Patents and Journal Papers as Credentials for Innovators

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Abstract: Patents and journal papers play important roles in technological progress. Both provide archival records of innovation; both disseminate new knowledge. Beyond this, however, patents and journal papers also provide valuable credentials for innovators. To examine this in greater detail, we introduce a simple working model of systematic knowledge, and argue that patents and journal papers both make original contributions to the edifice of such knowledge. Although a patent certifies an inventor's original contribution to knowledge, however, it is not an overarching credential, whereas a refereed journal paper is both an original contribution to knowledge and a demonstration of an investigator's ancillary skills. Thus patents, although impressive on their own, reach their *full* value as credentials within a portfolio only when accompanied by other credentials that certify the ancillary skills demonstrated by journal paper authors. We conclude that the patents of inventors who have demonstrated such skills are the equal of journal papers in their value as credentials when an investigator's portfolio is evaluated holistically rather than element-by-element. Several examples drawn from academia illuminate this interpretation. Along the way, the discussion briefly turns to a number of related aspects, including a comparison of the qualities of peer review versus patent examination, the usefulness of patents' forward-citation counts as indicators of value, and the contributions of patent attorneys.

Introduction

What drives innovation? According to Jacob Bronowski, *"The most powerful drive in the ascent of man is his pleasure in his own skill. He loves to do what he does well and, having done it well, he loves to do it better. You see it in his science. You see it in the magnificence with which he carves and builds, the loving care, the gaiety, the effrontery. The monuments are supposed to commemorate kings and religions, heroes, dogmas, but in the end the man they commemorate is the builder."* [1]

In technical fields, the innovations that come from applying these skills enter the written edifice of knowledge through the publication of journal papers and patents. Both certify and commemorate the accomplishments of their creators – they serve as valuable credentials attesting to competence. In this context, a "credential" is a formalized indicator that a person possesses a particular, otherwise-difficult-to-observe attribute.[2]

Tradition well supports the notion that peer-reviewed journal papers are a fundamental record of accomplishment for scientists and research engineers. But what about patents? Should patents be accepted as the full equal of journal papers in the construction of the edifice of knowledge? Although the answers may be primarily of interest to philosophers and university tenure committees, such questions bring to mind something more general: to what extent are patents meaningful as credentials? What do they say about their inventors?

The Scientist Writes a Journal Paper

In principle, scientific discovery comes from deliberate investigation conducted according to the scientific method. The theoretical essence of the scientific method, as described by philosopher Karl Popper, is the construction and refutation of hypotheses.

Hypotheses form in an investigator's mind as seemingly random permutations of relevant facts and principles. The investigator may reject most nascent hypotheses as being untenable, based on the outcomes of thought experiments. Those that survive the investigator's thought experiments are ready for further examination by model building, laboratory evaluation, mathematical analysis, computer simulation, and so forth. Those that pass this further examination graduate into the realm of tenable propositions developed according to the scientific method. Unrefuted hypotheses are not claimed to be proved; rather, they may be admitted to the body of systematic knowledge through proper publication.

Systematic Knowledge

In a simple *ad hoc* model, useful here for discussion, the body of knowledge relevant to a field of investigation is *systematic* when:

(a) Potential contributions are subject to expert review before being admitted, so that the body of knowledge may advance without including errors and duplications;

(b) Facts and principles are preserved by archive and made readily accessible; and

(c) Facts and principles are indexed and related among themselves to provide order, with formal citations playing an important role.

The Inventor Works Much in the Same Way

Abraham Maslow describes invention as *"the sudden integration of previously known bits of knowledge not yet suitably patterned. The flash of discovery is most frequently the closure of a gestalt rather than the creation of something out of nothing – this is the moment of a-ha!"* [3] The inventor's mind ponders seemingly random permutations of relevant but perhaps unrelated, unlikely, and sometimes seemingly contradictory facts, principles, and observations, sorting through the possibilities and testing them by thought experiment until a plausibility emerges. Once the limits of the inventor's thought experiments are reached, a proposition that cannot be refuted by thought alone may be tested further, again for example by model building, by laboratory evaluation, by computer simulation, or by mathematical analysis. Thus, like scientific work, invention can be viewed as the creation and testing of hypotheses.

Beyond inventors' testing of hypotheses by one means or another, would-be inventions are subject to extensive review before they reach the state of patents. The first stage of review is often driven by economics. In contrast to the minimal expense of publishing a journal paper, the preparation and prosecution of a patent application can be quite burdensome. In the United States, the process from beginning to end typically costs more than $10,000. The lifetime cost of a multi-country, international filing can top $100,000. The point here is that whoever suffers these expenses – the "financial

backer" – will make a serious effort to ensure that the money is at least reasonably well spent.

Formal Review – The Examination of Patent Applications

The journey leading to a patent starts with the conception of an invention, as outlined above. Usually, the next steps are for the inventors to write an *invention disclosure* – an informal document describing their work – and to engage a patent attorney to prepare a formal patent application from the invention disclosure and file it with the U.S. Patent and Trademark Office (USPTO). The application drawn by the attorney includes a "specification," which explains the invention and describes a preferred embodiment; a set of drawings when appropriate; and a set of formalized claims that define and circumscribe the invention, to be understood with reference to the specification and drawings.

Patent attorneys must pass a specialized examination administered by the U.S. Patent Office, over and above a state bar examination for admission to the general practice of law. Perhaps more importantly, however, they are required to have earned a bachelor's degree in engineering or science in addition to a law degree. Many have earned advanced degrees in technical fields; more than a few have earned doctorates. Further, patent attorneys often acquire significant technical competence over the course of specialized practice. Thus, they are able to help an inventor focus on the nub of an invention, and sometimes contribute (without formal recognition) to its technical aspects. Additionally, ethical attorneys often discuss the likelihood of gaining a patent with their clients, thereby providing an additional stage of vetting, albeit optional and quite informal.

When an application arrives at the Patent Office, it is classified by technological species and assigned to an *examiner* for formal review. Examiners are specialists. They know their fields of technology, and are presumed to be fully competent by courts of law. An important part of an examiner's job is to determine whether a purported invention clears several thresholds, two of which are (1) the invention must be novel, meaning that the same thing has not already been done, and (2) the invention must not be obvious to those of ordinary skill in the art. The test for obviousness is neither explicitly defined nor straightforward. Rather, the question of obviousness is considered with reference to the USPTO's *Manual of Patent Examining Procedure,* which incorporates the body of pertinent case law (court decisions) and regulations. Obviousness is assessed according to reasonable standards. An invention does not need to baffle Albert Einstein and his five best graduate students in order to clear the bar.

In order to determine whether the purported invention clears these two thresholds, the examiner searches for *prior art*. Prior art comprises relevant teachings – patents, journal papers, textbooks, commercial offerings, and so forth – that predate the application under examination. In other words, the examiner looks for earlier work along the same lines. Based on the results of the search, the examiner then determines the patentability of each claim of the application under review, and communicates this to the

attorney in a *first office action*. The first office action may allow all of the inventors' claims, or allow only a subset of the claims, or reject all of the claims.

The attorney, often with the advice of the inventor, then responds to the examiner, either accepting the examiner's judgement or presenting a reasoned argument as to why the examiner has erred. The examiner replies to the attorney with another office action. This process can iterate through further cycles of examination if need be. *In essence, the patent examiner has the same role as the academic journal's editor and referees.*

The Invention Becomes a Contribution to Knowledge

Once an invention clears the formal examination hurdle, a patent is granted, and the invention becomes an original contribution to knowledge in the same way that the scientist's work becomes an original contribution to knowledge upon its publication. In particular, a granted patent satisfies the criteria of the *ad hoc* model proposed earlier:

(a) The contribution has been reviewed by an expert – a patent examiner – and normally by a financial backer, by an attorney, and by peers at the inventor's laboratory as well;
(b) Archived publication makes the invention available to others working in the field – the patent literature is public, as suggested by the etymology of the word *patent*; an abstract is published in the *Official Gazette of the United States Patent and Trademark Office*; and
(c) Forward and backward citations are recorded by the USPTO as they are encountered, thereby providing order.

The importance of crediting others' work by citation in the journal literature is a matter of ethics. In the patent literature, however, proper citation is required as a matter of law: the inventor and attorney are required to disclose to the examiner everything that they know about the prior art that could reasonably be considered material to the invention's patentability. There is no legal requirement, however, that either the attorney or the inventor do a deep search for prior art, or indeed any search at all. That responsibility falls on the examiner at the USPTO. But during the course of infringement litigation, a party seeking to overturn a patent will search the literature thoroughly, looking for prior art that serves to invalidate the patent in question but which was not considered by the examiner. Thus, it is competent practice to ensure that the examiner considers all of the prior art that is material to the patentability of an invention.

Works considered by the examiner are cited on the front page of each issued patent. Generally, these fall into three categories: U.S. patent documents, foreign patent documents, and "other publications." The category "other publications" includes journal papers, commercial technical literature, and commercial products. Such citations are, of course, backward citations – the examiner looks back in time to identify earlier work that is material to the patentability of the invention under examination. Conversely, as patents are granted and enter the body of systematic knowledge, they become available as references to be cited during the examination of newer patent applications. Thus, a backward citation by a newer patent creates a forward citation of an older patent.

Forward citation counts are useful metrics of both the journal literature and the patent literature. In the case of journal papers, a high forward-citation count is important because it conveys prestige to a paper's authors, and serves as a rough approximation of the intellectual import of the paper as well as the authors' capabilities. High forward-citation counts are also good measures of patents, although for a different reason: as a rough approximation, a patent's economic value is proportional to its forward-citation count. [4]

For example, U.C. Berkeley Professor Bronwyn Hall cites data from her study published in the *Rand Journal of Economics* reporting that a substantial economic premium accrues to portfolios that average at least 20 forward citations per patent. [5] According to another source, patents with at least 20 forward citations are more than three-times as likely to be involved in litigation than those with fewer than 20 (litigation indicates considerable interest, given its enormous cost). [6] For these and other reasons, a patent with at least 20 forward citations is generally thought to be "valuable" and "important." [7] Overall, the distribution of forward citations per patent is highly skewed, having the classic long tail of a Pareto (although the distribution is not exactly Pareto), wherein the mean value greatly exceeds the median.[8] This strongly suggests that the distribution of forward citations over a population of patents can be modeled according to a form of Lotka's inverse-power law. [9]

To illustrate why the link between forward citations and economic value is useful in a purely practical way, consider, for example, a cross-licensing negotiation involving a 1000-patent portfolio. It would be virtually impossible to evaluate each patent individually. Clairvoyance would be needed to quantify the future value of each patent, and a deep bench of technical and legal expertise would be needed even to understand the portfolio. Instead, counting the number of forward citations provides a rough, cost-effective way to gauge the portfolio's economic value.

The Quality of Peer Review and Patent Examination

How does the quality of patent examination compare with the quality of peer review of journal papers? In practice, the review of journal papers – peer review – has turned out to be a rather loose filter. The present situation regarding low replication rates in many fields illustrates this. One problem is "forum shopping" – there are legions of journals, each with its own ideas about quality. Some may be called "predatory," concerning themselves only with economic profit. Another is the simple carelessness, gullibility, tribalism, and capriciousness *occasionally* exhibited by those who review journal papers. Yet another is "p-hacking," or the torture of data until it confesses to *something*. Consequently, peer review as practiced today could be thought of as helpful but not sufficient to ensure the integrity of the body of journal literature.

Perhaps the same may be said, but only to a lesser extent, of patent examination. The issue of "forum shopping" does not apply to patent applications in the United States: there is only one USPTO. Moreover, Patent Office examiners are educated specialists who devote their full-time efforts to vetting patent applications. The same kind of full-

time involvement cannot be attributed to the uncompensated volunteers who serve as referees for journals. Further, patent examiners are disinterested parties, whereas the volunteers who review journal papers may be in professional or ideological alliance, competition, or conflict with the authors whose work they vet.

Nevertheless, patents are occasionally granted for the trivial and even the absurd. There are, however, about 12 million US patents extant. There will be outliers in any data set this large. These may be called "false positives," meaning that the examiners failed to weed-out some unworthy applications, and let them issue as patents. Determining the actual count of false positives is difficult, however, because we can observe the characteristics of only the output of the multi-stage, end-to-end vetting process, without having adequate knowledge of the characteristics of the input. This is an example of survivor bias. We know only the cases that make it through the system; we have no knowledge of how many unworthy candidates are denied along the way.

Suppose, for example, that 990 of 1000 unworthy candidates were to pass examination and issue as patents. This would clearly indicate a problem with examination. On the other hand, suppose that only one of the 1000 unworthy candidates were to pass examination and issue as a patent. This "failure rate" of one-in-a-thousand would be excellent by reasonable human standards, yet would still result in about 12,000 "junk" patents. Unfortunately, junk patents inevitably draw the attention of the press, which sometimes leads uninformed critics to question the integrity of the examination process.

The Analyst and the Synthesist

In his famous 1959 Rede Lecture at Cambridge University, C. P. Snow (Lord Snow) identified two cultures – the literary and the scientific – and remarked: [10]

> *"I believe the intellectual life of the whole of Western society is increasingly being split into two polar groups. . . . Literary intellectuals at one pole – at the other scientists, and as the most representative, the physical scientists. Between the two a gulf of mutual incomprehension – sometimes (particularly among the young) hostility and dislike, but most of all lack of understanding."*

The same might be said, although clearly to a lesser extent, about those who are inventors and those who are journal authors. There is an inherent cultural difference between the patent literature, which describes mostly the results of applied, commercial research, and the journal literature, which describes mostly the results of academic research.[11] To some extent, journal papers may be thought of as being driven by analysis, whereas patents may be thought of as being driven by educated intuition. Given this difference, the analyst might view the work of the synthesist as being somehow lesser, mistaking intuitive linkage with obviousness or triviality, especially when a product of intuition is not readily amenable to analysis. In the world of inventions and patents, however, the word "obvious" has particular meaning based on regulatory rulings and case law. Thus, as a practical matter, synthesists with granted patents may have a stronger argument than analysts in defending their work.

In the same Rede Lecture, Snow offered the following hyperbolic thought regarding the pure and the applied, apropos here but perhaps a bit unnecessarily harsh:

> *Pure scientists have by and large been dim-witted about engineers and applied science. They couldn't get interested. They wouldn't recognize that many of the problems were as intellectually exacting as pure problems, and that many of the solutions were as satisfying and beautiful. Their instinct – perhaps sharpened in this country* [England] *by the passion to find a new snobbism wherever possible, and to invent one if it doesn't exist – was to take it for granted that applied science was an occupation for second-rate minds.*

Inevitability and Obviousness

Over the long run, most advances seem to be inevitable, and sometimes even occur simultaneously among independent investigators. A nihilistic view might hold that the work of both scientists and inventors is therefore largely obvious, and is simply a consequence of the background. The question here turns on the word "obvious." In casual use, the word "obvious" means "easily perceived." Yes: most facts and principles, *once discovered and explained*, are indeed easily perceived by an intelligent audience. This does not mean that they are easily wrought, or that they can be timely wrought on demand, or that their contribution to knowledge is somehow diminished.

What a Patent is Not

A post-graduate student who is a candidate for a research degree is required to submit an academic thesis. The thesis may be thought of as an extended journal paper or a "stapled" collection of journal papers of ordinary length. In this realm, *an original contribution to knowledge* is the sometimes-elusive attribute that separates a doctor's thesis from a master's. Thus, a crucial step in writing a doctoral thesis is to identify a gap in systematic knowledge. One purpose of the thesis is, of course, to fill this gap. The same applies as well to a patent, which, by its very essence, fills a gap in systematic knowledge – an invention conveys, by definition, new knowledge.

Beyond this, however, an academic thesis has other purposes: to demonstrate the candidate's ability to carry a written argument logically from premises to conclusions, command of the field of inquiry and its literature, skill in the use of scholarly apparatus, and so forth.[12] The academic thesis thereby serves as a metaphor to illustrate what a journal paper is, and what a patent is not. A patent is not a demonstration of an inventor's ability to write or to carry an argument logically, as the manuscript itself is organized and written by an attorney. Further, a patent does not show that the inventor is aware of prior knowledge, or that the inventor can search the literature and place his or her work in context by way of citations. This is done by the patent examiner. Finally, a patent does not certify that the inventor is capable of testing hypotheses by experiment, mathematical analysis, or computer simulation, as the hypothesis may have been tested (if tested at all) by thought alone, especially in predictable fields.[13]

In other words, although a patent certifies an inventor's creativity and original contribution to knowledge, it is not necessarily an overarching credential, whereas an

academic thesis – and by extension a refereed journal paper – is both an original contribution to knowledge and a demonstration of the investigator's several other skills.

So Which is the Better Credential – A Patent or a Journal Paper?

This is a silly question, of course, whose answer hinges on the particulars of which patent and which journal paper. The question, however, is intended to be rhetorical, and to draw attention to the important but immeasurable quality of *gravitas*. Clearly, patents such as Edison's on the light bulb or Bell's on the telephone far outweigh papers such as the one now at hand. Conversely, Einstein's brief paper on the photoelectric effect surely outweighs any number of patents on potato peelers and bottle-cap openers.

In addition to disseminating new knowledge, patents and journal papers may be said to share another common purpose – to claim and defend turf. A journal paper brings its authors reputational credit by certifying that *their* efforts have added a particular brick to the edifice of knowledge. Any economic reward likely comes by way of career advancement. A patent, on the other hand, stakes-out economic territory through the control of licensing rights. A coproduct of the patent is its contribution of another brick to the edifice, and the commensurate credit that such brings to the reputation of the inventors. So the question of "Which is the better credential?" essentially reduces to the largely unspoken question "How big and important is the new brick?"

A Few Thoughts from Academia

As mentioned earlier, university tenure-and-promotion committees often consider questions of the kind examined here. Along the same vein, some have published guidelines that put patents into perspective. Four such examples are discussed below, followed by a fifth from a different kind of organization. Keep in mind that members of a university faculty have credentials attesting to the ancillary skills mentioned above, almost always by way of earlier journal publications and having earned a PhD.

The first example comes from Washington State University's Voiland College of Engineering.[14] Their approach is to divide accomplishments of research into two tiers. The higher tier includes peer-reviewed research papers and issued patents, with papers accorded the highest status within this tier. The lower tier includes books, book chapters, and invited presentations. Thus, patents are "ranked" below journal papers, but clearly above books and chapters.

The second example comes from Louisiana Tech University, which has the following to say about patents: [15]

> *"The filing of a patent resulting from an engineering or scientific research project is certainly evidence of a candidate's* [for promotion or tenure] *creativity. Patents are often the result of an extensive applied research effort, and in some cases, basic research. The patent is evidence that the candidate was able to successfully apply scientific and engineering principles to the solution of a problem or to satisfy a societal need. Due to proprietary and legal restrictions, the candidate is often prohibited from immediately publishing the work which led*

to the development of the patent. In such cases, the patent may serve as the only evidence of the candidate's scholarly activity in this regard. The candidate should include in the dossier evidence of the scientific quality of a patent, perhaps in a letter from independent outside sources."

Note four aspects of this example: (1) the inventive process is referred to as "scholarly activity," (2) a patent may exhibit "scientific quality," (3) evidence of "the scientific quality of a patent" is solicited, presumably to weed-out the patents on potato peelers and bottle-cap openers, and (4) a patent is acceptable as a stand-in for a delayed journal publication.

The third example comes from West Texas A&M University.[16] Their approach is to assign numerical points to various kinds of intellectual contributions (their term), and to use a candidate's point total as a metric for judging promotion or tenure. In the A&M system, the following are assigned four points each: "Major contributor to a peer reviewed publication in a discipline appropriate journal," and "Major contributor to a respectable discipline appropriate patent award." Here, the patent and the journal paper are treated as equals.

The fourth example comes from a small, liberal arts college in Massachusetts, Stonehill College. Their chemistry department simply notes that "We consider peer-reviewed publications and patents to be the final measure of successful scholarship."[17]

The final example comes from a different kind of organization – *Sigma Xi, The Scientific Research Honor Society*. Their criteria for full membership are:[18]

"*An individual who has shown noteworthy achievement as an original investigator in a field of pure or applied science is eligible for election to Full Membership. / This noteworthy achievement must be evidenced by publication as the primary author (defined in the manner appropriate to the discipline) on at least two different articles published in a refereed journal, patents, or refereed monographs. / Dissertations and theses alone are not considered sufficient for demonstration of this achievement and must be accompanied by at least two other publications."*

Note here that an applicant's portfolio is evaluated holistically rather than its individual components, wherein (1) patents and journal papers are assumed *a priori* to be equals, and (2) both patents and journal papers are identified as "publications." Full membership, however, further requires sponsorship and election by members (vetting). One trusts that the vetting weeds-out any low-gravitas, potato-peeler patents offered by candidates for admission. Curiously, the comment about dissertations and theses is not elaborated.

Multiple Authors and Inventors

Further complicating the situation, multi-author papers and multi-inventor patents have become commonplace. A seemingly routine practice is for a journal paper to list a plethora of authors, of which only a few beyond the principal author may have actually

contributed anything of intellectual substance. Various ways have been proposed to apportion credit realistically in these situations. Some assign more credit to sole-author papers than to multi-author papers. In the case of multi-author papers, credit is sometimes awarded in what might be called "fractional units," with the principal author receiving the lion's share. In some cases, citation counts and journal prestige are also taken into consideration.[19]

The situation for patents is more straightforward, at least in principle. Inventors may as well be listed alphabetically as in any other order. Each person listed as an inventor on a granted patent must have contributed to the *intellectual conception* of the invention – there is no differential endorsement of a "principal inventor" in any meaningful sense. Conversely, someone who works solely as a technician who reduces an invention to practice or works only as a scribe to "write things up" cannot legitimately claim inventorship. Getting this right is important, because a patent reporting incorrect inventorship can be found invalid in litigation. Now comes yet another caveat: the risk of invalidity can, on occasion, lead to the inclusion of questionable contributors as inventors. From a practical standpoint, it is better to err on the side of inclusion when listing inventors. This is because someone who is undeservedly included as an inventor is unlikely to complain, whereas someone who feels slighted by omission might be expected to object vigorously and emotionally, which could be quite troublesome in litigation.

Concluding Remarks

Patents and journal papers share a common purpose: to record and disseminate new knowledge. In creating this new knowledge, inventors and scientists work in much the same way, developing and testing hypotheses, looking for a sound hypothesis that withstands refutation, subjecting the result to expert review, and publishing in an open, cumulative literature. Although the patent and the journal paper differ significantly, they are, equally, original contributions to the edifice of systematic knowledge.

Nevertheless, a journal paper may be viewed as a broader credential than a patent for at least two reasons: (1) a journal paper is primarily the work of its principal author, whereas a patent is the work of the inventor, a highly-skilled attorney, and a patent examiner; and (2) because of the involvement of these other parties, a patent *per se* does not certify an inventor's competence with written expression, logical argument, the tools of scholarship, command of the related art or literature, and so forth, whereas a journal paper does so certify, at least in principle. In other words, a journal paper is a more encompassing credential than a patent. But given the apparent weakness of journal-paper review and the comparative strength of patent examination, it may be fair to say that a patent is a more trustworthy credential than a journal paper.

As a final example, consider two portfolios, each with four publications. The first consists of four patents; the second consists of two patents and two principal-author journal papers. Both portfolios provide valuable credentials that attest to their originators' abilities and contributions to knowledge. The second, however, also attests to the originator's ancillary skills, whereas the first does not. Thus, even though both

consist of four publications, the second is the stronger set of credentials – the *full* value of the patents as credentials is realized only when they are elements of a portfolio that also includes credentials attesting to the originator's ancillary skills.

This leads to a final "it all depends" situation. If an inventor has published as principal author in a primary journal (or written an academic thesis), this certifies the inventor's competence in the academic skills mentioned above. The inventor has "checked this box." Thus, for an inventor who has a record of primary journal publication, *and perhaps only for such an inventor*, patents may be accorded full status as the equals of journal papers in a holistic evaluation of his or her portfolio, based on the patents' original contributions to systematic knowledge combined with the journal papers' certification of the inventor's other skills. In other words, what a patent says about an inventor – its value as an intellectual credential – depends, in part, on what else the inventor brings to the table, whereas a journal paper stands independently.

Endnotes and Works Cited:

[1] Jacob Bronowski, *The Ascent of Man* (Boston: Little, Brown and Company, 1973), 116.

[2] Jason Rantanen and Sarah E. Jack, *Patents as Credentials*, 76 Wash. & Lee L. Rev. 311 (2019) https://scholarlycommons.law.wlu.edu/wlulr/vol76/iss1/8

[3] Abraham H. Maslow, *Maslow on Management* (New York: John Wiley & Sons, Inc., 1998), 231

[4] Bronwyn H. Hall, *Patent Data as Indicators* (London: World Intellectual Property Organization (WIPO) Meeting, Oct 2004); included in Bronwyn Hall, Adam Jaffe, and Manuel Trajtenberg, "Market Value and Patent Citations," *Rand Journal of Econ*omics 36 (Spring 2005) 16-38 https://eml.berkeley.edu/~bhhall/papers/HallJaffeTrajtenberg_RJEjan04.pdf

[5] *ibid.*

[6] "The Importance of Patent Citation Statistics in Research" (Santa Clara, California; the law firm "Patent PC") https://patentpc.com/blog/the-importance-of-patent-citation-statistics-in-research

[7] See, for example, C.L. Benson and C. L Magee, "Quantitative Determination of Technological Improvement from Patent Data," PLoS ONE 10 (4):e0121635. Doi:10.137/jopurnal.pone.o121635; https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0121635

[8] A substantial fraction of all issued patents receive no forward citations at all; the median value seems to be one forward citation per patent; the mean value hovers below 10 forward citations per patent due to the distribution's long tail; and 0.01% receive more than 100 forward citations. The exact values of these parameters depend on the field of invention, the time period covered by the study reporting the numbers, and the way in which time-period truncation is factored in for patents that have not yet fully matured.

[9] For an introduction to Lotka's Law, see Derek J. De Solla Price, *Little Science, Big Science* (New York: Columbia University Press, 1963) chap. 1

[10] C. P. Snow, *The Two Cultures and the Scientific Revolution* (New York: Cambridge University Press, 1961) 4-5

[11] J. J. Gilman, "Research Management Today," *Physics Today* (College Park, MD: American Institute of Physics, 1991) 42-48

[12] Paul E. Koefod, *The Writing Requirements for Graduate Degrees* (Englewood Hills, NJ: Prentice-Hall, Inc., 1964) throughout

[13] American jurisprudence admits the possibility that an invention, particularly an uncomplicated one, may be fully understood by thought alone. These fields are called *predictable*, meaning that anyone with relevant skill would be able to understand and predict the behavior of the inventive configuration, *in retrospect*, by applying known principles. In this sense, mechanical and electrical inventions may be predictable, whereas biological and chemical are generally not.

[14] *Supplementary Procedures and Criteria for Tenure and Promotion* (Pullman, WA: Washington State University, Voiland College of Engineering and Architecture, 27 Oct. 2015) https://vcea.wsu.edu/faculty-staff/documents/2016/01/tenure-and-promotion-guidelines-vcea.pdf/

[15] *Tenure and Promotion Guidelines*, (Ruston, LA: Louisiana Tech University, College of Engineering and Science, July 2021) https://coes.latech.edu/documents/2022/08/tenure-and-promotion-guidelines.pdf/

[16] *Standards for Tenure and Promotion* (Canyon, TX: West Texas A&M University, College of Engineering; as revised 1 June 2021) https://www.wtamu.edu/_files/docs/academics/academic-affairs/TP%20Standards%20COE66.pdf

[17] *Scholarship Criteria for Tenure and Promotion*," (Easton, MA: Stonehill College; Chemistry Department) https://stonehill-website.s3.amazonaws.com/files/resources/scholarship-criteria-booklet-august-2020-ac.pdf

[18] "Becoming a Member" (Research Triangle Park, NC: *Sigma Xi, The Scientific Research Honor Society,* 2024) https://www.sigmaxi.org/members/becoming-a-member

[19] See, for example: Nils T. Hagan, "Deconstructing doctoral dissertations: how many papers does it take to make a PhD?" *Scientometrics* (2010) 85:567-579