potential patent enforcement through litigation – are more valuable than the considerable costs of patent litigation.

Data identifying litigated patents (and the numbers of times they were asserted in litigation) were obtained from the Stanford Non-Practicing Entity (NPE) Litigation Database ("Stanford NPE Database").[20] The Database records litigation by practicing entities, non-practicing entities, and other patent owners to enforce patent rights. The database covers over 43,000 patent enforcement lawsuits filed after 2007, capturing information for each suit on the patent owner, the patents asserted (identified by patent number), and type of owner involved in the suit.

The Stanford NPE Database indicated that very few patents in the 1995 sample were litigated (at least in the period since 2007 covered by the Database). Only 143 of the 15,000 patents in the sample were found to have been involved in litigation. This low number of litigated patents (and the corresponding counts of times patents were asserted in litigation) corresponded to the following litigation figures for the 1995 patent sample:

Figure 3
Summary Statistics on Patent Litigation Features

1995 Sample	Likelihood Litigated	Times Litigated
Mean	0.009533	0.032533
Std Dev	0.097176	1.657606
Min	0	0
Max	1	196

4. *Claim Counts*

Claim counts for patents also have been used by researchers as measures of probable patent value.[21] Patents with more claims are assumed to have greater breadth and to control broader ranges of potentially infringing conduct than patents

[19] *See, e.g.,* D. Harhoff, F.M. Scherer, & K. Vopel, *Citations, Family Size, Opposition and The Value of Patent Rights*, 32 RSCH. POL'Y 1343, 1343 (2003).

[20] For a description of the database and some initial research conclusions drawn from it, *see* Shawn P. Miller et. al., *Who's Suing Us? Decoding Patent Plaintiffs since 2000 with the Stanford NPE Litigation Dataset,* 21 STAN. TECH. L. REV. 235, 243–75 (2018).

[21] Jean Lanjouw & Mark Schankerman, *Patent Quality and Research Productivity: Measuring Innovation with Multiple Indicators,* 114 THE ECONOMIC J. 441 (2004), https://academic.oup.com/ej/article-abstract/114/495/441/5085644?redirectedFrom=fulltext.

with fewer claims, all else being equal. By providing broader infringement claims, patents with more claims are likely to have more value than those with fewer claims.

Information on the number of claims in each patent in the 1995 patent sample was obtained from the AclaimIP database.[22] The following summarizes the claim count data for patents in the sample:

Figure 4
Summary Statistics on Claims

1995 Sample	Claims
Mean	13.63787
Std Dev	10.69327
Min	1
Max	167

B. *Validating Quick Citations as Predictors of Patent Value*

Each of the three measures of patent value – patent renewals, litigation assertions, and claim counts – was found to be significantly associated with quick citation counts, validating from three different perspectives the use of quick citations as predictors of patent value. This subsection describes these findings.

1. *Quick Citations as Predictors of Patent Renewals*

This study examines the association between quick citations and patent renewals for both groups of related patents and for individual patents. For groups of similar patents – such as all patents related to a category of technology or all patents emerging from a particular geographic area – quick citations can aid projections of probable patent renewal rates (and average patent values) for each group. For specific patents, quick citations can aid projections of the likelihood that particular patents will be renewed to full term (and, accordingly, that the corresponding patents have perceived value, at least in the eyes of their owners). As described in this subsection, quick citations have statistically significant relationships to patent value predictions at both group and individual patent levels.

a. *Quick Citations and Patent Renewals by Technology Type*

Fractions of full-term patent renewals for patents grouped by technology type reflect the likelihood that a typical or average patent in that technology group was extended to full term (and, accordingly, was regarded as a valuable patent by its owner). For example, 60 percent of patents regarding a particular type of technology were renewed to full term, the average probability that a patent in the group was

[22] ACCLAIMIP, *supra* note 13.

renewed was 60 percent. Comparisons of these renewal fractions across technology types provide means to identify technology fields with relatively high percentages of valuable patents. Quick citations can project fields with high renewal rates without waiting for actual renewals. Hence, as described in this subsection, variations in quick citations point to technology fields with high and low percentages of valuable patents.

1) Regression Analyses by Technology Type

To examine the relationships between quick citations and patent renewals for specific technologies, mean quick citations and fractions of renewed patents were computed for groups of patents covering similar technologies. Patents were deemed to involve similar technologies if they fell within the same technology subcategory within the National Bureau of Economic Research's (NBER's) technology classification system.[23] This system defines six major technology categories and a number of technology subcategories.[24] The NBER classification system is a long-standing research tool and has been used for technology groupings in a number of major patent studies.[25]

The following figure illustrates the clear (and surprisingly strong) relationship across technologies between mean quick citations and the likelihood of full-term patent renewals. The figure plots the fraction of patents renewed for individual technologies as a function of the mean quick citations for the same technologies. The fraction of patents extended to full term within a technology group is equivalent to the average likelihood that a patent in the group was extended to full term.[26] This average likelihood is strongly associated with differences in quick citation values as indicated by the grouping of the plotted values around the regression-estimated line in the figure.

Each circle in the figure corresponds to a NBER technology subcategory (the number next to the circle identifies the subcategory represented by the circle). Each circle conveys three types of information: 1) the size of the circle indicates the number of patents within the 1995 patent sample falling within the labeled NBER subcategory, 2) the horizontal or "X" position of the circle corresponds to the mean quick citations for that NBER subcategory, and 3) the vertical or "Y" position of the circle corresponds to the fraction of patents in the subcategory that were extended to their full terms through appropriate maintenance fee payments. Thus, for example, the circle labeled "24" in this figure corresponds to patents in NBER subcategory 24 (involving

[23] Bronwyn H. Hall, Adam B. Jaffe & Manuel Trajtenberg, *The NBER Patent Citations Data File* 13, 41 app'x.1 (Nat'l Bureau of Econ. Rsch., Working Paper No. 8498, Oct. 2001), https://www.nber.org/papers/w8498.pdf (describing this system).

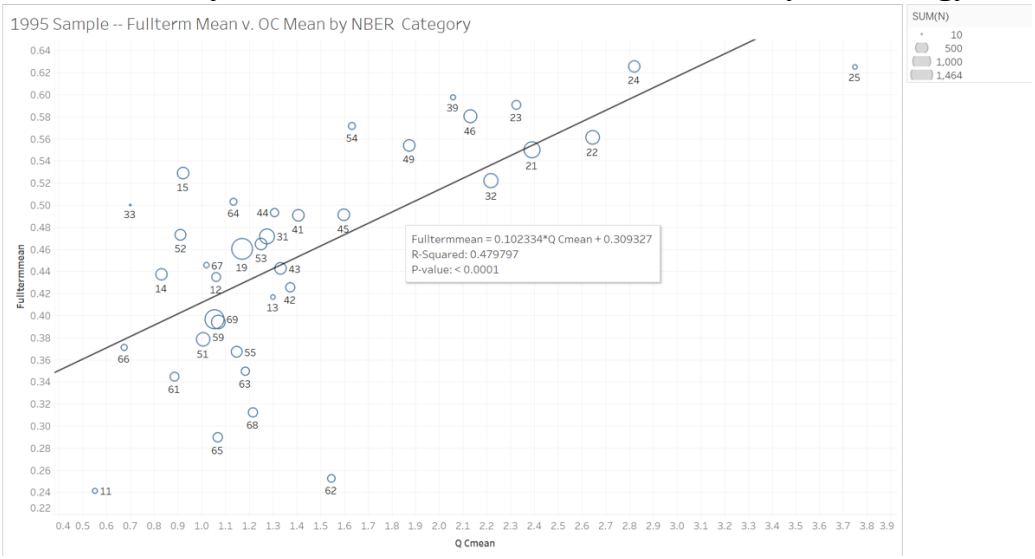
[24] The six major NBER technology categories involve the following types of advances: 1) Chemical, 2) Computers and Communications, 3) Drugs and Medical, 4) Electrical and Electronics, 5) Mechanical, and 6) Other Technologies. The full list of technology subcategories within these six areas can be found at Alan C. Marco, Michael Carly, Steven Jackson, & Amanda F. Myers, *The USPTO Historical Patent Data Files* 25 tbl.2 (OCE, USPTO Working Paper No. 2015-1, June 2015), https://www.uspto.gov/sites/default/files/documents/USPTO_economic_WP_2015-01_v2.pdf.

[25] *Id*.

[26] For example, if 40 of 100 patents in a particular NBER technology subcategory were extended to full term, the average likelihood that a patent in this subcategory was extended was 40/100 or 40 percent.

computers and communications advances in information storage). The size of the circle indicates that the 1995 patent sample included 438 patents within this NBER subcategory. The position of the circle indicates that there were approximately 2.825 mean quick citations (X axis) to patents in this subcategory and that approximately .6256 or 62.56 percent (Y axis) of the patents were extended to their full terms via appropriate maintenance fee payments.

Figure 5
Mean Quick Citations and Fractions Full Term by Technology



The relationship between quick citations and fractions of patents extended to full term is clear across all technology types. This relationship is summarized for the complete set of data by the linear regression line plotted in the figure. The strength of the relationship is reflected in the regression results as follows:

Full Term Fraction = (.1023) x Quick Citation Mean + .3093

$r^2 = .4798$

$p < .0001$

The p value indicates that the relationship between mean quick citations and mean full term fractions is statistically significant at the .0001 level. The r^2 figure indicates that this relationship explains about 47.98 percent of the variation in full term extension percentages across technologies.

This result suggests that quick citations (and the innovator interest they signal) are remarkably strong predictors of the perceived value of classes of technologies (such as the NBER technology subcategories reflected in this figure). Almost half of the variation in value between are predicted by a single factor—subsequent inventor interest. The remaining variations in group value (approximately 52.02 percent of the

variations) probably stem from differences in technologies unassociated with differences in inventor interest (such as distinctions in the resources needed to conduct research in different fields or differences in the complexity of effective research projects). Putting aside these unmodeled further factors, it is clear that hot technology fields (as measured from high mean quick citations) are consistently associated with frequent patent renewals and correspondingly frequent projections of high technology value.

Some interesting features of the variations in full term patent renewals (and, by implication, in the overall value suggested for each technology classification) can be deduced from the positioning of the circles in Figure 5. For example, all the circles for technology subclasses with numbers in the 20s (corresponding to various types of advances concerning computers and communications) are grouped in the upper right portion of this figure, indicating that these subclasses had both high fractions of full term extensions (suggesting high perceived value in the eyes of patent owners) and high mean quick citations (suggesting surges of substantial innovator interest in the immediate period after patent issuance). These findings regarding high innovator interest and perceived invention value for computer and communications advances are consistent with other evidence of extensive research activity and proven invention value concerning such advances in the period surrounding 1995.[27]

Another interesting feature on this figure lies in the grouping in the lower left corner of circles for technologies in the miscellaneous "Other" subcategories – that is, for technology subclasses with numbers in the 60s. This grouping suggests that advances in these subclasses were generally perceived as having relatively low value. Furthermore, the circles for these advances are located away from the regression line in the figure, indicating that quick citations alone are less complete predictors of patent renewals for these "Other" technologies than for further technology types reflected in the figure. Some of the unexplained variation may correspond to the inclusion of especially diverse technologies within particular subclass among the "Other" technology category, reflecting the role of these subclasses as "miscellaneous" or "catch all" bins for categorizing technologies that do not fit elsewhere in the technology classification scheme.

Given that the relatively ill-defined "Other" technology subcategories may generate atypical patent renewal and valuation data because they reflect less similar advances than other NBER subcategories, a further analysis of patent renewals was completed excluding the Other technology data. The results were as follows:

Full Term Fraction = (.0921) x Quick Citation Mean + .3440

$r^2 = .5976$

$p < .0001$

[27] A number of landmark developments in computer technology and related commerce occurred in 1995, reflecting the intensity and commercial success of research into computer and communications advances in that period. Key developments in 1995 included work on the technology that would underlie Google's search engines, the opening of ecommerce giant Amazon.com, and the unveiling of IBM's Deep Blue parallel computing system that would later play world-class chess. *See generally Computer history – 1995*, COMPUTER HOPE, https://www.computerhope.com/history/1995.htm (last visited Mar. 8, 2021).

These regression coefficients are essentially the same as those reached for the full data set, but with an indication that quick citations explain an even higher percentage of the variation in full term patent renewals (and associated patent value) outside of the technologies in the "Other" categories. The percentage of variation explained jumped to approximately 59.76 percent for all types of technologies other than the miscellaneous, poorly defined (and arguably more technologically diverse) technologies reflected in the Other technology subclasses with numbers in the 60s.

2) Comparison to Prior Research Benchmark

A prior research benchmark provides useful background in interpreting the highly similar value predictions in the present study. MIT researchers, following a study of quick citations and value growth for 28 widely different technologies,[28] also found that quick citations had a strong role in predicting variations in technology value.[29] Like the study described at the end of the prior subsection, the MIT study avoided poorly matched technology groupings (such as the data on miscellaneous Other technologies) and focused instead on data concerning 28 carefully defined technologies. The researchers identified functional criteria for each of the technologies (such as kilowatts per dollar cost for fuel cells or kilobits per second per dollar cost for electrical telecommunications) and used these as value measures.[30] They then tracked percentage improvements in the 28 value measures over the years 1976 to 2013. Mean quick citations during the same years were calculated for patents covering the same 28 technologies. Quick citations were tested – along with many other technology and patent features – as possible predictors of the measured changes in technology value. Quick citations (in conjunction with adjustments for the average years of issue of the citing patents) were found to be the best predictors of technology value changes. Quick citations explained about 58 percent of variations in patent value growth across the 28 technologies under study.[31]

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[28] The 28 highly diverse technologies examined included: 3D-printing (industrial stereolithography), aircraft transport, camera sensitivity, capacitor energy storage, combustion engines, computed tomography (CT), electric motors, electrical energy transmission, electrical information transmission, electrochemical battery energy storage, electronic computation, flywheel energy storage, fuel cell energy production, genome sequencing, incandescent artificial illumination, integrated circuit information storage, integrated circuit processors, LED artificial illumination, magnetic resonance imaging (MRI), magnetic information storage, milling machines, optical information storage, optical information transmission, photolithography, solar photovoltaic energy generation, superconductivity, wind turbine energy generation, and wireless information transmission. *See* Benson & Magee, *supra* note 5, at 20 tbl's A–F (access by clicking "S1 File"). The 28 technologies examined, and the means used to identify patents related to those technologies, are described further in C. L. Magee et al., *Quantitative Empirical Trends in Technical Performance*, 104 TECH. FORECASTING AND SOC. CHANGE 237, 237–45 (Mar. 2016).

[29] *See* Benson & Magee, *supra* note 4, at 2.

[30] *See* Magee et al., *supra* note 28, at 241 fig.1.

[31] *See* Benson & Magee, *supra* note 4, at 2 (reporting a Pearson's correlation coefficient (r) between quick citations and technology value growth rates of .76, suggesting that (with an r^2 of .5776) quick citations explained about .58 or 58 percent of the variation in technology value growth for various technologies).

The similarity of the results found in the MIT study (approximately 58 percent of variations in value growth predicted) versus here (approximately 60 percent of variations in value likelihood predicted when poorly defined "Other" technology categories are excluded) provide useful information for interpreting and confirming the present results. The MIT study, while using a different measure of technology value, focused on variations that should track those examined in the present study. Value will tend to grow most for technologies with the highest frequency of invention value. Increases in these two measures should go hand in hand across technologies. Hence, predictions of variations in one should be matched by predictions in the other. The fact that quick citations were able to predict value changes to the same degree (that is, able to predict similar percentages of the overall variation in value) in the two studies provides confirming evidence of the important and consistent role of quick citations in predicting invention value.

Furthermore, the similar findings in the two studies link subjective patent value measures to objective patent value indicia. The MIT study established that quick citations are good predictors of externally measured invention value (as reflected in functionally significant technology characteristics like growth in the number of kilowatts per dollar generated by fuel cells). These results link quick citations to variations in objectively measured invention value. The present study links quick citations to subjectively perceived invention value as expressed in patent owners' patent extension decisions. The similarity of results – in both positive relationships between quick citations and predicted technology value and amounts of value differences that quick citations were able to predict – suggests that quick citations are measuring underlying technology development features that are influences on both subjective and objective patent value.[32]

The common influence here may be that quick citations serve as proxies for innovator interest and that such interest is, on average, a highly important contributor to the ultimate success of various technology fields (and to patent owners' interpretations of inventions within those fields). Whether this underlying logic – or another – accounts for the shared predictive links between quick citations and both objective and subjective patent value cannot be determined from the data relied on here but is certainly worthy of further study.

b. *Quick Citations and Patent Renewals by Geographic Source*

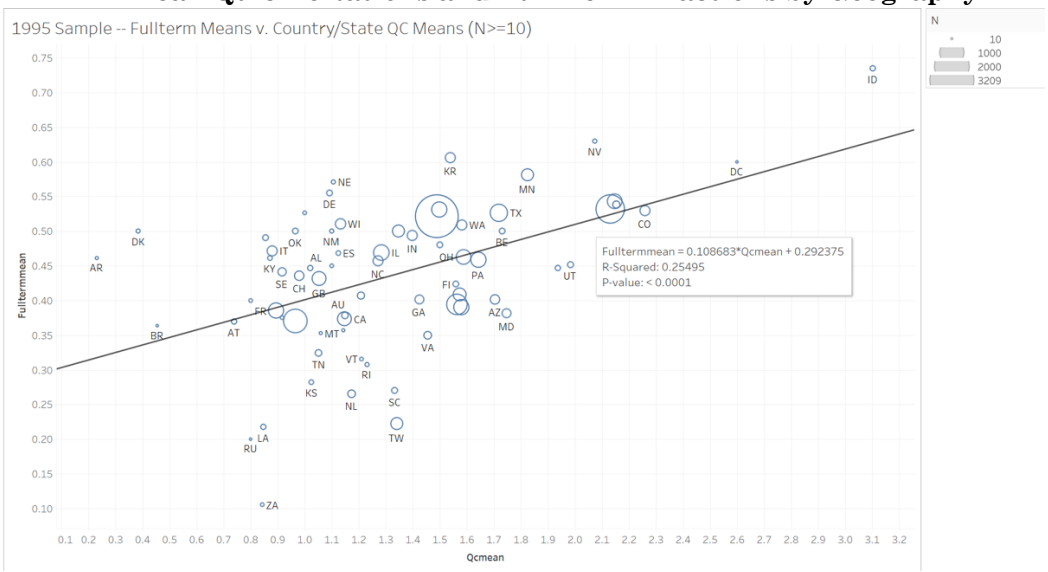
A similar analysis grouping patents by geographic source also found that quick citations were strong predictors of variations in patent value across different invention locations. For this analysis, the geographic source of an advance was presumed to be

[32] The similar ability of quick citations to predict value differences across technology types is particularly striking given the different technology grouping methods used in the two studies. The MIT study used 28 narrowly defined technology categories, resulting in 28 pairs of quick citation and value growth data points for study. The present study used a completely different technology grouping system (reflected in the previously defined NBER technology classification criteria), resulting in 26 pairs of quick citation and value likelihood data points for study (corresponding to the 26 NBER technology subcategories other than the 9 excluded Other technology subcategories with numbers in the 60s). From these different technology groupings, the two studies found highly similar predictive capabilities of quick citations across disparate technology types.

the location of the first named inventor listed on each patent in the 1995 patent sample under study. Information on quick citations and fractions of patents extended to full term was calculated for all countries with at least 10 patented advances in the 1995 patent sample, with the exception of advances from the United States which were handled differently. Because advances from the United States represented 63.36 percent of the total, using a single data point to represent all the advances from the United States would simply outweigh the data for other countries in the analysis. To avoid this, smaller units of geography were used to plot data from the United States. Quick citation means and full-term patent fractions were calculated for individual American states producing advances. These state-level figures reflected about the same numbers of advances per state as the country-level figures used for foreign advances.

The resulting geographic data broken down by countries and American states are plotted in the following figure. Each circle corresponds to advances from a single foreign country or American state. As before, the size of each circle reflects the number of patents represented while the position of the circle indicates the mean quick citations and full-term fraction for the labeled geographic source.

Figure 6
Mean Quick Citations and Full-Term Fractions by Geography



A few of the circles in this figure warrant special explanation to clarify the labeling. The large circle near the center represents patents from Japan (the largest source of patents from a foreign country in the 1995 patent sample with 3209 patents). The three overlapping circles without labels to the right of the center of the figure (near the circle for Colorado (CO) with 170 patents) represent advances from the states of California (1418 patents), Massachusetts (359 patents) and Oregon (91 patents). Interestingly, both the mean quick citations and full-term percentages for these four states (California, Massachusetts, Colorado, and Oregon) were almost identical, reflecting the similarity in their technological strength in the applicable period (setting

aside the differences in the volumes of innovations produced in the four states as indicated by the differences in the sizes of the circles for these states).

The results for these four states illustrate important distinctions between per-innovation and total volume interpretations of innovation production and quality. In sheer numbers of advances, California stands alone as both a high volume producer (as indicated by the relatively large size of the circle for that state) with a large fraction of highly regarded advances (as indicated by the positioning of its circle high on the Y axis indicating a relatively high fraction of full term patents). However, if one shifts to per-innovation quality, the similar positioning of the four circles for California, Massachusetts, Colorado, and Oregon in this figure suggests that the average or typical innovations from these four states had roughly similar perceived value (as indicated by their similar per-patent likelihood of full-term patent extension) and innovator interest (as indicated by their similar mean quick citations).

Overall, the grouping of the data in this figure along the plotted line confirms the clear relationship between quick citations and perceived patent value (as reflected in fractions of patents extended to full terms) across geographic sources of innovation. The regression line in the figure corresponded to the following regression results:

Full Term Fraction = (.1087) x Quick Citation Mean + .2924

$r^2 = .2550$

$p < .0001$

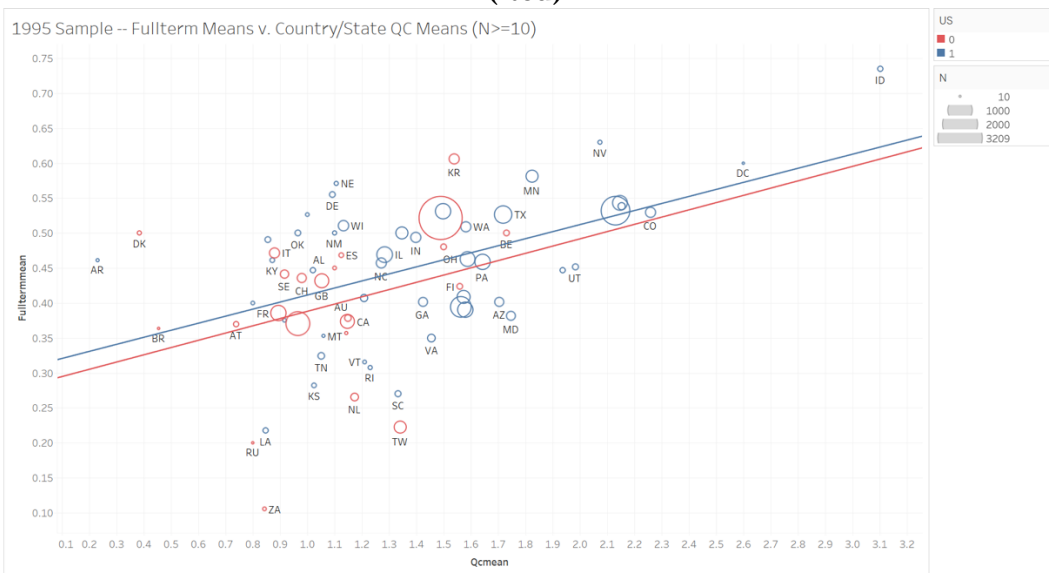
This indicates that quick citations explained about .2550 or 25.50 percent of the variation in full term renewals (and perceived patent values) across the geographic areas indicated.

These results (particularly the relative r^2 figures) indicate that quick citations are more effective in predicting technology to technology differences in typical patented invention value than in predicting similar differences across invention locations. This may be because inventors gauge their interest in innovations (of the sort that is measured in quick citations) based much more on the substance of technologies (and differences in such substance) than on where it comes from. Differences in levels of interest are much more tied to (and predictive of) differences in technology type than differences in technology source.

It is also possible that differences in the mix of technologies pursued in different locations is driving the differences across regions seen in this study. A region that emphasizes a high interest technology will attract more innovator interest and quick citations than a region with a greater emphasis on developing advances concerning low interest technologies. The choices of which technologies to pursue (and, hence, the mix of technology emphasis peculiar to a location) is part of the value-defining process being characterized by regional predictions of typical innovation value. Whether typical regional value is determined by high level decisions about what technologies to pursue or lower-level factors like differences in regional inputs (both personnel and physical resources) to particular projects are considerations beyond the scope of this project. Unpacking the sources of the regional differences in projected invention value seen in the present study will be a worthwhile project for another time.

The statistically significant links found in this study between mean quick citations and patent renewal rates for different locations suggests that quick citations can be useful in characterizing the typical or average value of patents and patented advances emerging from different regions. For example, just by breaking down the quick citation and renewal information from Figure 6 into separate data on United States and foreign advances, interesting valuation differences emerge. The following figure displays the data for United States-originated patents (blue) and foreign-originated patents (red) separately (with corresponding regression lines plotted):

Figure 7
Mean Quick Citations and Full-Term Fractions – US (Blue) and Foreign (Red)



Two interesting features are illustrated in this figure. First, the relationship between quick citations and patent renewals is very similar across advances originating inside and outside the United States (as indicated by the parallel relationship between the two regression lines meaning that they have essentially identical slopes). The usefulness of quick citations as indicators of patent value (at least within the United States patent system) seems clear for innovations emerging across the world.

Second, while there is some overlap between United States and foreign sources – as reflected in circles in the center of the figure -- all of the locations with top value outputs and high innovator interest (reflected in circles located in the upper right corner of the figure) are locations within the United States. By contrast, a number of industrialized countries producing relatively large numbers of inventions patented in the United States have circles located in the lower left corner of the figure reflecting relatively low patent values and low innovator interest. This is true for advances from Great Britain, France, Germany (represented by the unlabeled circle next to that for France), and China. The reasons for these apparently low values and low interest showings are not apparent from the data under examination in this study but certainly

deserve additional research attention given the much better showings for many American locations.

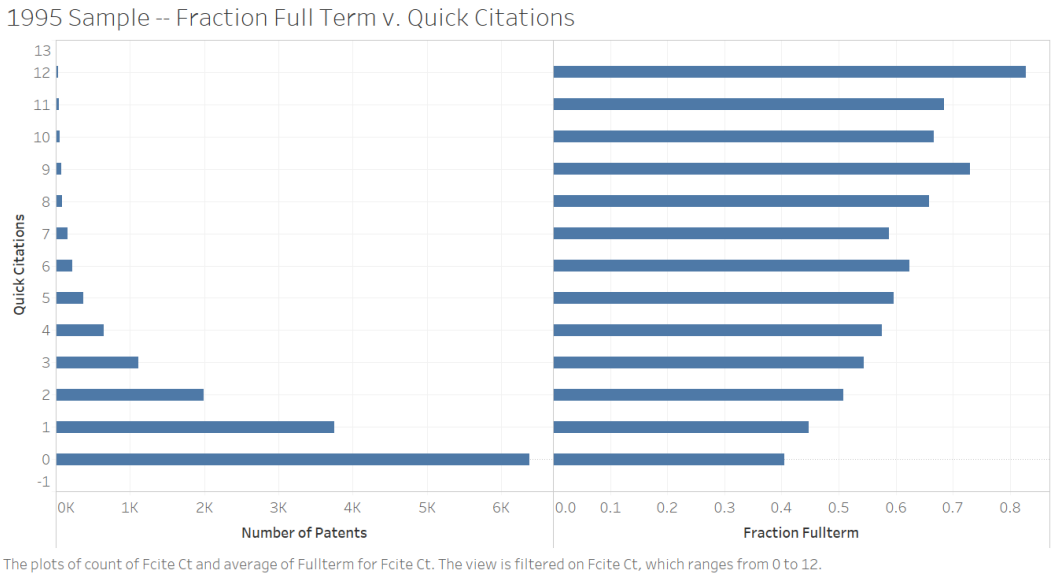
C. *Quick Citations and Patent Renewals for Individual Advances*

To this point, discussions have focused on the relationships between quick citations and patent renewal data for groups of related patents – that is, for groups of patented innovations of similar technology types or geographic sources. This subsection shifts the analysis to specific patented inventions. The relationship between quick citations and likely patent renewal (and likely patent value) holds true down to the individual patent level. This subsection describes the relationship between quick citations and patent renewals for individual inventions and presents a regression model for analyzing the effect of quick citations on the likelihood of patent renewals.

1. *The Relationship Across All Technologies*

The following figure summarizes the positive relationship between increasing quick citation counts for individual patents and the likelihood of full-term patent extension (for quick citations 0-12):[33]

Figure 8
Full Term Fractions by Quick Citations (All Technologies)



[33] The range of quick citations from 0 to 12 covered in this figure corresponds to 99.37 percent of the patents in the 1995 patent sample under scrutiny. The remaining .63 percent of patents with higher quick citation counts are not included because they are spread among a wide range of higher quick citation values and would be difficult to include in a small plot.

For comparison, the fraction of patents extended to full term for all 15,000 patents in the 1995 sample was .4648, meaning that patents with 12 quick citations (having a full-term extension rate of about 0.8) were almost twice as likely as average to be maintained to full term. The large number of patents seen here with no quick citations reflects the initial neglect that most patented advances receive early in their life. As will be discussed more thoroughly below, many of these initially neglected patents will never receive attention during the remainder of their enforceable period or after. This inattention will ultimately explain their assessment as worthless. However, for each additional quick citation an advance receives, its likelihood of being continued to full patent term increases.

Exploring the relationship between quick citations and patent renewals more systematically, an ordered logit analysis was performed using the renewal of patents at 4, 8, and 12 years to define a four-level ordered dependent variable. The four levels in this variable corresponded to 1) patents that were allowed to lapse due to non-payment of maintenance fees due 4 years from issuance, 2) patents that lapsed due to non-payment of fees due 8 years from issuance, 3) patents that lapsed due to non-payment of fees due 12 years from issuance, and (4 patents that were extended for their full terms (based on payment of all necessary fees).

2. *Tracing the Linkage of Early and Late Citations to Patent Renewals*

Early-stage patent citations as measured from quick citations contain different information on innovator interest in advances than later forward citations made during the remainder of a patent term. Later citations – that is, citations to a patent in subsequently issued patents where the citing patent was issued more than three years after the cited patent – are referred to here as "late citations". These reflect differences in inventor interest in a period distinct from the development of a cited patent.

Of course, many patented inventions (and related technologies embedded in the inventions) are targets of innovator interest both initially (as measured by quick citations) and later (as measured by late citations). Such inventions will have high levels of both quick citations and late citations. Conversely, some inventions are never popular resulting in low figures for both quick citations and late citations. Some inventions are never of interest to later innovators, resulting in 0 quick citations and 0 late citations.

To scrutinize the relationship between quick citations and late citations in explaining patent renewal rates, two evaluations were completed. First, the correlations between quick citations and late citations and between each of these and full-term patent renewals were calculated. Second, a breakdown of patent renewal rates for different combinations of high and law quick citations and late citations was completed to trace the impacts of both early and late innovator interest in predicting patent renewals.

a. *Correlations Between Early and Late Citations*

Counts of early and late citations for the advances in the 1995 patent sample showed surprisingly low correlations, indicating that figures for these two types of citations captured different information on innovator interest in cited patents. Despite capturing different information, the two types of citations each explained about the same amount of variation in patent renewal levels. The correlations found were as follows:

Figure 9
Correlations Between Early and Late Forward Citations

Correlation Coefficients	Quick Citations	Late Citations	Full Term
Quick	1.00		
Late Citations	0.38	1.00	
Full Term	0.14	0.15	1.00

The low correlation coefficient (0.38) for the relationship between quick citations and late citations indicates that counts of these two types of citations varied independently. Only about $0.38^2 = .1444$ or about 14.44 percent of the variation in one was explained by variation in the other. However, the similar correlation figures between each of these types of citations and the extension of a patent to full term (0.14 versus 0.15) indicates that quick citations and later citations were about equally effective in predicting whether a patent was extended to full term. This suggests that either early popularity of an advance with innovators (as indicated in a high quick citation count) or later popularity (as indicated by a high late citation count) would correspond to a heightened likelihood that a patent would be renewed to its full term.

b. *Renewal Variations with Early and Late Innovator Interest*

To capture the variation of patent renewal rates for advances that were popular with inventors early in the life of a patent or later in the life of a patent (or both), renewal rates were computed for 25 combinations of early and late citations. Five levels of citations were created for each of the counts of quick citations and late citations producing 5 x 5 combinations. The following figure summarizes the renewal variations found for combinations of early and late citations:

Figure 10
Renewal Variations for Differences in Quick and Late Citations

	Late Citations											
		0		**Bottom 90 %**		**90 to 94 %**		**95 to 99 %**		**Top 1 %**		**Total**
	N	Full Term	N	Full Term	N	Full Term	N	Full Term	N	Full Term	N	Full Term
Quick Citations												
0	468	0.2799	5666	0.4077	151	0.5430	81	0.6543	12	0.6667	6378	0.4051
Bottom 90 %	167	0.3174	6024	0.4653	361	0.6233	262	0.6985	49	0.7347	6863	0.4808
90 to 94 %	2	0.5000	745	0.5597	126	0.5873	113	0.6903	22	0.8182	1008	0.5833
95 to 99 %	0	0.0000	339	0.5398	111	0.7568	105	0.7619	34	0.8235	589	0.6367
Top 1 %	0	0.0000	52	0.6154	30	0.6667	46	0.8696	34	0.9706	162	0.7716
Total	637	0.2904	12826	0.4479	779	0.6226	607	0.7150	151	0.8146	15000	0.4648

In this figure, each pair of "N" and "Full Term" figures corresponds to a combination of quick citations and late citations. For example, at the lowest citation levels (represented by cells in the upper left corner of the figure), the combination of 0 quick citations and 0 late citations was gained by 468 patents in the 1995 patent sample. Of those patents, only .2799 or approximately 28 percent were renewed to extend to their full term.

At least four interesting characterizations of innovator and patent owner behaviors are supported by the breakdowns in this figure. First, there were clear, positive relationships between citation counts and higher renewal rates across all levels of quick citations and late citations. Even for patents with little initial interest (as reflected in the 0 quick citations received by 6378 of the patents), elevated rates of late citations produced increases in rates of full-term renewals. Thus, for the 468 patents with 0 quick citations and 0 late citations, the renewal rate was a mere .2799 or about 28 percent. However, looking horizontally across the cells in the figure, for the 12 patents that also had 0 quick citations but that gained late citations in the top 1 percent of all patents, the renewal rate was an elevated .6667 or about 67 percent, over 2 ½ times the rate for the initially overlooked patents that never gained any later attention.

Second, there were large differences in the renewals for patents at extreme levels of early and late interest. Patents that were consistently interesting to innovators both early and late had very high renewal rates. The 34 patents that had both quick and late citations in the top 1% had renewal rates of .9706 or about 97 percent (33 of the 34 patents were renewed to their full term). In contrast, patents with consistently low interest were rarely renewed. The 468 patents with 0 quick citations and 0 late citations (meaning that they were not cited in the first three years after issuance and never cited in later patents) were renewed only .2799 or about 28 percent of the time. Clearly, strong neglect and strong interest corresponded to patents with low and high value in the minds of their owners as reflected in owners' decisions to abandon (that is, not renew) or retain most of the respective patents.

Third, patents that started well with high levels of quick citations were highly unlikely to be completely neglected in the later period covered by late citations. Of the 162 patents that received quick citations in the top 1% of all patents, none received 0 late citations. Only 52 or about 32 percent of these 162 patents had late citation counts in the lowest 90 percent for all patents. This suggests that there were few patent advances that were "flashes in the pan" reflecting strong initial interest that faded wildly in later periods. Strong early interest corresponded in many cases to owner confidence in their patents for the full remaining patent terms. The renewal rates for

these 52 patents was .6154 or about 62 percent, indicating that owners were heartened by initial interest in their patents and held the course to renew many of them despite fading later interest.

Fourth, patents that started weakly but gained interest had intermediate track records in renewals. For example, of the 6378 patents with 0 quick citations (reflecting at best weak initial innovator interest), 12 nonetheless received late citations in the top 1% of all patents. These 12 patents were renewed at a rate of .6667 or about 67 percent of the time. This renewal rate falls between the 28 percent rate for consistently neglected patents and the 97 percent rate for consistently interesting patents. Apparently, some inventions were overlooked initially but gained later strong interest from innovators. Patented advances of this type – with low initial but high late interest – might be thought of as "late bloomer" inventions with value or innovation potential that apparently takes longer than most inventions to gel (or to be revealed) and gain innovator interest. Some patent owners, disappointed by initially low interest in their patents or by the uncertainties of shifting interest over time, lost faith in the value of their patents and allowed them to lapse at a higher rate than owners of patents with consistently high interest.

To summarize, weak or strong innovator interest in *both* early and late periods of patent life resulted in very low or high owner estimates of patent value and low or high renewal rates accordingly. Popularity in *either* early or late period corresponded to intermediate renewal rates, suggesting that some late bloomer or declining interest patents were still seen as having sufficient value by owners to justify intermediate renewal rates. Flash in the pan advances (having high initial interest and essentially no later interest) were few, suggesting that most patented advances were followed by at least few later innovation efforts (corresponding to at least a few late citations).

The four innovator and owner combinations in this description are summarized in the following table:

Figure 11
Early and Late Interest Behaviors

	Late Citations	**Low (0)**		**Medium (0 to 90%)**		**High (Top 1%)**	
Quick Citations	**Low (QC=0)**	Consistently Neglected by Innovators	LOW RENEWALS (28%)	Neglected Initially -- Weak Later Interest	MEDIUM-LOW RENEWALS (41%)	Late Bloomers -- Recognized Belatedly and Strongly	MEDIUM-HIGH RENEWALS (67%)
	Medium (0 to 90%)	Early Weak Interest Drops	RARE: MEDIUM-LOW RENEWALS (32%)	Consistently Weak Interest	MEDIUM-LOW RENEWALS (47%)	Early Weak Interest Grows	MEDIUM-HIGH RENEWALS (73%)
	High (Top 1%)	Flashes in the Pan -- Strong Early Popularity Fades	NONE	Early Strong Interest Fades	MEDIUM-HIGH RENEWALS (62%)	Early and Late Strong Interest	HIGH RENEWALS (97%)

3. *Separating Out Effects of Quick Citations on Patent Renewals*

In order to estimate the impacts of subsequent innovator interest (as reflected in quick citations) distinct from other factors potentially influencing patent renewals, a regression model was developed using the control variables for the following factors potentially affecting patent renewal rates:

1) Invention technology type (as reflected in the classification of patented advances within NBER technology categories, with the mechanical invention category (category 5) serving as the base or "reference" state);

2) Invention environment complexity (as measured from the number of inventors contributing to a patented advance);

3) Invention organizational source (as reflected in a dummy variable recording whether a patent was immediately assigned upon issuance, a type of assignment that usually indicates that the patented advance was made by an employee working in an organizational environment and assigning a resulting patent to his or her organizational employer); and

4) Invention geographic source (as represented by a dummy variable indicating if a patented advance originated from a foreign source, thereby using inventions from the United States as the base or reference state).

The dependent variable was a four-level ordered value, with the orders corresponding to patents that were 1) allowed to lapse at the 4-year point, 2) allowed to lapse at the 8-year point, 3) allowed to lapse at the 12-year point, and 4) renewed to full term through payment of all fees needed to gain a full patent term.

Two related analyses were completed using ordered logit calculations. In one analysis, quick citations were used as an independent predictor variable in combination with the control variables just mentioned. In a second analysis, the same model (including the control variables) was used but, instead of quick citations, all forward citations received by patents over their full life were used as an independent predictor variable. The results were as follows (the left column in the figure represents the results for the model involving quick citations and the right column corresponds to the model based on full forward citations):

Figure 12
Ordered Logit Results – Patent Renewals at 4, 8, and 12 Years

Model 1						**Model 2**				
Renewals	Odds Ratio	Robust Std. Err.	z	P>z		Renewals	Odds Ratio	Robust Std. Err.	z	P>z
Quick Citations	1.110962	0.009534	12.26	0		All Forward Citations	1.008108	0.000664	12.26	0
Inventor Number	1.064922	0.010907	6.14	0		Inventor Number	1.064086	0.010893	6.07	0
Employer Assigned	2.715149	0.122543	22.13	0		Employer Assigned	2.771042	0.125717	22.47	0
Chemical	1.03571	0.052998	0.69	0.493		Chemical	1.036404	0.052752	0.7	0.482
Computers & Communications	1.4744	0.080927	7.07	0		Computers & Communications	1.464408	0.080209	6.96	0
Drugs & Medical	1.221604	0.074724	3.27	0.001		Drugs & Medical	1.028963	0.063875	0.46	0.646
Electrical & Electronic	1.223942	0.061252	4.04	0		Electrical & Electronic	1.227202	0.061314	4.1	0
Other Technologies	0.84094	0.042722	-3.41	0.001		Other Technologies	0.838781	0.042562	-3.46	0.001
Foreign Invention	0.835875	0.026706	-5.61	0		Foreign Invention	0.888848	0.028798	-3.64	0
/cut1	-0.62993	0.053581				/cut1	-0.5708	0.054264		
/cut2	0.5416	0.053033				/cut2	0.605981	0.05394		
/cut3	1.298339	0.053903				/cut3	1.369513	0.05495		
Pseudo R^2	0.034					Pseudo R^2	0.0386			

As the results in the left column reveal, quick citations were statistically significantly related to the likelihood of patent renewals controlling for the effects of technology differences, inventor numbers, and foreign invention sources. Advances with one additional quick citation were about 1.11 or 10 percent more likely to be renewed (at each stage of renewal) than patents without such a citation.

Interestingly (as shown by a comparison of the R^2 results for the models in the left and right columns of this figure), quick citations were almost as effective in predicting patent renewals as the full number of forward citations received by patents over their full life.[34] This suggests that quick citations contain about as much information about likely patent renewals as full forward citation tallies determined over complete 20-year patent terms. Quick citations appear to be as useful as full period forward citations but much more easily determined (after only three years of citation monitoring) and timely available (at relatively early stages in the life of inventions and associated patents when key decisions about invention development and associated resource commitments are yet to be made).

4. *Quick Citations as Predictors of Patent Litigation*

Additional analyses in the present research examined the relationship of quick citations to the involvement of patents in litigation and, where patents were litigated, to the number of litigation assertions of patents. These analyses are described in this subsection.

To assess the relationship between quick citations and the assertion of a patent in litigation, logit analyses were conducted using a dummy variable for the assertion

[34] The pseudo R^2 figures of 0.034 and 0.0386 for the two models were almost identical, indicating that they explained almost the same amount of the variation in full term patent renewals.

of a patent (at least once) in litigation. As with prior analyses, a pair of evaluations was completed, one using quick citations as an explanatory independent variable and a second comparison study using full forward citations as an explanatory variable. The same control variables for differences in technology type, inventor numbers, and invention sources were used as before. The results were as follows:

Figure 13
Logit Results for Probability of Patent in Litigation

Model 1						**Model 2**				
Litigated Patent	Odds Ratio	Robust Std. Err.	z	P>z		Litigated Patent	Odds Ratio	Robust Std. Err.	z	P>z
Quick Citations	1.132548	0.015924	8.85	0		All Forward Citations	1.004168	0.000804	5.2	0
Inventor Number	1.067594	0.063453	1.1	0.271		Inventor Number	1.062562	0.064773	1	0.32
Employer Assigned	0.73966	0.176218	-1.27	0.206		Employer Assigned	0.717048	0.171427	-1.39	0.164
Chemical	0.667488	0.230336	-1.17	0.241		Chemical	0.710303	0.247564	-0.98	0.326
Computers & Communications	1.510099	0.441722	1.41	0.159		Computers & Communications	1.892556	0.541585	2.23	0.026
Drugs & Medical	1.569943	0.47402	1.49	0.135		Drugs & Medical	1.430189	0.447955	1.14	0.253
Electrical & Electronic	0.815182	0.262076	-0.64	0.525		Electrical & Electronic	0.940013	0.306958	-0.19	0.85
Other Technologies	1.035582	0.310133	0.12	0.907		Other Technologies	1.077292	0.329144	0.24	0.807
Foreign Invention	0.245776	0.059877	-5.76	0		Foreign Invention	0.248936	0.061108	-5.66	0
Pseudo R^2	0.0786					Pseudo R^2	0.0761			

Controlling for the effects of technology differences, inventor group sizes, and foreign invention sources, quick citations were a statistically significant predictor of whether a patent was litigated. A patent with one additional quick citation was about 1.13 times or 13 percent more likely to be litigated than a patent without such a quick citation. A comparison of the results in the left and right columns of this figure indicates that quick citations were marginally better predictors than full forward citations of whether a patent would be litigated.[35] This indicates that quick citations are not only more conveniently ascertained indicators but may also be more accurate predictors of litigation patterns (and associated patent value) than forward citations determined over full patent terms.

Some assessments of patent value based on litigation patterns have emphasized the number of times a patent has been asserted in litigation as a measure of value rather than whether a patent has been litigated at least once. Using litigation assertion frequency as a dependent variable, further regression analyses were completed. As previously, a pair of analyses was performed – one based on quick citations and a parallel analysis based on full forward citations. The results are shown in the following figure:

[35] This slightly higher predictive ability is suggested from the marginally higher R^2 value for the model based on quick citations over the similar model based on full forward citations.

Figure 14
Poisson Linear Probability Results for Number of Times Patent Litigated

Model 1						**Model 2**				
Times Litigated	Incident Rate Ratios	Robust Std. Err.	z	P>z		Times Litigated	Incident Rate Ratios	Robust Std. Err.	z	P>z
Quick Citations	1.105976	0.047573	2.34	0.019		All Forward Citations	1.002925	0.000551	5.31	0
Inventor Number	0.9980271	0.097676	-0.02	0.984		Inventor Number	0.9878391	0.102859	-0.12	0.906
Employer Assigned	0.780721	0.383963	-0.5	0.615		Employer Assigned	0.7813756	0.419204	-0.46	0.646
Chemical	1.228087	0.544882	0.46	0.643		Chemical	1.271506	0.564958	0.54	0.589
Computers & Communications	12.15366	9.565548	3.17	0.002		Computers & Communications	14.55043	9.475093	4.11	0
Drugs & Medical	3.285214	1.182342	3.3	0.001		Drugs & Medical	2.929251	1.226762	2.57	0.01
Electrical & Electronic	1.423781	0.669585	0.75	0.452		Electrical & Electronic	1.5589	0.804374	0.86	0.39
Other Technologies	1.236225	0.394957	0.66	0.507		Other Technologies	1.25192	0.404129	0.7	0.486
Foreign Invention	0.1303996	0.084661	-3.14	0.002		Foreign Invention	0.1264795	0.074193	-3.52	0
Pseudo R^2	0.1632					Pseudo R^2	0.1583			

Quick citations were again statistically significant indicators (at the p>.05 level) of patent value (as measured in this case from ligation assertion counts). Patents with an additional quick citation were 1.11 times or approximately 11 percent more likely to be litigated an additional time than patents lacking the additional quick citation). As indicated by the R^2 values for the two models shown, quick citations were slightly better predictors of variations in litigation assertion frequency than forward citations assessed over full patent terms.

5. *Quick Citations as Correlatives of Patent Breadth and Value*

Further evaluations in the present study considered quick citations as factors tracking patent breadth (with patent claim counts serving as proxies for patent breadth). Patent breadth is often used as a rough measure of patent value on the basis that broader patents tend to sweep in larger ranges of potentially infringing conduct than narrow patents, making the broader patents more valuable than narrow ones all else being equal. Hence, if quick citations have a positive relationship to patent claim counts, these citations also can point to perceived patent value in the eyes of parties who measure value from patent breadth.

To examine the relationship between quick citations and claim counts, two further regression analyses were completed, one with quick citations as a predictor variable (using the same control variables as before) and a second substituting full forward citations as the predictor variable. The results are shown in the following figure:

Figure 15
Poisson Linear Probability Results for Number of Patent Claims

Model 1						**Model 2**				
Number of Claims	Incident Rate Ratios	Robust Std. Err.	z	P>z		Number of Claims	Incident Rate Ratios	Robust Std. Err.	z	P>z
Quick Citations	1.030666	0.002812	11.07	0		All Forward Citations	1.001204	0.000141	8.57	0
Inventor Number	1.041948	0.004569	9.37	0		Inventor Number	1.041997	0.004574	9.37	0
Employer Assigned	1.125663	0.020774	6.41	0		Employer Assigned	1.128473	0.020657	6.6	0
Chemical	1.027668	0.021566	1.3	0.193		Chemical	1.029746	0.021601	1.4	0.162
Computers & Communications	1.073919	0.023904	3.2	0.001		Computers & Communications	1.099806	0.024353	4.3	0
Drugs & Medical	1.037898	0.02495	1.55	0.122		Drugs & Medical	1.002329	0.024356	0.1	0.924
Electrical & Electronic	1.036856	0.020907	1.79	0.073		Electrical & Electronic	1.050311	0.021107	2.44	0.015
Other Technologies	1.011864	0.020947	0.57	0.569		Other Technologies	1.014882	0.021005	0.71	0.475
Foreign Invention	0.7722844	0.010137	-19.69	0		Foreign Invention	0.7776944	0.010262	-19.05	0
Pseudo R^2	0.0379					Pseudo R^2	0.0400			

Quick citations were again statistically significant predictors of patent value (with value measured from the number of claims in patents). A patent with one additional quick citation was 1.03 times or about 3 percent more likely to have an additional claim than a patent lacking the additional quick citation. As with prior analyses, a comparison of the R^2 figures for the analyses in left and right columns indicates that quick citations were almost as good predictors of claim numbers as forward citations over the full period of patent duration.

IV. Interpreting the Link Between Quick Citations and Patent Value

While the present preliminary study has not surveyed innovator and commercializing actions in the manner needed to confirm behavioral mechanisms linking quick citations and patent value, a few reasons can be suggested for the significant, positive relationship between quick citations and patent renewals (and corresponding private estimates of patent value) found here. This section contains some preliminary thoughts on the reasons behind the relationship.

A. *Forward Citations Reflect Careful Innovation Neighborhood Mapping*

Forward patent citations originate from carefully conducted technology location "mapping" by patent specialists other than inventors.[36] Parties contributing to this mapping include patent searchers, patent attorneys or agents, and patent examiners.

[36] Patent citations by patent applicants are submitted as part of the technology background or "prior art" information that must be included in every patent application. Christopher A. Cotropia, Mark A. Lemley, and Bhaven Sampat have described the reasoning behind applicants' duties to submit prior art in connection with filing patent applications (duties that are typically met on behalf of patent applicants through actions of specialists like patent searchers who collect prior art information and patent attorneys or patent agents who aid in drafting and submitting patent applications):

Once an inventor has decided (at least tentatively) to seek a patent, a patent searcher will usually conduct specialized searches of prior patents (and other documents describing publicly disclosed technologies) to delineate the technology background or "prior art" backdrop to the inventor's advance. A patent attorney or agent[37] will use the patent search results in drafting a patent application, emphasizing in the drafting the features of the new advance that differ from the prior art. A patent application will include citations to earlier prior art patents that describe the immediate technology surroundings of the new advance and the baseline from which differences between the prior art and the new invention can be appreciated.[38] Once a patent application is submitted to the United States Patent and Trademark Office (USPTO), a patent examiner will review the application for compliance with patent law standards and potentially add further patent citations to better define the relevant prior art.[39] Citations to prior patents emerging from this process paint a picture of earlier, conceptually-related innovations that comprise the technology context or "neighborhood" of the new advance covered by a patent application.

> Patent law imposes a duty of candor on patent applicants. They must disclose any material prior inventions, uses, and publications ("prior art") of which they are aware to the Patent and Trademark Office (PTO); failure to do so can render the resulting patent unenforceable. The idea is that applicants should help patent examiners decide whether an invention is patentable by submitting what is likely to be the most relevant information. And we trust that examiners will do so; when the patent issues we imbue it with a strong presumption of validity.

Christopher A. Cotropia et al., *Do applicant patent citations matter?*, 42 RSCH. POL'Y 844, 844 (2013).

[37] *See generally* Cathie Kirik, *Working With a Patent Practitioner,* INVENTORSEYE (Jan. 2011), https://www.uspto.gov/learning-and-resources/newsletter/inventors-eye/working-patent-practitioner (Both patent attorneys and patent agents are qualified to submit patent applications to the United States Patent and Trademark Office (USPTO) on behalf of inventors. Both types of parties must be admitted to the United States patent bar under standards and procedures administered by the USPTO. For purposes of patent application submissions, patent attorneys and agents are equally entitled to undertake actions on behalf of inventors. Patent attorneys (but not patent agents) are also admitted to the bar of at least one state, allowing them to advise inventors or other clients on other aspects of patent law such as patent enforcement and patent litigation.).

[38] *See* 35 U.S.C. § 102 (2021) (At least one feature differing from the prior art is needed to make a new advance "novel" in relation to past technology and to qualify the advance for a United States utility patent.).

[39] Prior patents, as identified in patent citations that become forward citations for the cited patents, constitute the primary source of prior art considered by patent examiners in reviewing patent applications. One study identified the fraction of prior art references reflected in patent citations as follows:

> Over three-quarters of the submitted art against which patentability is evaluated (32,208/42,397 references) comes from applicants. Overall, most of the art (64%) is previous U.S. patents or patent applications. Notably, examiners account for a much larger share of citations to U.S. patents than of other types of art. Examiners account for 34% of citations to U.S. patents, versus 6% for non-patent art and for foreign patents. This is consistent with prior suggestions that patent examiners primarily search prior U.S. patents. They have less ability to search foreign patents and unpublished sources of non-patent art, so the overwhelming majority of other references are those provided by applicants.

Cotropia et al., *supra* note 36, at 846 (citations and footnotes omitted).

Patents cited in a patent application (and in a resulting patent) may or may not have been reviewed by the innovator filing the application. Many inventors indicate that they do not read prior patents as sources of information on earlier advances, making it unlikely that a prior, cited patent directly informed and influenced the development of a later invention and the patent on that invention which cited the earlier advance.[40]

However, whether or not an inventor read or knew of an earlier cited advance is irrelevant to the quality of citation information in locating later advances within particular technology neighborhoods and in characterizing the intensity of ongoing interest in those neighborhoods. Patent citations describe the technology neighborhood occupied by a citing advance regardless of whether the innovator involved knows of the prior patents in that neighborhood. The efforts of patent searchers, patent attorneys, and patent agents to identify relevant prior art ensure that the mapping of neighborhoods of related technologies through patent citations are generally accurate. Patent citations reflect conclusions by these patent specialists about technology similarity between citing and cited patents. Large numbers of quick citations indicate that there is a vibrantly growing neighborhood of conceptually similar technology designs containing both the cited and citing patents. Private patent specialists define and characterize these neighborhoods through their aggregate actions in making patent citations in patent applications. In a similar fashion, patent examiners, who may add further patent citations to a patent (including citations to patents that have not been reviewed by the inventor involved), can add to and refine the definition of the technology neighborhood of citing patents.[41]

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[40] Inventors, asked about their sources of technical information leading to their advances, seldom point to reviews of prior patents as information sources. Many innovators do not monitor and review patent documents. As summarized by Mark A. Lemley:

> [R]esearching a new area of technology by reading patents seems a doubtful idea at best. Far better for engineers to learn from article preprints, conferences, and conversations with colleagues. And indeed what evidence we have suggests that scientists in most fields turn to those sources for their scientific learning. If they read patents at all, it is to know what is owned, not what is known.

Mark A. Lemley, *The Myth of the Sole Inventor,* 110 MICH. L.REV. 709, 746-47 (2012), https://repository.law.umich.edu/cgi/viewcontent.cgi?article=1125&context=mlr (footnote omitted). *But see* Lisa Larrimore Ouellette, *Do Scientists Read Patents?*, IP WATCHDOG (July 18, 2013), http://www.ipwatchdog.com/2013/07/18/do-scientists-read-patents/id=43401/ (reporting that 64 percent of scientists surveyed in the field of nanotechnology indicated that they had read patents and 60 percent found useful technical information there); *see also Lisa Larrimore Ouellette, Do Patents Disclose Useful Information,* 25 HARV. J. L. & TECH. 545 (2012), http://jolt.law.harvard.edu/articles/pdf/v25/25HarvJLTech545.pdf. Innovators may receive important information on previously patented advances through patent-influenced disclosures, even if the information is not obtained through reading patent documents. An innovator, reassured by the filing of a patent application that disclosure of an advance will not undercut his or her full opportunity to commercialize an advance under patent protections, may freely disclose the advance through published papers, presentations at academic conferences, or Internet postings. Thus, patent-influenced disclosures may promote technology development based on patented advances even if not through patent documents themselves.

[41] *See* Cotropia et al., *supra* note 36, at 846 (describing the significance that patent examiners place on cited patents they find themselves and which represent contributions to the definition of prior art made by examiners beyond the information submitted by patent applicants).

B. *Quick Forward Citations Describe Hot Invention Neighborhoods with High Value*

Past studies have recognized the usefulness of quick forward citations in predicting technology value growth.[42] Quick citations are robust predictors of variations in future technology value growth across diverse fields.[43] Quick citations not only predict future technology growth more effectively than forward citations over the full life of patents, they provide useful predictions much earlier in the life of patented technologies (three years after the issuance of cited patents) than waiting for the completion of full patent terms (typically twenty years from filing of a patent application) for measurement of full term patent citation information.[44]

Researchers concluded that quick forward citations predicted technology development value because quick citations are markers for especially dynamic technology development. High mean quick citations are present in technology fields where many advances had "immediate importance" in the development of further advances.[45] High mean quick citations indicate both that the cited advances probably contributed significantly to the development of the relevant technology (importance) and that this significance was apparent to researchers early in the life of the cited patents (immediacy).[46] Like groups of patents with high quick citation means, individual patents with high quick citation values are indicators of nearby technology domains (including numerous citing advances conceptually similar to the heavily cited patents) that have importance and immediacy in later technology development.[47]

Whether evaluated at the group level (via mean quick citations) or for an individual patent, quick citation counts track innovator interest in technical domains and individual inventions. Interest indicates probable value for two related reasons.

First, subsequent inventors are interested in particular advances and nearby technology neighborhoods because the innovators (and the companies or other

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[42] *See* Benson & Magee, *supra* note 5, at 11.

[43] *Id.*

[44] Early identification of promising technologies will usually be desirable. Quick assessments can aid research choices by identifying patents and technologies that appear to have little interest from later innovators and probably little value in further studies. These assessments can set aside patented technologies that are likely distractions to productive current research. Conversely, quick assessments can point to the most promising areas in current innovation, aiding additional efforts and resources (including more supporting investments) to the promising areas.

[45] While they did not provide detailed accounts of cases of immediate importance in particular technology fields – and noted that the concept of immediate importance was not previously developed in the literature of technology development – Christopher L. Benson and Christopher L. Magee saw the immediate technology importance indicated by high quick citation levels as consistent with the types of disruption and innovation redirection of technology fields noted by Clayton Christenson and the importance of technological discontinuities recognized by Philip Anderson and Michael L. Tushman. *See* Benson & Magee, *supra* note 5, at 11 (citing discussions of technology disruption in Clayton Christensen, THE INNOVATOR'S DILEMMA: WHEN NEW TECHNOLOGIES CAUSE GREAT FIRMS TO FAIL 39–42 (1997) and discussions of technological discontinuities in Philip Anderson, Michael L. Tushman, *Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change*, 35 ADMIN. SCI. Q. 604, 604–33 (1990)).

[46] Benson & Magee*, supra* note 5, at 11.

[47] While their research did not address individual patented advances, this patent-level characterization of the implications of high quick citation levels adopts Christopher L. Benson and Christopher L. Magee's interpretation of quick citations as indicators of invention importance and immediacy. *Cf.* Benson & Magee, *supra* note 5, at 11.

organizations that support them) have perceived the potential value of their targeted technology and are trying to cultivate part of that perceived value via their own innovation efforts. Their later inventions are essentially "votes of confidence" in the technology areas being pursued. Their aggregate forward citations (and, in the short run, their quick citations) reflect their accumulated knowledge about and commitment to the value of the technologies they are pursuing. Their resulting quick citations are crowd sourced indicators of likely value in the invention domains towards which they have swarmed.

Second, in some cases, large numbers of forward citations indicate that the cited advances are actually being reused or improved by the citing inventions. If this is the case, the reuse or improvement may expand the range of potential applications of the cited advance, with a corresponding expansion and increase of potential royalties or profits from enforcement of the cited patents. Seen this way, quick citations are estimates of the probable range of interest and numerosity of applications of the cited advances, supporting corresponding estimates of the size of patent-influenced profits from those applications. Quick citations simply reflect how broad or frequent future applications of the patented and cited advance are likely to be and, therefore, how much profit-making potential is associated with future enforcement of the cited patent.

V. CONCLUSIONS

Whether value is represented by patent renewals, litigation patterns, or claim counts – all previously recognized as useful and accurate proxies for patent value – quick citations have statistically significant and positive relationships to patent value. These relationships hold true when data is grouped by technology type or geographic invention source, making it possible to use quick citation means for particular technology types and sources to identify technology fields and geographic locations producing high value inventions with especially high frequency.

Quick citations use crowd sourced information from inventors to identify innovation trends and concentrations. Characterizations of technology fields and sources with quick citations can produce timely technology development information with widespread practical value. Given that quick citations are measurable relatively early in patent life, these citations can characterize technologies and their sources while new technologies or new local strengths in technology production are still in development. The resulting information on promising technology innovation directions and potential for commercialization can assist with important decisions on innovation research choices, funding commitments, training needs, and career potential. As inputs to these important considerations and more, quick citations promise to be valuable tools in future patent and innovation analyses.