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An Economic Analysis of the Use of Citations in the Law

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This paper examines the use of citations analysis as an empirical tool for understanding aspects of the legal system and for improving the performance of the system. Emphasis is laid on the use of such analysis as a means to evaluate courts and judges (and therefore as a judicial-management tool), to test hypotheses about judicial behavior, and to evaluate and improve legal scholarship. It is argued that economic models, particularly of reputation and of human capital, can frame and guide the use of citations analysis in law.

Introduction

Scarcity of quantitative scholarship has been a serious shortcoming of legal research, including economic analysis of law. When hypotheses cannot be tested by means of experiments, whether contrived or natural, and the results assessed rigorously by reference to the conventions of statistical inference, speculation is rampant and knowledge meager. The situation can be improved, I shall argue, by making greater use of citations analysis, guided by economic theory, as a methodology of quantitative empirical research. Both adjudication, a central practical activity of the legal

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system, and legal research are citation-heavy activities. Judges, lawyers who brief and argue cases, and law professors and students engaged in traditional legal-doctrinal research could all be thought, with only slight exaggeration, to make their living in part by careful citation both of judicial decisions and of law-review articles and other secondary materials. The seriousness with which the legal profession takes citations suggests that the analysis of citations in law is likely to uncover more systematic features, a more consistent practice, of citing than would a similar analysis in fields for which citing is of less consequence. Counting citations is already a well-established method of empirical research in law, economics, sociology (especially the sociology of science), and academic administration. It is being used increasingly in law¹—mainly in economic analysis of law—yet it remains limited in relation to potential topics. Statistical analysis of citations practices has become fast and cheap as a result of faster, more powerful computers, and of computerized citations indexes.² The cost of citations analysis thus is falling. But the fact that a particular kind of research is feasible, even easy to do, cannot explain why anyone wants to do it. Low cost is not enough; there have to be benefits—and anyway the opportunity costs of adopting one research method over another are not low. Citations analysis is growing mainly because it enables rigorous quantitative analysis of elusive but important social phenomena such as reputation, influence, prestige, celebrity, the diffusion of knowledge, the rise and decline of schools of thought, *stare decisis* (that is, the basing of judicial decision on previous decisions—

1. Many of the legal citations studies are cited in this paper. Several appear in the conference volume “Interpreting Legal Citations” (*Journal of Legal Studies*, supplement, 2000). The papers given at the conference covered a wide range of topics, including law school rankings, whether lateral hires to law school faculties are better scholars than faculty members promoted from within, the growth of nonlegal citations in judicial opinions, and the application of fractal analysis to citations.

2. These are primarily the indexes for the natural sciences (Science Citation Index), social sciences (Social Sciences Citation Index), and the arts and humanities (Arts and Humanities Citation Index) published by the Institute for Scientific Information. In addition, for law—which has a long and rich history of citation counting; see Shapiro (1992)—the West Publishing Company has excellent computerized databases of both judicial opinions and legal articles. The original legal citations service, Shepard’s Citations, was in fact the inspiration for the ISI indexes (Baird and Oppenheim, 1994, pp. 2, 3). The World Wide Web is also usable for citations analysis; search engines such as AltaVista can be used to count “hits” to named individuals, books, or articles. For uses of the Web in this way, see Landes and Posner (2000) and Neth (1998).

precedents), the quality of scholarly output, the quality of journals, and the productivity of scholars, judges, courts, and law schools.³

Citations analysis is not an inherently economic methodology; most of it has been conducted without any use of the theories or characteristic empirical techniques of economists. It is an empirical methodology usable by a wide range of disciplines. But I shall argue that an economic framework fosters precision in its use. Indeed, the human capital model developed by economists may actually be essential to using citations analysis to compare and evaluate individual performance, whether by judges or by scholars.

The Reasons—and the Motives—for Citing

Citations (that is, mentions of a previous work, published or unpublished, or simply of an author's or other person's name) figure prominently in many forms of documentation (electronic as well as printed), including patents, newspaper and magazine articles, scholarly journals, and books. In case-law systems, such as those of the United States and England, citations, mainly but not only to previous decisions, are a conspicuous feature of most judicial opinions. It does not follow from the commonness of citing that citing is an activity worth studying. That depends on why a work or author is cited. If there were no reason—if citations were random—this would be an interesting finding but there would be little point in studying citation practice further; indeed, there would be no practice of citing to study. But, if only because citing is not costless—there is the bother of finding the citation, and the possibility of criticism for misciting or failing to cite—it would be surprising if citations were random, and there is evidence that they are not, even in fields less committed to precedent and therefore to citation than law is. Notably, citation counts have been consistent predictors of the receipt of high academic honors, such as the

3. The literature of citations analysis is by now vast, and I will not attempt exhaustive citation. The pioneers were sociologists of science. See, for example, Merton (1973). For a book-length discussion, now unfortunately rather out of date, by the founder of the ISI, see Garfield (1979); it is somewhat updated, however, in Garfield (1998). Baird and Oppenheim (1994) give a good overview of the field; for reference to science citations, see Schoonbaert and Roelants (1996).

Nobel prizes in the sciences (Cronin, 1984; Feist, 1997; cf. McAllister, Anderson, and Narin, 1980; So, 1998). As I note later, citation studies of eminent judges yield results consistent with the more common, qualitative indicia of judicial distinction.

Several reasons for citing come to mind. The first, which is dominant in historiography, is simply to identify a source of information, so that the reader of the citing work can verify the accuracy of statements of fact made in it. “Historical footnotes list not the great writers who sanction a given statement or whose words an author has creatively adapted, but the documents, many or most of them not literary texts at all, which provided its substantive ingredients” (Grafton, 1997, p. 33). The second reason for citing, which is closely related, is to incorporate a body of information by reference, that is, to guide the reader to a place where he can find the information if interested in it. Let me merge these two reasons for citing into one—“information”—which is to be understood broadly, as taking in ideas and arguments as well as facts. The motive for the informational citation is simply to respond to a demand for information.

The next reason for citing, which I’ll call “priority,” is to demonstrate compliance with any applicable norm against plagiarism by acknowledging the authorship of ideas, arguments, or (in the case of citations to “prior art” in patent applications) technology used in the citing work. In scientific and social scientific fields, with the partial exception of law, most citations are “priority” citations. Strictly, priority citations are a subset of informational citations; the priority is in making an argument, discovering an idea, or inventing a product or process. But whereas a writer will make informational citations without prodding, simply in order to make his work more valuable to the reader, he will make priority citations (except to himself!) reluctantly, under the constraint of the antiplagiarism norm.

Most self-citations are designed either to incorporate by reference information contained in other works by the citer, to establish the priority of some earlier work of his over work done by others since then, or to advertise his previous work in the hope that more people will read it. One of the worries about citations analysis is that as it becomes more familiar, citation behavior will become strategic, and authors thus will cite themselves more in order to increase their citations count. That is, the gains from self-advertising will be greater and so the number of such citations will increase because the cost of additional self-citations is low. But actually

this gambit is unlikely to succeed, because it is so easy to subtract out self-citations in counting citations to a person's work. Reciprocal citing may be a more serious problem. One can imagine informal deals between academic allies to jack up each other's reputations by citing each other heavily, although they will encounter the usual problems of holding a cartel together. There is some evidence that journal editors receive citations in the journals they edit that they would not receive if they were not editors—citations designed to increase the likelihood that the citing article will be accepted for publication (Lange and Frensch, 1999; Wright, 1994).

Another common reason for citing is to identify works or persons with which or with whom the author of the citing work disagrees. These citations ("negative citations") are motivated not by antiplagiarism norms but by the need to establish the context of the citer's work. Not to cite one's opponent would be like reviewing a book without naming the book or its author.

Still another reason for citing, one particularly important in law and other "authoritarian" institutions such as hierarchical churches and totalitarian states (consider the reason for citations to *Mein Kampf* in Nazi Germany or for citations to the works of Marx and Engels in communist societies), is to provide an authoritative basis for a statement in the citing work. I'll call this "authority" citing. In a system of case law, previously decided cases provide a reason independent of analytical power for reaching a particular outcome in the current case, and the citation of such a case is an invocation of that authority. This is true even when the citation seeks to distinguish or overrule the previous case. The citation is motivated by the authority of the previous case, which may have to be deflected or destroyed in order to enable the desired outcome of the current case. But many judicial decisions have an informational rather than an authority-related role; they are cited as shorthand for legal doctrines, cogent arguments, or forceful articulations of relevant ideas or policies. Few judicial citations are "priority" citations, however, because there is no antiplagiarism norm in adjudication. In this respect the situation in law resembles that in literature before creativity became defined as originality (Posner, 1998, pp. 389–405).

A final reason for citing, call it the "celebratory," is midway between informational citing and authority citing. The feature of the cited work

that induces the citation is the work's prestige or reputation.⁴ By associating it with his own work, the citer enhances the credibility of his work. Because this is a common reason for citing, there is added uncertainty about the meaning to be ascribed to a citation. It can signify an acknowledgement of priority or influence, a useful source of information, a focus of disagreement, an acknowledgment of controlling authority, or the prestige of the cited work or its author. All of these are forms of influence, in a broad sense, and that may be enough to justify lumping them together for purposes of citations studies concerned with measuring influence. But they differ as proxies for quality, and measuring quality is the focus of some citations studies.

This problem, the interpretive problem presented by citation behavior, is related to another problem, the problem of responsible citation behavior, which arises from the distinction between a reason for citing and a motive for citing.⁵ Many self-citations, for example, are motivated by a desire for self-aggrandizement, or by sheer laziness—the cost of finding one's own work to cite is less than the cost of finding someone else's. Not all are, though. Indeed, self- and other citations to a person's work might well turn out to be positively correlated at least for heavily cited authors, because the previous work of a productive and influential scholar may be a large part of the knowledge base of his current work. In the case of judicial citations, the Landes study, discussed later, finds a positive correlation between self- and other citations and explains that a judge who writes his own opinions is more likely both to be an influential judge and to cite himself a lot, because he is more familiar with his previous decisions than his law clerks would be if they were writing his opinions.

Resuming the catalog of "impure" motives for citing, I point out that some citations reflect a desire to flatter the author of the cited work, who may be in a position to assist the citer's career or may be a likely journal referee of the cited work. And some scholarly citations are motivated by piety or gratitude, or by a desire to make a display of erudition. I have mentioned the possibility of reciprocal citing. It is even conceivable that in highly competitive fields of scholarship, young scholars especially might be reluctant to cite their peers, and prefer to cite the dead, who are no

4. There is an analogy to celebrity endorsements of products. See Agrawal and Kamakura (1995).

5. For a rare study of the motives for citing, see Wang and White (1995).

longer competitors. Most important, because the cost of inaccurate citing usually is low (primarily the cost is being subjected to criticism for miscitation or for failing to find the most apt work to cite), there is much careless citing, and so quantitative studies of citations are bound to contain a lot of "noise." But imperfection of data is nothing new—nor, as we shall see, does it disable useful statistical analysis—and there is some competitive constraint on irresponsible citing because rival scholars have an incentive to expose such practices, unless the irresponsibility merely takes the form of citing to excess.

The Heterogeneity Problem

Even if all citers were scrupulous and accurate, the heterogeneity of citations would make simple aggregation prone to mislead, even after such obvious sources of distortion as self-citations were removed. Suppose, for example, that an academic department relied on the number of citations to an academic's scholarly writing as a factor in deciding whether to give him tenure. Suppose further that the principal criterion for tenure was originality. The writings of the individual under consideration might have garnered a great many citations, but if they were mostly informational in character—perhaps he had written a series of review articles that provided convenient summaries of previous work—the count of his citations would give a misleading impression of whether he deserved tenure.

This is a greater source of distortion than the possibility that many of the citations to the individual's work are negative. Negligible work is more likely to be ignored than to be cited. A negative citation often indicates that a work has gotten under the skin of the critic, perhaps because it mounts a powerful challenge to established positions or ways of thinking.

The signal, or information, conveyed by a citation, or by a count of citations, varies for still other reasons as well. A newspaper citation to a scholar's work is a better indication of the popular appeal of his work than is a citation in a scholarly journal to that work, but the latter is a better indication of the work's scholarly character. A citation made by a distinguished scholar or appearing in a high-quality journal is better evidence of the quality of the cited work than a citation by an undistinguished scholar or in an undistinguished journal. A citation by the same or a lower court,

for which the cited case is authoritative, is a weaker signal of respect or regard for the cited case or its author than a citation by a higher or coequal court, which is not required as a matter of *stare decisis* to follow, distinguish, or otherwise refer to the cited case.

The number of citations to a scholarly work or a judicial opinion may, moreover, reflect adventitious factors, in particular the size of the population of potential citers and the citation conventions of particular disciplines. “The erudite scholar (rightly or wrongly associated with an older Germanic tradition) who displays his learning in his footnotes is hardly recording the strong intellectual influences which have acted upon him. The ostensibly casual scholar (surely trained at Oxbridge) considers citation beyond a name, preferably misspelled, to be a pedantical display” (Stigler and Friedland, 1975, p. 485). Comparisons across fields and, because of growth in the number of journals, over time are therefore difficult to make. Even within a single field differences in specialization can confound citation comparisons; other things being equal, more specialized, applied work is cited less often than more general work (such as a survey article or a theoretical article)—the potential audience is smaller for the former than for the latter. Similarly, theoretical journals tend to be more frequently cited than applied journals, and in particular the “balance of trade”—citations of a journal versus citations by the journal—runs in favor of theoretical and against applied journals (Stigler, 1994). Also, methodological articles, and judicial opinions dealing with procedural issues, tend to be cited more frequently than substantive works because they have a broader domain of applicability.

Differences in the vintages of cited works also make comparison difficult. The older the work, the more time it has had to accumulate citations, but the number of citations is apt to be depressed by shifts in interest away from the topic of the cited work or by the appearance of up-to-date substitutes for it. In economic terms, the stock of knowledge capital created by scholarly or judicial activity, just like a stock of physical capital, both is durable and depreciates. A further problem in interpreting the number of citations to a work is that it may be difficult to distinguish empirically between a work that is no longer cited because it has been totally depreciated and a work that has been so influential that the ideas in it are now referred to without citation to the work and often without mention of the author’s name (e.g., the theory of relativity, or the theory of evolution,

or the concept of consumer surplus). “An innovator’s work is accepted and used by others. The influence may be most powerful when we simply do not cite at all” (Stigler and Friedland, 1975, p. 486). For example, counting citations to the writings of Adam Smith or Jeremy Bentham would be certain to produce an underestimation of their influence—and in Bentham’s case for the additional reason that he published little during his lifetime and much of his influence was through personal contact with people who became his followers and transmitted his influence through their own writings.⁶

A point closely related to the last is that differences in citation rates may be magnified because of the information costs of citers, which may fall with the number of times a work is cited (cf. Adler, 1985). The more often the work is cited, the more familiar it becomes, reducing the cost of recalling and locating the work relative to the cost of recalling and locating a less cited and hence less familiar work. This is a kind of network externality, akin to that which makes telephone service more valuable the more subscribers it has or a new word more valuable the more people know its meaning.

Another way to see this is to think of the citer as a shopper among competing “brands.” Because no citation royalty is paid to the author of the cited work, the more familiar the brand the cheaper it is to cite it rather than to cite a substitute. John Rawls is thus the standard citation for the concepts of the original position and the veil of ignorance, even though those concepts were explained earlier by John Harsanyi;⁷ Harsanyi is less well known than Rawls and so it is “costlier” to cite him. The cost of citing the better-known work is lower not only to the citer, but also to his audience, to which a citation to a familiar work may convey more information. A raw comparison of the number of citations to Rawls and to Harsanyi would thus exaggerate the relative quality, originality, or even influence of the two theorists.

For all the reasons that I have been discussing in this and the preceding section, and for other reasons as well,⁸ the use of counts of citations

6. The problems of using citations analysis to gauge intellectual influence are well discussed in Zuckerman (1987).

7. As acknowledged, somewhat grudgingly as it seems to me, in Rawls (1971, p. 137, n. 11), citing Harsanyi (1953, p. 434).

8. Chapman (1989, pp. 336, 339–41) lists 25 problems with using citation data published by the ISI (see note 3 above) to estimate the quality or impact of research.

for purposes of evaluation or hypothesis-testing must be approached with caution. But it is equally important to realize that the existence of “noise” in data does not invalidate quantitative analysis. Critics of citations analysis often fail to note that if errors in data are randomly distributed with respect to the variable of interest (such as research quality or impact), they are unlikely to invalidate the conclusions of the study, provided that the data sample is large (Stigler, 1987). A related point is that errors that equally bias both sets of data being compared do not bias the comparison (*id.*, p. 333), and so if, for example, the question is whether a particular scholar or journal was more heavily cited in 1999 than in 1989, many of the errors that might distort the number in each year can be ignored as not affecting the comparison. But, equally clearly, responsible citations analysis requires great care in methods of aggregation, correction, and interpretation. I shall give illustrations of the necessary adjustments in the course of explaining the two main uses of citations analysis that have emerged to date—as a tool of management and as a means of hypothesis testing.⁹

I have discussed the principal ones in the text, but it may be useful to list all 25 to give the flavor of the critical literature. In Chapman's words, “Some journals not considered”; “Exclusion of citations in books”; “Bias toward applied research”; “Psychology is in [both] the SCI [Science Citation Index] and SSCI [Social Sciences Citation Index]”; “Referencing [i.e., citing] conventions”; “Inclusion of letters, abstracts, book reviews”; “Prestige of publication outlets”; “One ‘citation’ even if there is repeated reference to the work”; “First-authors only [i.e., only the name of the first-listed author to a coauthored work is indexed]”; “Cross-disciplinary comparisons; and psychology's multi-dimensionality”; “Comparisons of individuals; and ‘straight’ versus ‘complete’ counts”; “Social factors influence choice”; “‘Stars’ are overwhelming”; “Name-initial homographs”; “Bias against some married women [if they have published under more than one name]”; “Bias against newcomers”; “Few to cite in a narrow specialty; and self-citations”; “One person—several alphabetical entries”; “Human errors at ISI”; “Obliteration by incorporation”; “Methods/recipe papers—spuriously inflated citations?”; “Citation does not necessarily denote approval”; “Citation without knowledge”; “Quantity is not quality”; “Citations reflect existing recognition.” See also Cronin (1984, pp. 63–73), and MacRoberts and MacRoberts (1986). Chapman (1989, p. 342) acknowledges that some of the criticism of citations analysis may be due to sour grapes on the part of scholars who discover that they are not heavily cited.

9. I do not, however, discuss efforts to develop objective measures of citation content analysis. See, for example, Swales (1986).

Citations Analysis as a Management Tool

When an enterprise produces goods that are sold in an explicit market, the valuation of its output is straightforward, and generally it is also feasible to determine the contribution of the enterprise's employees and other suppliers to that output. But not all enterprises are of this kind. Two notable exceptions are research universities and appellate courts. A principal output of both types of enterprise is published work that is not sold. This has been thought in some quarters to preclude analyzing the outputs of these institutions in market terms (O'Neill, 1998, pp. 155–57). An economist would be inclined to question this conclusion. Academics and judges, economists are prone to believe, are not much different in basic tastes and drives from other people, and universities and courts are subject to budget constraints that require economizing activity. Academic and judicial productivity is much discussed, and comparisons (across academics, academic departments, courts, judges) are attempted. The problem is one of measurement rather than of fundamental incentives and constraints. If that problem can be solved, the market for professors and judges can be assimilated to normal labor markets. Citations analysis can make a significant contribution to the solution, and this is important for operating in these markets as well as for understanding their operation.

For example, the federal government has for the last 15 years been encouraging its research laboratories to focus more on research having commercial applications. Has the change in policy been effective? A study of government patents found that government research is indeed being cited more frequently in private patents (Jaffe, Fogarty, and Banks, 1998). The Patent Office has strict requirements about citing the "prior art," as it is called, and this provides a basis for believing that counting citations in patents provides meaningful, though not wholly reliable, information about the utility of the cited inventions.¹⁰ The application of this methodology to the evaluation of research programs, academic or otherwise, is straightforward (Brown, 1996; Nederhof and Van Wijk, 1999; Oppenheim, 1997).

10. The authors tried to verify the accuracy of the citations, and found that 75% were meaningful, the rest essentially noise (Jaffe, Fogarty, and Banks, 1998, p. 202). Baird and Oppenheim (1994, p. 7) estimate that at least 20% of citations are erroneous.

In my own work on judicial administration, I have suggested that weighting the number of decisions of a federal court of appeals by the number of citations to those decisions by other courts of appeals, which is to say courts not bound as a matter of *stare decisis* to follow the cited court's decisions, yields a meaningful measure of judicial output. This measure can be used to compare the productivity of the different courts (Gulati and McCauliff, 1998, pp. 198–200; Posner, 1996a, p. 234). It cannot be the complete measure, if only because it implicitly weights unpublished decisions, which are not citable as precedents, at zero, even though they are an important part of the output of modern appellate courts. An unpublished decision resolves a dispute, which is a useful thing to do even though it does not create a citable precedent. Some adjustment should be feasible, however, to yield a total productivity figure. And when productivity is regressed on the different production functions of the different courts, it becomes possible to suggest improvements, as I'll note later.

An even more audacious use of citations as a judicial management tool is to "grade" appellate judges by the number of other-court citations to their opinions. Landes, Lessig, and Solimine, in an ambitious study that I'll call "the Landes study" for the sake of brevity, rank federal appellate judges in just this way (Landes, Lessig, and Solimine, 1998).¹¹ There are comparability problems: the judges are appointed at different times and to courts that have different caseloads, and the number of judges as well as the number of cases is changing over time. The authors seek to overcome these problems by regressing other-court citations on variables that include—besides the judge himself—the judge's length of service, his court's caseload, the date on which he was appointed, and other factors that are expected to influence the number of citations that the judge would receive were he of average quality. The coefficient on the judge variable thus indicates how many other-court citations are due to his personal characteristics rather than to the factors that are not judge-specific which influence citations. Since those factors cannot be controlled for perfectly, the ranking that the Landes study produced is at best a rough guide to the relative quality (or influence, or reputation—it is not altogether clear which is being measured) of the judges in the sample. Still, it may well

11. This is not the only focus of their study; I discuss other aspects of it later. For a somewhat similar study, but of Supreme Court Justices, see Kosma (1998).

be an improvement over purely qualitative efforts to evaluate appellate judges.

Entire courts can be evaluated similarly. In view of current criticisms that the U.S. Court of Appeals for the Ninth Circuit is weak, perhaps because of its large size (it is almost twice as large as the next largest federal court of appeals), and should be split up or otherwise revamped or reformed, it is natural to inquire how that court fares when this method of evaluation is used. The answer is, not very well. It ranks eleventh out of the 13 federal courts of appeals and the low ranking of the Federal Circuit (which is number 13) is probably due to that court's highly specialized jurisdiction. Among the generalist circuits, the Ninth ranks eleventh out of 12 (the twelfth being the Sixth Circuit). Even the D.C. Circuit, which is also specialized, though less so than the Federal Circuit, outranks the Ninth Circuit (at 10).¹²

Citations analysis is more commonly used to rank scholars than judges (Gordon and Purvis, 1991; Medoff, 1989; Shapiro, 2000; Sen, 1998) and as such is now widely used as a management tool in connection with the hiring and promotion of faculty in research universities (Gray, 1983). This is a natural use of citations analysis because the principal output of the faculty of such universities is published research and the more heavily a research paper is cited, the more influential and important it is likely to be. Again, comparability problems must be overcome; it would be ridiculous to count citations of rival candidates of very different length of service and think that one had made a meaningful comparison, unless perhaps the younger (not necessarily in age, but in length of time in academia) had more citations than the older. But adjustments similar to those made in the Landes study in order to compare the output of different judges should be feasible, and with these adjustments citations analysis becomes a reasonably objective (though it should not be the only) basis for making decisions on hiring, promotion, and salary. The need for an objective basis for such decisions is particularly important in an era in which academic

12. Landes, Lessig, and Solimine (1998, p. 318 [Table 5], p. 277 [Table 1], p. 332). Using a somewhat different sample, however, the Landes study shows the Ninth Circuit receiving an average number of other-court citations (Landes, Lessig, and Solimine, 1998, p. 331 [Table A4]). Other quantitative measures of judicial performance support a negative evaluation of the Ninth Circuit. See Posner (2000).

administrators can be forced to defend their personnel decisions in the courts against charges of racial, sexual, or other invidious discrimination.

Citations analysis can similarly be used to evaluate the scholarly impact (presumably correlated with the quality) of scholarly journals and academic presses. This has been in fact one of the most common applications of such analysis (Hodgson and Rothman, 1999; Leibowitz and Palmer, 1984; Tahai and Kelly, 1996). A journal's "impact factor" (conventionally, the number of citations in year t to articles published in the journal in years $t - 1$ and $t - 2$ divided by the number of those articles) can in turn be used to weight a scholar's citations by multiplying the number of citations to his work by the impact factor of the journals in which those citations appear.¹³ The aim is to correct objectively for differences in journal, and hence citation, quality. The method only seems to involve double counting. Citations are used to weight the journal, and if it is heavily cited this might seem to imply that articles cited in it will be cited by later journals as well. But that is not necessarily so. Suppose an article by A is cited in an article by B published in heavily cited (hence imputed to be high-quality) journal X . B 's article can be expected to be cited more frequently than if it had been published in a lower-quality journal, but articles citing B 's article will not necessarily cite articles cited by B , such as A 's article. Nevertheless the fact that B cited A is, given that B 's article appeared in a high-quality journal, a mark in A 's favor.

The impact-factor measure has been criticized as "entirely miss[ing] the archival impact of the journals and giv[ing] much greater weight to those publications of a more ephemeral nature or to those publications more concerned with debates about current issues than with research" (Stigler, 1994, p. 98).¹⁴ So impact-adjusted citations must themselves be adjusted, but with this qualification, they can be used to rank both individual scholars and entire departments more objectively than by raw citation scores (Dusansky and Vernon, 1998, p. 157; Fish, 1998, p. 1077).

The practical utility of citations ranking of scholars is not limited to academic administration. As I have already intimated, in cases in which academics claim to have been discriminated against by the university that employs them, citations analysis can be used to help determine whether

13. See, for a critical discussion of this procedure, Anonymous (1998).

14. For a striking example, see Perdew and Tipler (1996, pp. 15, 97).

the alleged discrimination was invidious or was instead based on the plaintiff's lack of scholarly distinction.¹⁵

Hypothesis Testing with Citations

The use of citations analysis in academic research is conceptually distinct from its use in academic or judicial administration but overlaps as a matter of practice. The patent study I cited earlier can be used to evaluate the government's research policy but also to test hypotheses about the economics of technology transfer (Jaffe, Fogarty, and Banks, 1998, pp. 202–3; Jaffe, Trajtenberg, and Henderson, 1993). We have seen that studies of judicial citation practices can be used both to evaluate courts and judges and to test hypotheses about judicial behavior and explain differences in productivity across courts and judges. They can be used to identify and trace academic networks and to chart the rise and decline of rival schools of thought within a discipline (Landes and Posner, 1993).

There are three closely related economic models that can be used to guide research that employs citations analysis: a human capital model, a reputation model, and an information model. All are closely related to the discussion in the first section of this paper of the motives for citation. The motives are assumed to be self-interested, and economic models tease out the implications of assuming rational self-interested action.

I will emphasize the human capital model, which is the most important for reasons that will become clear, and discuss the other two very briefly. In a reputation model (Posner, 1990), emphasis is laid on the fact that reputation is something accorded by the "reputers" to advance their own self-interest, for example their interest in economizing on information costs. This can produce, as I hinted earlier, a "superstar" effect, in which small differences in quality generate huge differences in income, or, in this case, in citations (cf. Rosen, 1981). The sociologist Robert K. Merton argued in this vein that scholars would use an author's reputation as a screening device, and hence tend to cite better-known authors

15. Cases in which citations analysis has been used for this purpose include *Tagatz v. Marquette University*, 861 F.2d 1040, 1042 (7th Cir., 1988); *Weinstein v. University of Illinois*, 811 F.2d 1091, 1093 (7th Cir., 1987); *Demuren v. Old Dominion University*, 33 F. Supp. 2d 469, 481 (E.D. Va., 1999), and *Fisher v. Vassar College*, 852 F. Supp. 1193, 1199–2001 (S.D.N.Y., 1992), overruled on other grounds, 70 F.3d 1420 (2d Cir., 1995), modified, 114 F.3d 1332 (2d Cir., 1997) (en banc).

more frequently than was warranted by any actual difference between the quality of their work and that of less well-known authors (Merton, 1968). He called this phenomenon the "Matthew Effect" after the statement in the Gospel according to St. Matthew that to he who has more will be given. Merton's conjecture is supported by a study which finds that journals that use "blind" refereeing (that is, that do not disclose the author's name to the referee) are cited more frequently, after correction for other differences, than nonblind-refereed journals (Laband, 1994).

In a recent paper that compares Web "hits" and newspaper citations to leading legal scholars with citations to these scholars in scholarly journals, Landes and I found a greater superstar effect for celebrities than for scholars (Landes and Posner, 2000). We conjectured that this is a function of the extent of the market. The general public's interest in law is quite limited, and the public demand for the output of legal scholars is therefore easily satisfied by a handful of high-profile figures. The scholarly community has a much broader interest in legal scholarship and therefore values the output of a much larger number of scholars.

In the information model, citations are conceived of as creating a stock of information. The analyst can use the model to illuminate such issues as the geographic diffusion of information, as in the patent study that I cited earlier, and the rate at which the stock depreciates, for example as a function of the generality, and hence adaptability to changing circumstances, of the cited work. A related approach, sociological rather than economic in character, seeks to demarcate schools of thought by identifying patterns of cross-citation (Stigler and Friedland, 1975).

In the standard human capital model used in labor economics, earnings are modeled as a function of the investment in the worker's human capital (that is, his earning capacity). His stock of human capital grows in the initial stages of his working career as a result of on-the-job training and experience. But like other capital, human capital depreciates, and eventually the worker's total stock of human capital declines when new investment falls below the replacement level as the worker approaches retirement. The reason new investment falls eventually is that the shorter the worker's remaining working life, the less time he and his employer have to recover the cost of any new investment.

Earnings (E) and years worked (time, t) are thus related as in

$$E(t) = a + b_1 t_1 - b_2 t_2 \quad (1)$$

where $E(t)$ is annual earnings as a function of time (years worked from first job to retirement), a is an earnings component that is independent of investment in human capital and is assumed to be constant over time, b_1 represents an annual increase in earnings brought about by investments in human capital, and $-b_2$ represents an annual reduction in earnings caused by depreciation of the individual's stock of human capital. The peak year of earnings (t^*) is found by differentiating $E(t)$ with respect to t and setting the result equal to zero (satisfaction of the other conditions for a maximum can be assumed), yielding $t^* = b_1/b_2$. An individual reaches his peak year of earnings later the more his earnings are raised by investments in human capital (b_1) and the smaller the effect of length of service (hence imminence of retirement) in reducing his earnings by causing him to invest less in replacing human capital as it depreciates (b_2). If $E(t)$ is replaced by the natural log of $E(t)$, then the coefficients (b_1 and b_2) can be interpreted as rates of growth.

The twist that human capital citations analysis gives to the standard model is to replace earnings with citations. This is an appropriate adjustment in the case of activities in which earnings are not well correlated with output. The federal judiciary provides an excellent example. All judges of the same rank (district judges, circuit judges, and so forth) are paid the same salary, regardless of years of service, reversal rate, number of opinions published, or any other factor that might be used by a private employer to determine a worker's marginal product.

In many universities, too, faculty compensation is on a lockstep basis, and even when it is not, salary differentials are invariably far smaller than any reasonable estimate of differences in the academic output of different members of the faculty.¹⁶ A possible explanation is that an academic's full income includes fame (Stephan, 1996) and so varies across academics in accordance with differences in the quality of their work.¹⁷ This point

16. Nevertheless, there is evidence that number of citations to an academic's work is a significant predictor of his salary. See, for example, Sauer (1988) and Diamond (1986). This is presumably because scholarly fame is positively correlated with the value of the scholar's output.

17. Empirical evidence for this conjecture in the case of economists is presented in Levy (1988).

has been made in distinguishing between science and technology. “**Science** aims at increasing the stock of knowledge, while the goal of **technology** is to obtain the private rents that can be earned from this **knowledge**” (Dasgupta and David, 1987, p. 529). Because the achievement of the scientist’s goal depends on complete disclosure, and complete disclosure impedes the obtaining of rents, science must devise an alternative method of compensation. “The rule of priority is a particular form of payment to scientists” (id., p. 531). This can help us understand why the acknowledgment of priority is a norm of scholarship. And the usual form of acknowledgement of priority is citation. However, citations acknowledge other forms of scholarly contribution as well.

The economic model of citations as an earnings substitute recognizes that variance in earnings is not a function just of length of service and investments in human capital. The variable that I labeled a represents the other factors that influence output, including quality variables such as intelligence, judgment, and writing skill that are only loosely (and sometimes not at all) related to training or other forms of investment in human capital. Recall that in the Landes study the human capital model was used to predict differences in the output of court of appeals judges, and the residual (unexplained) differences were then used to rank the judges, that is, to determine their relative endowments of a .

An alternative method of getting at a is to limit the comparison of citations to judges serving on the same court in the same period of time, thus obviating the need to make adjustments for differences in caseload composition and in the dates of the cited works, or to scholars of the same approximate age or length of service. I have used this cruder method of adjustment to verify the superior quality or influence of Benjamin Cardozo and Learned Hand relative to their colleagues on the New York Court of Appeals and U.S. Supreme Court (for Cardozo) and the U.S. Court of Appeals for the Second Circuit (for Hand) (Posner, 1990, pp. 83–90; 1995, pp. 188–92; see also Greely, 1996, pp. 133–50). For broader comparisons, however, the human capital model is indispensable, as it enables correction for differences in the location of a judge or scholar in the life cycle.

We need not view a as a black box; the Landes study sought to explain the rankings of federal court of appeals judges by such factors as self-citation, the degree to which the judge’s court has a specialized jurisdiction (which would tend to reduce the number of citations by other

courts), and whether the judge had attended an elite law school, received a good rating from the American Bar Association when he was evaluated for appointment, or had previous judicial experience (Landes, Lessig, and Solimine, 1998, pp. 320–24). All the factors but the last were found to have a statistically significant relation to the judge's rank, and in the predicted direction.

The study did not find any effect of race or sex on the number of judicial citations. In contrast, a recent study of citations in scholarly journals to legal academics finds that being female or a member of a minority is associated with being cited less frequently after correction for other factors, such as field and length of service. The implication is that affirmative action, which is common in law schools' faculty hiring, leads, as opponents contend, to the hiring of less-qualified minority and female candidates, as measured by their scholarly output once hired. Indeed, the author finds significant discrimination against Jewish males, who other things being equal are cited much more frequently than other legal academics (Merritt, 2000).¹⁸ Of course, the Jewish males might just be better than the other groups. The acid test for discrimination would be to compare the number of citations to marginal Jewish males to the number of citations to the marginal members of other groups; if the first number were higher, implying that the hiring of more Jews would raise the total number of citations to the faculty, this would be evidence of discrimination.

Another recent study of the legal academy finds a negative relation between research output as measured by citations and hiring one's own graduates as distinct from hiring graduates of other law schools (Eisenberg and Wells, 2000). Still another recent study contributes to our knowledge of the legal-academic production function by finding (though on the basis of a very small sample) that scholarship and teaching are net complements rather than substitutes in the production of scholarship (Lindgren and Nagelberg, 2000). My study of the citations output of the federal courts of appeals (Posner, 1996a, pp. 234–36) similarly casts light on the production function of appellate courts, showing for example that the greater the number and length of a court's majority opinions, and the fewer the number of footnotes and of dissenting opinions, the greater

18. That is not, however, Merritt's interpretation of her data. A different study (Kolpin and Singell, 1996), also employing citations as a proxy for quality, finds discrimination against women by economics departments.

will be the number of citations to that court by other courts. Footnotes in judicial opinions tend to confuse the reader, and a dissenting opinion undermines the majority opinion not only by indicating a lack of unanimity but also by expressing criticisms of the outcome that the majority would have preferred to pass over in silence.

The study also found that citation-weighted output fell as the number of judges on the court rose, which is consistent with the evidence mentioned earlier regarding the Ninth Circuit. Further light is cast on this issue by regressing the other-court citations data in the Landes study on the number of judgeships per circuit. The result is a negative correlation that barely misses statistical significance at the conventional 5% level. (The *t* statistic is -2.091 , and the r^2 is .33.) This is additional evidence that increasing the number of judges of an appellate court reduces the quality of the court's decisions.

The Landes study was limited to judges of the same court system (allowing for some differences in specialization), and my studies have been limited to judges of the same court or to courts of the same system (the federal courts of appeals, again). When citations to heterogeneous courts are aggregated, citation totals may still be meaningful as measures of influence, but they cease to be meaningful as measures of quality. The same is true of studies of scholarly citations. Comparing total scholarly citations across all legal scholars (Shapiro, 2000) may be a valid measure of influence, but it cannot be a valid measure of quality, since differences in citations across fields may reflect differences in the size of fields and in the number of journals in different fields, and even citation conventions, rather than differences in perceived quality. But aggregating scholarly citations by field over time is a valid method of charting the rise and fall of different fields, for example (in law) economic analysis, feminist jurisprudence, and doctrinal analysis.¹⁹ For that matter, comparison of citations

19. In Landes and Posner (1993, p. 424), we concluded that

the influence of economics on law was growing at least through the 1980s (it is too early [in 1993] to speak about the 1990s), though the rate of growth may have slowed beginning in the mid-1980s; that the growth in the influence of economics on law exceeded that of any other interdisciplinary or untraditional approach to law; and that the traditional approach [of legal scholarship]—what we call “doctrinal analysis”—was in decline over this period relative to interdisciplinary approaches in general and the economic approach in particular.

across fields is meaningful if what one is interested in is the relative size of different fields; the amount of citation activity is one measure of the amount of research in or knowledge produced by a field.

Treating a body of judicial opinions as a capital stock invites attention to the depreciation of precedent, a topic that Landes and I addressed in the first economic study of legal citations (Landes and Posner, 1976). The analogy to physical capital is here quite close. A specialized machine can be expected to obsolesce more quickly than one that can be adapted to different tasks, since the former is less adaptable to change. Similarly, the more general a precedent is, the less rapidly it is likely to depreciate. And just as a sturdy machine can be expected to depreciate less rapidly (other things being equal) than a fragile one, so the more authoritative the court (for example, the Supreme Court relative to a lower federal court), the more slowly the precedents it produces are likely to depreciate, as our study indeed found. We can also expect the depreciation rate to be higher, the greater the rate of legal change—and so I found in a comparison of English and American cases (Posner, 1996b). And a big change in law, such as the abolition of the general federal common law by the *Erie* decision,²⁰ can have a dramatic effect in obsoleting precedent (Landes and Posner, 1980).

The age profile of citations is relevant to the study of scholarship, including legal scholarship, as well as judicial behavior. Other things being equal, the half-life (or other measure of decay) of citations to scholarly work and scholarly journals is shorter the more progressive the discipline (or subdiscipline, such as economic analysis of law, critical legal studies, or feminist jurisprudence) in the sense that it is continuously generating new research that yields findings that supersede earlier findings. But citation half-life is longer the more rapidly the number and size of the discipline's publication outlets are growing. The reason for the latter, less obvious effect is that a rapid expansion of outlets creates more opportunities for older articles to be cited, assuming there is some citation lag (in part because of the Matthew Effect—the new journal is not as heavily cited as the old until it accrues a reputation) so that the articles in the new outlets will not be cited immediately (Abt, 1998).

20. *Erie R.R. v. Tompkins*, 304 U.S. 64 (1938).

The net depreciation of human capital is a function not only of the depreciation rate but also of the rate of new investment. That rate falls off not only because the expected return is truncated by retirement but also because of the aging process. Judging is a famously geriatric profession, especially in the common law countries, such as England and the United States. In part this is an artifact of the lateral-entry method of filling judgeships in these countries: the older the average age of entry, the older the average age of the profession is bound to be. But another possibility is that in a judicial system which relies heavily on precedent—a backward-looking mode of decision making—aging will take a lesser toll on ability than in a profession such as mathematics that emphasizes the manipulation of abstract models.²¹ This hypothesis can be tested by relating citations to the age of the judge whose decision is being cited; I have done this and found little evidence of a negative aging effect before the age of 80 (Posner, 1995, pp. 182–96).

Conclusion

To summarize, citations analysis guided by economic theory offers substantial promise of improving our knowledge of the legal system, in particular its academic and judicial subsystems. Much has been done already, as I have tried to show; much remains to be done, if I am correct that citations analysis is a versatile, rigorous, practical—and, increasingly, an inexpensive—tool of empirical research.

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21. Psychologists distinguish between "fluid intelligence," the ability to manipulate abstract symbols, and "crystallized intelligence," the ability to work from a long-established knowledge base, such as knowledge of one's language.

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