

## A REVEALED PREFERENCE STUDY OF MANAGEMENT JOURNALS' DIRECT INFLUENCES

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*Our study develops and uses a new methodology for analyzing journal citations to recent publications to determine which management journals now have the greatest influence on the field of management. It analyzes the 23 637 academic journal references cited in the 1275 articles published in 17 key management journals during 1993 and 1994, focusing on citations to references published up to the modal vintage of 4 years earlier. Most cited as a percentage of all these references was Strategic Management Journal (11%), followed by Academy of Management Journal, Journal of Applied Psychology, Organizational Behavior and Human Decision Processes, Academy of Management Review, Administrative Sciences Quarterly, and Journal of Management—accounting in total for 51 percent of all citations. Strategic Management Journal, whose subfield of strategic management has become a major concern of management in general, has developed as the predominant academic journal influencing the field of management. Our measures of journal influence provide information which can aid management scholars, practitioners, department heads, and university libraries to decide on efficient choices of journals for research and for manuscript submissions, for evaluation, and for subscriptions. Just seven management and social science journals, led by Strategic Management Journal, contain more than half of the cited articles published recently. Copyright © 1999 John Wiley & Sons, Ltd.*

### INTRODUCTION

While management as a field of study has its roots in applied psychology, sociology, and economics, it has developed, and continues to develop, a corpus of theory of its own. The intention of this paper is to present a novel methodology for identifying measures and venues of the evolving field of management.<sup>1</sup> We employ

a citation-based analysis because citations provide a relatively objective measure of one of the primary direct influences on a scholar's research.<sup>2</sup> A distinct advantage of our study is its breadth. Our data set is the 1275 articles published in 17 source journals over a 2-year period, which contained 45,000 citations to the work of predecessors upon which current research is based.

The results of our study provide some insight into adaptation of the field of management to changes in the business environment, and particularly into the growing importance of strategic

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<sup>1</sup> The common publication policy of the source journals used in this study is to publish manuscripts that provide at least a marginal contribution to the existing body of literature. It can be inferred, then, that the body of literature is continually evolving and developing. Therefore, we believe that all pub-

lished articles contribute to the development of management theory.

<sup>2</sup> There are a number of possible direct influences on a scholar's research, including colleagues, former professors, life experiences, etc. However, citing a given article provides a public acknowledgement of an influence whereas the other possible influences cannot be objectively verified.

management. A recent phenomenon in management has been the development of a new form of strategic planning involving not just top management but all levels and areas within firms (Byrne, 1996). This new strategic focus transcends academic fields, incorporating developments in organizational behavior, strategy, human resources management, and other management subfields. The impetus behind this trend in management theory and practice has been a need for strategy flexibility in light of an increasingly complex and competitive business environment. Companies need to determine their competitive advantages more quickly and to orient the structure of the entire company to exploit these advantages, and thus need to broaden involvement in the development and implementation of corporate strategies. One of the core competencies of the field of strategic management is its inclusion of a large number of studies that are cross-functional, cross-level, and cross-theoretical (Meyer, 1991). It is not surprising, then, that the journal explicitly concerned with all aspects of strategic management (i.e., strategic resource allocation, organizational structure, entrepreneurship and organizational purpose, leadership, strategic decision processes, etc.) was the most cited journal in our study, using our methodology to limit the citations examined to those of modal vintage or more recent.

Our paper begins with a discussion of the importance of performing studies examining the relative impact of various journals within an academic field. Such studies aid individual academics, academic departments, university libraries, and the journals themselves. Particularly salient in today's environment of shrinking university library budgets, such studies provide a meaningful input into the journal subscription process. The study then describes the difference between stated preference (survey designs) and revealed preference studies, noting that the two are complementary. In general, stated preference studies tend to have a long memory, in that opinions of research outlets tend to be built up over time and such perceptions tend to change relatively slowly. Revealed preference studies tend to provide a more adaptive measure of a journal's impact in that such studies examine the relative amount that a journal is actually used (cited) in the literature. Next, the forms of citation analysis are presented, along with a discussion of the advantages and disadvantages of the different forms.

Our methodology then is presented in general terms and supplemented by a more specific statistical presentation in the Appendix. Finally, a description of our data and the results of our tests are presented.

## MOTIVATION FOR EVALUATING RELATIVE JOURNAL INFLUENCE

Studies investigating journal rankings are undertaken for a variety of reasons. The preponderance of such studies infers that there is value to the academic community for periodically examining the status of academic journals. Individuals, academic departments, university libraries, and the journals themselves derive some benefit from such studies.

Weinstock and Coe (1969), MacMillan and Stern (1987), MacMillan (1991), Gordon and Purvis (1991), and Park and Gordon (1996) intimate the value of journal rankings for evaluating an individual's publication record for tenure and promotion decisions. However, researchers are motivated not only by career issues such as tenure and promotion, but also with finding research outlets which subject their ideas and life's work to peer scrutiny with the goal of having their work evaluated, extended, and supported (or refuted) with the possibility of having a real impact on the world that surrounds them. It can be inferred that those journals most often cited contain the ideas which are most closely scrutinized, evaluated, and extended.

Moore and Taylor (1980), Howard, *et al.*, (1985), Stahl, Leap, and Wei (1988) and Armstrong and Sperry (1994) provide rankings of academic institutions based on their management faculty's ability to publish in top rated journals. The validity of such rankings is based upon the selection of the top rated journals. Therefore, the process by which journals are evaluated should be objective and should incorporate recent changes in a journal's impact on the academic field.

Almost all universities in the United States are examining their journal collections due to budgetary pressures (He and Pao, 1986). For example, Dickinson (1995) notes that the University of North Carolina eliminated 2000 journal subscriptions since the late 1980s and would have

eliminated an additional 2000 subscriptions if additional funding were not found. As Brown suggests, the cancellation of scholarly journal subscriptions relates to the fact that 'subscription costs have increased 2000% or more since 1970, while the consumer-price index was increasing 276% (1994: 5).' Given these budgetary problems, university libraries need to make informed decisions regarding their journal collection. Because departments at the universities are asked to provide input into the subscription decisions, it is important for each department to have access to an updated rating of their related journals.

The academic journals, sponsoring organizations, and journal editors compete in a shrinking market for journal subscriptions. Beyond economic survival (and as a means to ensure it), the journals desire to make an impact by publishing articles which extend and expand knowledge of a given subject matter. Ranking journals, especially when based on usage, provides an objective means for self-evaluation.

## STATED PREFERENCE VS. REVEALED PREFERENCE

The means by which journals are evaluated can be divided into two basic categories: stated preference studies and revealed preference studies. Stated preference studies take the form of surveying members of an academic field. Revealed preference studies rely upon citation analysis—an examination of the articles cited in a group of source journals or articles. Both methodologies have advantages and disadvantages.

Rationales for using a stated preference study to evaluate publication outlets often follow the line of reasoning that Coe and Weinstock used in evaluating management journals. They stated:

because [promotion and tenure] decisions are made by committees and administrators outside of the individual discipline, the content of publications may be less relevant than the images of the journals in which they appear . . . For a full comprehension of university performance appraisal and reward systems, therefore, one must obtain insights into the images of the journals in the various disciplines. (1984: 660)

In other words, it is the perception of the quality of the publication outlet which impacts the faculty evaluation process. Unfortunately, these

perceptions are often clouded by individual biases. Extejt and Smith (1990) attempted to determine the extent of bias in their study of behavioral sciences and management journals. They found that respondents attributed a lower acceptance rate to a higher-quality journal (other studies have found similar results, such as Weinstock and Coe, 1969; and Coe and Weinstock, 1984). Although this bias may exist, it may be unimportant, since authors clearly self-censor. If they think their work is not good, they do not send it to a top journal. Thus acceptance rates often are surprisingly high and articles often are surprisingly good at top journals. Further, a significant bias was found in favor of academic oriented journals and against practitioner and mixed-audience journals. Thus, while stated preference studies capture an important input into the faculty evaluation process, they suffer from biases which are not easily overcome with a survey design.

Revealed preference studies attempt to overcome the inherent subjectivity of stated preference studies by relying upon journal citations in published articles. Sharplin and Mabry summarize the rationale for using citation analysis as follows:

It is well accepted that measures of citations frequency provide objective means of evaluating the impact of scholarly research on other research. Certainly, the intended purpose of publications in academic journals is to impart knowledge to others, furthering the advancement of the discipline and related areas. The number of references to particular works, therefore, provides a way of evaluating not only the researchers themselves, but the journals in which they publish. (1985: 141)

The form of most citation analysis studies is comprised of two steps. First, the researcher identifies a set of source journals from which to obtain the citations. Second, the researcher evaluates the citations made in these journals. As will be discussed later, numerous techniques are used in evaluating citations, some simple and others quite complex. Citation analysis is more objective than survey designs, but suffers from biases of its own. The selection of the source journals may significantly impact the resulting citations, especially in journals that have a high rate of self-citation. In addition, the method of evaluation can insert forms of bias. MacRoberts and MacRoberts (1989) note biases such as variations in

the citation rate related to type of publication, nationality, time period, and size and type of academic specialty which exist to varying degrees in interpreting citations.

While there are advantages and disadvantages of stated and revealed preference studies, both types are interrelated, and it should not be surprising that they correlate positively (Wallmark and Sedig, 1986; Franke, Edlund, and Oster, 1990; Baird and Oppenheim, 1994; and Johnson and Podsakoff, 1994). Stated preference as perception of high-quality research outlets may be the starting point in selecting the source journals for citation analysis (Sharplin and Mabry, 1985). On the other hand, revealed preference in the results of citation analyses are likely to have an impact on researchers' perceptions of high-quality outlets.

The two measures of journal quality may use different time horizons, in that perceptions of journal quality tend to have a long memory, while the citation analyses can show recent changes in journal quality. That is, an individual's perceptions (an evaluation process) change gradually over time as new information is processed in a fashion similar to an autoregressive anchor-adjustment model (see Hogarth and Einhorn, 1992). On the other hand, citation analysis examines which journals provide significant inputs to current developments, thus focusing more on recent research than do stated preference studies. Citation analysis is in effect a leading indicator of future perception changes.<sup>3</sup>

Due to the assumed lagged process in which

the perceptions of a journal's quality develops, we believe that citation analysis provides the more timely as well as the more objective measure of a journal's quality and impact. As such, our study uses the revealed preference paradigm, that is, citation analysis.

## FORMS OF CITATION ANALYSIS

Citation analysis studies can take many different forms: from the simple to the complex. The most simple form of citation analysis consists of examining the raw citation count. A number of studies have used this methodology to rank journal influence in the field of management, including Blackburn and Mitchell (1981) and Sharplin and Mabry (1985). They are simple to interpret, in that each citation is a revealed influence to the published article. This does not infer that citations capture the entire universe of influence upon the author, but reveals the prior published research that had enough influence that the author felt compelled to recognize that influence publicly.

Detractors of the raw citation counts base their criticism on two broad fronts: questioning the overall validity of citations measuring influence and indicating a potential for bias in citation analysis.

### Validity of citations measuring influence

The validity of citation studies in general depends upon the degree of reliance that one puts on citations' measuring influence. For example, it is invalid to suggest that citations are the population of the influences an author used. It is readily acknowledged that the citation is simply a subset of the total population of influences. For a more in-depth discussion of this and other assumptions of citation analysis see Brooks (1986), MacRoberts and MacRoberts (1989), Liu (1993), and Baird and Oppenheim (1994). Baird and Oppenheim respond to these criticisms as follows:

What is embarrassing for the critics of citation counting is this fact: whatever measure you take for the eminence of an individual scientist or of a journal or an institution, citation counts provide strong correlation with that result. This must be very frustrating for the people who criticize

<sup>3</sup> For example, Extejt and Smith (1990) performed a stated preference study to rate management journals concerned with the behavioral aspects of management. Subjects surveyed were members of the Academy of Management who belonged to the Organizational Behavior, Organizational Theory, Organizational Development or Personnel/Human Resources divisions. Though 54 management journals were listed in the survey instrument and each respondent was asked to add and evaluate any additional journals, surprisingly, the *Strategic Management Journal* was not included in the analysis. However, Johnson and Podsakoff (1994) performed a citation analysis ranking 40 management journals covering three time periods (which overlap the Extejt and Smith, 1990, study)—1981, 1986, and 1991—and found that the *Strategic Management Journal* was the 16 most cited journal by 1986 (6 years after its inception) and had risen to sixth by 1991. Comparing these studies suggests that acceptance of the *Strategic Management Journal* by non-Strategy/Business Policy scholars as a top journal (MacMillan, 1991, found Business Policy scholars ranked the *Strategic Management Journal* as the top journal) has lagged the journal's use.

citation counting, but demonstrates that, despite the 'noise' produced by the vagaries of citations, the 'signal' still comes through strongly. So, despite the many valid criticisms of the crudity of citation counting, the fact is that they reasonably reflect the esteem that a particular author or paper enjoys. Citation counts provide an easily calculated measure of the impact that the author has had on his or her community (1994: 8).

### Potential for bias in citation analysis

The potential for bias has been the primary reason for the development of a large number of other, more complex, citation analytical techniques. These techniques rely upon the raw citation counts but limit the ages of the citations used and/or attempt to normalize the data.

Based on de Solla Price's (1965) immediacy factor, Quandt (1976) examined the citation patterns of economics research and found that half of the citations in his sample were 6 years old or less. He noted caution in performing a citation analysis on all citations because the average age of the citations would be skewed if research on the history of thought was cited (i.e., Aristotle or St. Thomas Aquinas). Thus Quandt used a trimmed mean age (arbitrarily cutting off the ages of the citations at 75 and 150 years) and the median age of citations. Likewise, Lovell (1973) and McDowell (1982) limited the ages of citations in their examinations based on mean or median citation age.

The normalization process usually is an attempt to control for the total number of articles (Garfield, 1972) or pages published (Sharplin and Mabry, 1985). Garfield's (1972) impact factor is used by the ISI<sup>4</sup> in their *Social Sciences Citation Index*:

$$\text{Impact factor } (n) = \frac{\sum_{t=1}^n c_t}{\sum_{t=1}^n p_t} \quad (1)$$

where  $c_t$  is the number of citations of articles published  $t$  years ago,  $p_t$  is the number of articles

published by the journal  $t$  years ago, and  $n$  is the order of the index. Garfield's (1972) impact factor uses an order of 2 years which limits citations to the 2 most recent years preceding the year of publication. This can be seen best in Figure 1, where the two darkened columns indicate the ages of citations used by Garfield. A rationale for the most appropriate model order (or cut-off for citations to include in the analysis) has not been forwarded to date. Supporting the need for a systematic rationale for determining the most appropriate model order, Egghe noted:

in some research areas this value of IF [impact factor] is not ideal in the sense that, instead of considering two years, another number of years might produce a higher impact factor. If the two-year impact factor of Garfield is good for measuring the importance of life science journals, the same cannot be said for mathematics journals. (1988: 567)

The inference from this is that the 2-year cut-off may be inappropriate for certain academic fields. Another problem of Garfield's impact factor is its interpretation. Citations-per-published-article does not measure a journal's impact on the current literature. By using the total citation count within a number of published articles, a journal's influence is shown rather than just that of the average article.<sup>5</sup>

Given that our interest is simply to evaluate the relative influence that all journals have had on developing management theory based upon the revealed usage of those journals, we believe a methodology which is broad in scope and easy to interpret should be used.

### CITATION PROPORTION

Journals which are most frequently cited are those which have had the most influence on the current

<sup>5</sup> For example, assume that there are only two journals in an area of interest: *Journal A* and *Journal B*. Assume that *Journal A* was cited 10 times and published 10 articles over the time period being examined. Similarly, *Journal B* was cited 90 times and published 90 articles over the same time period. Both journals have the same impact factor, but can it be said that the two journals have had the same influence on the literature? It would be appropriate to suggest that both journals are equally efficient in generating citations, but *Journal B* has had a greater contribution to the current literature by a factor of nine times.

<sup>4</sup> ISI refers to the Institute for Scientific Information which publishes impact factors for the social sciences in the *Social Sciences Citation Index*.

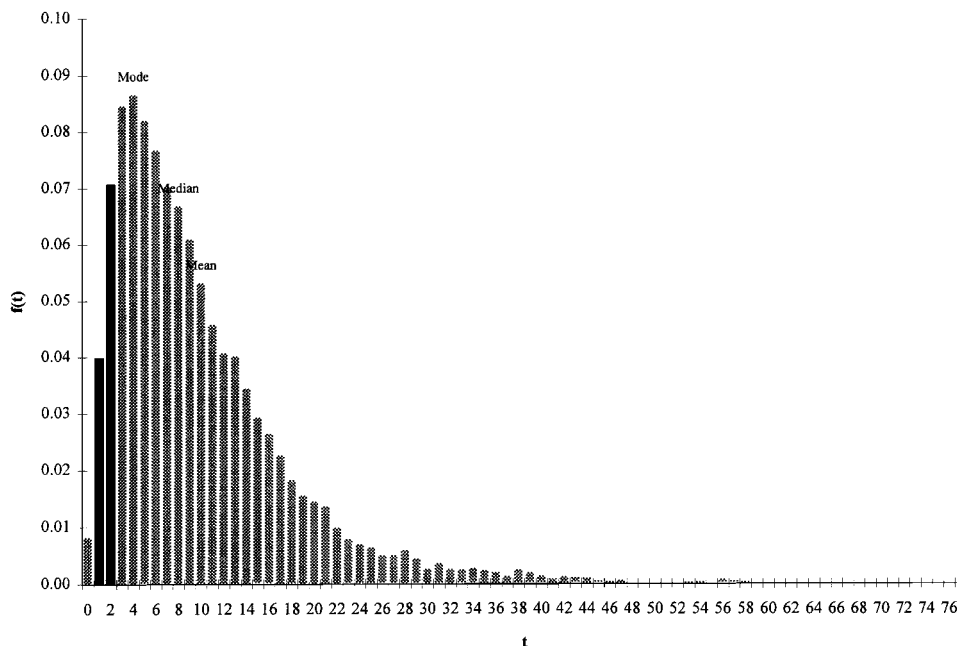


Figure 1. Histogram of citations

literature. However, simply examining the total citation counts tends to bias results in favor of older journals. In an expanding social science such as management, we expect that there are two primary bodies of literature which impact currently developing theory. First, there should be a significant influence from social sciences such as psychology, sociology, and economics. Second, developments in the field of management also should have a significant influence. Older references tend to be from supporting fields, while more recent citations tend to emanate from the field of management (after Quandt, 1976).

De Solla Price (1965) and Quandt (1976) suggest that the distribution of the ages of citations may be an important factor in examining citations patterns, and that the distribution of citations is skewed. Thus, the median or mode would provide a better indication of time lag of influence than does the more commonly used mean.

The various alternative impact factors have not provided a rationale for the order of the model selected. For example, Garfield (1972) and the *Social Sciences Citation Index* use an order of two which was selected to guard against potential biases of older journals. However, by limiting the citations examined to the 2 years prior to the source publication, important information is being

lost. Alternatively, when the order of the model is too large, the relative impact of supporting field journals (and older journals, in general) tends to diminish the resulting impact factor for journals important today.

Our methodology directly determines the most appropriate order of the model by evaluating the distribution of the citations and selecting the most appropriate measure of central tendency for that distribution (see next section). Further, we develop a citation proportion which evaluates the citations of a given journal relative to all citations from all journals cited from our source journals. The measure for a particular journal is:

$$\text{Citation proportion } (n) = \frac{\sum_{t=1}^n c_t}{\sum_{t=1}^n \sum_{i=1}^k c_{t,i}} \quad (2)$$

where the numerator is the summation of all citations of a journal over the time period from the year of publication of the source journals to some selected time period cut-off,  $n$ . We refer to the time period cut-off as the order of the model. The denominator is the summation of all citations examined (for  $k$  number of journals) over the

same time period. The denominator, then, does not change for each journal examined.<sup>6</sup>

## THE ORDER OF THE MODEL

We provide a rationale and procedure for the determination of the order of the model. Garfield (1972) uses an order of two but provides little support for his choice. As Egghe (1988) notes, a model of a different order would likely provide a better measure of impact. However, the methodology of selecting the optimal number of years to be included in any citation study does not exist in the current body of literature. In fact, only a few authors have attempted to incorporate the citation distribution explicitly into the journal rating process (Lovell, 1973; McDowell, 1982; and Glanzel and Schubert, 1988).

Following de Solla Price (1965) and Quandt (1976), we choose the lag time for the maximum point of the citation distribution as a minimal time period to be examined. To determine the maximum, we must first identify the distribution (i.e., normal, exponential, Weibull, gamma, generalized gamma) of the citations. Then the appropriate measure of central tendency can be calculated—one which will identify the maximum point of the distribution as well as identify the appropriate order of the model.

Because the citation patterns cannot take on negative values, the generalized gamma distribution and its nested models are adopted as a flexible alternative to the usual normal distribution. Empirically, the generalized gamma distribution has been found to fit time distributions in many instances. For example, Addison and Portugal (1987) and Swaim and Pogursky (1992) used the generalized gamma distribution of unemployment duration. McDonald (1984) used the generalized gamma distribution to describe U.S. family income. As shown in Appendix 1, the

generalized gamma model nests several commonly used distributional models, including the exponential, Weibull, gamma, and log-normal by setting the various parameters equal to predetermined values.

## DATA

The intent of our study is to be as accurate and broad in scope as possible in the examination of management journal quality.<sup>7</sup> For a revealed preference study, breadth of analysis is dependent upon the selection of the source journals. The selection process consists of reviewing prior published studies of management journal quality (Weinstock and Coe, 1969; Blackburn and Mitchell, 1981; Sharplin and Mabry, 1985; Salancik, 1986; MacMillan and Stern, 1987; Stahl *et al.*, 1988; Blackburn, 1990; Extejt and Smith, 1990; MacMillan, 1991; and Johnson and Podsakoff, 1994) and selecting a core group of the top 17 management journals available on the *Social Sciences Citation Index* (SSCI) citation data files for 1993 and 1994.<sup>8</sup> Our judgement for inclusion as source journals was based on the stated manuscript topics in the submission guidelines for each journal. In some cases (particularly the *Journal of Applied Psychology* and *Personnel Psychology*) the publication policy could be considered either management or psychology. In these cases, determination as a management journal relied on the department of the editor and the sponsoring organization.<sup>9</sup> For the time period examined, these source journals published 1275 full articles with a total citation count of 45,286. Our subset of those for analysis are the 23,637 references to academic journals. Other citations, to books, monographs, working papers, dissertations, maga-

<sup>6</sup> Using the aforementioned example of *Journal A* and *Journal B*, the calculation of the citation proportion would be as follows:

$$\begin{aligned}\text{Citation proportion}_{(A,n)} &= \frac{10}{100} = 0.10 \\ \text{Citation proportion}_{(B,n)} &= \frac{90}{100} = 0.90\end{aligned}$$

<sup>7</sup> To this end, we study journals from the field of management in general, not simply those of a particular subfield as many studies have, including Extejt and Smith (1990), MacMillan (1991), Blackburn (1990), and MacMillan and Stern (1987).

<sup>8</sup> These were the most recent data files available at the time of data collection.

<sup>9</sup> In the case of the *Journal of Applied Psychology*, the journal is sponsored by the American Psychology Association and the journal editor is a psychology professor. Conversely, the editors of *Personnel Psychology* are primarily management professors. As such, we did not consider the *Journal of Applied Psychology* a management journal. Examining the results of Salancik (1986) suggests that the *Journal of Applied Psychology* has a high rate of self-citation which could have biased our results had it been included as a source journal.

zines, newspapers, government publications, and other similar nonacademic journal sources were excluded from the analysis.

Table 1 provides descriptive statistics for the 17 source journals listed in column one. The second and third columns show the number of source articles and citations, respectively, for each journal, the fourth column the average number of citations per published article, and the fifth column the proportion of self-citation for each journal. The average percentage self-citation for the set of source journals was only 5 percent, ranging from 0 percent to 9 percent.

## RESULTS

### Determination of the citation distribution

To identify the optimal age of citations to analyze (i.e., the appropriate order of the model) we use the generalized gamma density function (see Appendix, Equation 10) and its four nested distribution models (exponential, Weibull, log-normal, and gamma). To visualize the estimated distributions relative to one another we present each distribution in Figure 2. The parameters for each distribution are estimated using maximum likelihood as described in the Appendix. The actual

frequencies of citations vs. time lag after publication are plotted to indicate the fit with each of the five models. From this visual analysis, it is apparent that the log-normal and the generalized gamma distributions are the two that provide the closest fit.

Another means of determining the best match between the actual citation frequencies and each of the distribution is by using the log-likelihood function (Equation 11 in Appendix), whose results are presented in panel C of Table 2. The criteria for comparison is the largest log-likelihood function which indicates the closest match of the distribution to the data (the generalized gamma distribution with a log-likelihood function value of  $-27,421.10$  has the smallest negative value—that is, the largest value). As expected, the next closest match was the log-normal distribution with a log-likelihood function value of  $-27,693.80$ .

Panel A of Table 2 provides the parameter estimates for each of the five models along with the related *t*-statistics (below each parameter estimate). Each of the parameter estimates for all models have significant *p*-values of at least 0.001.

A formal test to determine whether the generalized gamma distribution was, in fact, statistically different from the other models was

Table 1. Description of source articles and citations

Journal	Source articles	Academic citations	Mean citations per article	Proportion of self-citation
<i>Academy of Management Journal</i>	75	5,223	70	8
<i>Academy of Management Review</i>	37	2,839	77	5
<i>Administrative Science Quarterly</i>	35	2,138	61	9
<i>California Management Review</i>	64	1,479	23	1
<i>Harvard Business Review</i>	134	113	1	1
<i>Human Relations</i>	123	5,811	47	3
<i>Industrial and Labor Relations Review</i>	69	2,103	30	4
<i>Industrial Relations</i>	48	1,390	29	2
<i>Journal of International Business Studies</i>	68	3,221	47	9
<i>Journal of Management</i>	63	3,476	55	2
<i>Long Range Planning</i>	137	2,082	15	7
<i>Organizational Behavior and Human Decision Processes</i>	140	5,476	39	4
<i>Organizational Dynamics</i>	65	957	15	1
<i>Personnel Psychology</i>	54	2,142	40	9
<i>Research in Organizational Behavior</i>	3	199	66	4
<i>Sloan Management Review</i>	64	1,281	20	0
<i>Strategic Management Journal</i>	96	5,356	56	7
Total	1275	45,286		
Average over journals			41	5



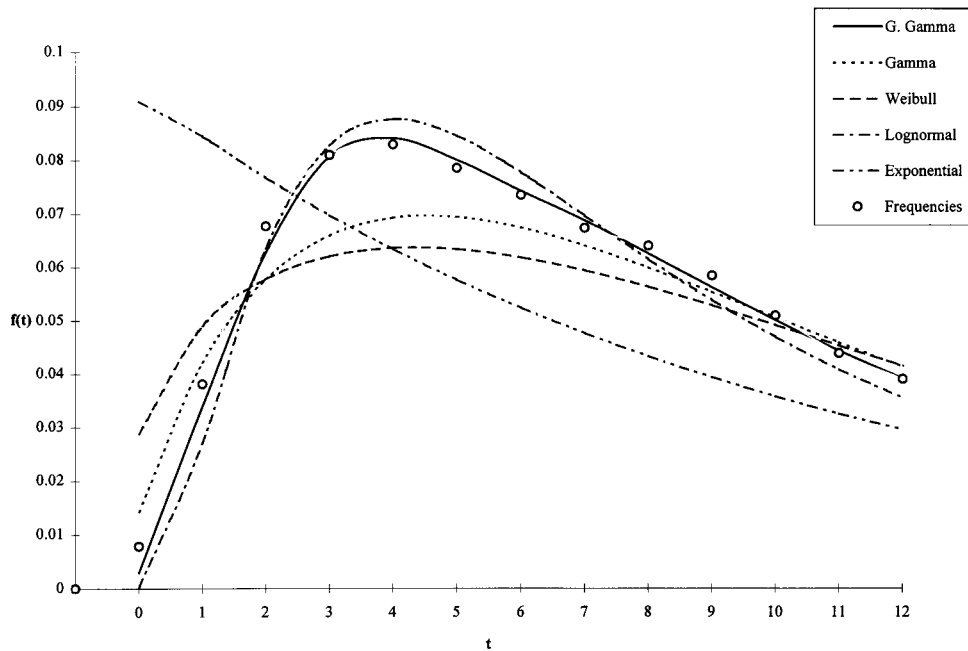


Figure 2. Observed frequencies and estimated distribution models

also performed. While the log-likelihood function identifies the best-fitting model (generalized gamma in this case), this formal test was performed to test the following set of null hypothesis:

$H_0$ : The exponential (log-normal, Weibull, gamma) distribution provides a better fit of the data than the generalized gamma distribution.

Panel D of Table 2 provides the results of this test. The results indicate that there is a significant difference between each of the models and the generalized gamma distribution. As such, the null hypothesis was rejected in each case and, therefore, the generalized gamma distribution is shown to provide the best match to the data.

Panel B of Table 2 provides the measures of central tendency for the five calculated distributions. What should be evident is that the measures of central tendency are close to one another, regardless of the distribution chosen, with the exception of the mode of the exponential distribution. Rounding to the nearest year provides a mean age of citations 10–11 years, a median age of citations 8–9 years, and a mode age of citation 4–5 years. Since the best distribution is the generalized gamma, the best measures of central tendency are a mean age of 10.5 years, a median age of 8.3 years, and a mode age of 4.2 years.

Given the skewness of the generalized gamma distribution, we propose that the best measure of central tendency is the mode, followed by the median and the mean.

### Age of journals

One of the main criticisms of using citations to rate journals is a presumed bias towards older journals and against newer journals. When all citations are used (i.e., when the order of the model is not limited) there is a bias in favor of older journals. For example, without an age limitation on the citations, the average age of the top 10 (20, and 30) journals is 42 years (48 years, and 46 years, respectively). In contrast, when the mode (4 years) of the citation distribution is used to limit the age of the citations analyzed, newer journals are able to compete, with the average age of the top 10 (20, and 30) journals based on citations 4 years old or less equal to 20 years (24 years, and 26 years, respectively).

### Journal influence

For comparison purposes, the citation proportion of the top 65 most cited journals are presented

Table 2. The maximum likelihood estimate of probability distributions of citation elapsed time

Description:	G. gamma	Log-normal	Gamma	Weibull	Exponential
<i>Panel A</i>					
Basic specification:					
$\beta$	-2.17	2.07	1.73	2.45	2.35
	-6.06	394.29	29.56	458.40	286.04
$\sigma$	2.12	0.78	1	0.72	1
	24.01	231.32	49.53	228.71	
Coefficients of descriptive models:					
$\rho$ (shape)	0.47	1.28	1 <sup>a</sup>	1.39	1 <sup>a</sup>
	8.99	231.15		228.59	
$\theta$ (shape)	7.87		1.86	1 <sup>a</sup>	1 <sup>a</sup>
	12.42		24.69		
$\lambda$ (scale)	8.77	0.13	0.18	0.09	0.11
	5.44		17.11		122.53
	2.79	191.47		188.33	
<i>Panel B</i>					
Location estimators: <sup>b</sup>					
Mean	10.46	10.73	10.46	10.53	10.46
Median	8.29	7.91	8.66	8.87	7.25
Mode	4.20	4.30	4.84	4.62	0.00
<i>Panel C</i>					
Log-likelihood function	-27,421.10	-27,693.80	-27,717.79	-28,259.38	-30,240.05
<i>Panel D</i>					
Likelihood ratio test, $\chi^2_{(v)}$		545.40	593.38	1676.56	5637.90

Note: *t*-statistics are under the parameter values.

<sup>a</sup>Given parameter values for individual members of the generalized gamma distribution.

<sup>b</sup>The unit of measurement is in years.

in Table 3 and Table 4. The total impact of journals presented in Table 3 shows their citation proportions without regard to the age of the citations. The top 65 journals cited accounted for 17,451 citations, or over 70 percent of the academic citations available for analysis.<sup>10</sup> When the age of the citation is not limited, the long-lagged contributions of psychology and sociology journals becomes apparent. The most cited journal, with a citation proportion of 9.05 percent, was the *Journal of Applied Psychology*. The *Journal of Personality and Social Psychology* and *Psychological Bulletin* rank seventh and eighth, with citation proportions of 3.43 percent and 3.06 percent, respectively. The cumulative citation proportions for psychology and sociology journals

total 31.77 percent<sup>11</sup> and the cumulative citation proportion for economics journals totals 8.32 percent.<sup>12</sup> In comparison, the proportion of citations from management journals of the top 65 journals cited is 63.6 percent, with the top five management journals (*Academy of Management Journal*, *Administrative Science Quarterly*, *Organiza-*

<sup>11</sup> These journals included the *Journal of Applied Psychology*, *Journal of Personality and Social Psychology*, *Psychological Bulletin*, *American Sociological Review*, *American Journal of Sociology*, *Psychological Review*, *American Psychologist*, *Journal of Experimental Social Psychology*, *Journal of Occupational Psychology*, *Annual Review of Psychology*, *Advances in Experimental Social Psychology*, *Annual Review of Sociology*, *Acta Psychologica*, *Psychological Reports*, and *Journal of Abnormal Psychology*.

<sup>12</sup> These journals include *American Economic Review*, *Journal of Political Economy*, *Journal of Financial Economics*, *Quarterly Journal of Economics*, *Rand Journal of Economics*, *Econometrica*, *Review of Economics and Statistics*, *Journal of Labor Economics*, *Journal of Economic Behavior and Organization*, *Journal of Law and Economics*, and *Journal of Economic Literature*.

<sup>10</sup> We limited our analysis to the top 65 most cited journals because beyond that point the number of management journals as compared to related social science field journals was relatively low. As such, in Equation 2,  $k = 65$ .

Table 3. Total impact: Journals ranked by citation proportion

Rank	Journal	First publication	Proportion of citations
1	<i>Journal of Applied Psychology</i>	1917	9.05
2	<i>Academy of Management Journal</i> <sup>a</sup>	1963	8.27
3	<i>Administrative Science Quarterly</i> <sup>a</sup>	1956	8.03
4	<i>Organizational Behavior and Human Decision Processes</i> <sup>a</sup>	1985	6.69
5	<i>Strategic Management Journal</i> <sup>a</sup>	1980	6.37
6	<i>Academy of Management Review</i> <sup>a</sup>	1976	6.37
7	<i>Journal of Personality and Social Psychology</i>	1965	3.43
8	<i>Psychological Bulletin</i>	1904	3.06
9	<i>Personnel Psychology</i> <sup>a</sup>	1948	2.43
10	<i>Harvard Business Review</i> <sup>a</sup>	1922	2.21
11	<i>Human Relations</i> <sup>a</sup>	1947	2.13
12	<i>Industrial and Labor Relations Review</i> <sup>a</sup>	1947	2.11
13	<i>Journal of International Business Studies</i> <sup>a</sup>	1970	2.06
14	<i>Management Science</i>	1954	2.03
15	<i>American Sociological Review</i>	1936	2.01
16	<i>Research in Organizational Behavior</i> <sup>a</sup>	1979	1.95
17	<i>Journal of Management</i> <sup>a</sup>	1975	1.95
18	<i>American Economic Review</i>	1911	1.79
19	<i>American Journal of Sociology</i>	1895	1.39
20	<i>Psychological Review</i>	1894	1.21
21	<i>Journal of Political Economy</i>	1892	1.09
22	<i>Journal of Financial Economics</i>	1974	1.07
23	<i>California Management Review</i> <sup>a</sup>	1958	1.07
24	<i>Journal of Vocational Behavior</i>	1971	1.05
25	<i>Long Range Planning</i> <sup>a</sup>	1968	1.04
26	<i>American Psychologist</i>	1946	0.91
27	<i>Journal of Management Studies</i>	1964	0.87
28	<i>Organization Science</i>	1990	0.81
29	<i>Industrial Relations</i> <sup>a</sup>	1961	0.81
30	<i>Quarterly Journal of Economics</i>	1886	0.80
31	<i>Journal of Marketing Research</i>	1964	0.79
32	<i>Journal of Marketing</i>	1936	0.72
33	<i>Academy of Management Executive</i>	1990	0.65
34	<i>Journal of Experimental Social Psychology</i>	1965	0.65
35	<i>Rand Journal of Economics</i> (previously <i>Bell Journal of Economics</i> )	1970	0.62
36	<i>Journal of Finance</i>	1946	0.61
37	<i>Econometrica</i>	1933	0.61
38	<i>Journal of Occupational Psychology</i>	1975	0.60
39	<i>Annual Review of Psychology</i>	1950	0.57
40	<i>Organizational Dynamics</i> <sup>a</sup>	1972	0.57
41	<i>Research in Personnel &amp; Human Resource Management</i>	1983	0.51
42	<i>Organizational Studies</i>	1981	0.50
43	<i>Sloan Management Review</i> <sup>a</sup>	1970	0.50
44	<i>Review of Economics and Statistics</i>	1919	0.47
45	<i>Science</i>	1880	0.45
46	<i>Journal of Human Resource [Management]</i>	1966	0.44
47	<i>Journal of Labor Economics</i>	1983	0.43
48	<i>Journal of Organizational Behavior</i>	1977	0.42
49	<i>Journal of Consumer Research</i>	1973	0.42
50	<i>Advances in Experimental Social Psychology</i>	1964	0.41
51	<i>Human Resource Management</i>	1962	0.40
52	<i>Group and Organization Studies</i>	1976	0.40
53	<i>Journal of Economic Behavior and Organization</i>	1980	0.39
54	<i>Journal of Law and Economics</i>	1958	0.39

Table 3. Continued

Rank	Journal	First publication	Proportion of citations
55	<i>Annual Review of Sociology</i>	1975	0.36
56	<i>Journal of Industrial Economics</i>	1952	0.34
57	<i>Management International Review</i>	1961	0.32
58	<i>Journal of Business Venturing</i>	1985	0.32
59	<i>Acta Psychologica</i>	1941	0.32
60	<i>Journal of Economic Literature</i>	1963	0.32
61	<i>Research Policy</i>	1972	0.30
62	<i>Psychological Reports</i>	1955	0.28
63	<i>Columbia Journal of World Business</i>	1965	0.28
64	<i>Journal of Business Research</i>	1973	0.28
65	<i>British Journal of Industrial Relations</i>	1963	0.27

<sup>a</sup>Journals that include source articles.

*tional Behavior and Human Decision Processes*, *Strategic Management Journal*, and *Academy of Management Review*) accounting for 35.73 percent of the total. The proportion of citations from management journals of the top 65 journals cited is 63.6 percent.

When we limit the age of the citations to only those citations equal to or younger than the mode of the citation distribution (4 years old), the core impact picture appears (see Table 4).

While the *Journal of Applied Psychology* still accounts for about 9 percent of all citations 4 years or younger, the journal no longer is the most cited journal. Both *Strategic Management Journal* and the *Academy of Management Journal* surpass the *Journal of Applied Psychology*. In addition, the cumulative citation proportion for the psychology and sociology journals falls to 16.13 percent while the cumulative citation proportion for economics journals falls to 4.4 percent. As expected, the number of management journals at the top of the listing increases. Without the age constraint, four psychology and sociology journals are within the top 15 most cited journals, whereas with the age constraint only one psychology journal remains in the top 15. These facts support the hypothesis that management theory is made up of two primary components: a basic supporting social science field component which has developed its theory over a number of years, and a more recently developed management component where more salient refinements to useful theories have evolved and continue to develop. The journals which have had the most impact in developing the latter

component include *Strategic Management Journal* (10.6%), *Academy of Management Journal* (9.57%), *Organizational Behavior and Human Decision Processes* (7.58%), *Academy of Management Review* (5.55%), and *Administrative Science Quarterly* (5.33%). These five management journals account for 38.63 percent of the total citations 4 years old and younger.

Though not presented, we calculated the citation proportions for citations 8 years old and younger (median age of citations) and 10 years old and younger (mean age of citations), respectively. As the age of the citations increases, the results approach those of the non-age censored data presented in Table 3. We observe a 'bubbling effect' where management journals increase their total relative proportion as the ages of the citations approaches the peak of the citation distribution. For example, when the mode of the distribution is used to limit the citations analyzed (model order of four,  $n = 4$ ), the proportion of citations attributed to management journals is 75.4 percent. In comparison, as the order of the model increases to eight (median) and 10 (mean) years, the proportion of citations attributed to management journals declines to 69.4 percent and 68.5 percent, respectively. Our methodology allows for the maximum number of citations to be examined while simultaneously maximizing the relative impact of management journals as compared to related supporting social science field journals.

While we leave the ultimate decision to the reader, we strongly believe that the rankings based on the mode age of citations as the cut-

Table 4. Core impact: Journals ranked by citation proportion truncated at mode

Rank	Journal	First publication	Proportion of citations
1	<i>Strategic Management Journal</i> <sup>a</sup>	1980	10.64
2	<i>Academy of Management Journal</i> <sup>a</sup>	1963	9.57
3	<i>Journal of Applied Psychology</i>	1917	8.71
4	<i>Organizational Behavior and Human Decision Processes</i> <sup>a</sup>	1985	7.58
5	<i>Academy of Management Review</i> <sup>a</sup>	1976	5.55
6	<i>Administrative Science Quarterly</i> <sup>a</sup>	1956	5.33
7	<i>Journal of Management</i> <sup>a</sup>	1975	3.89
8	<i>Organization Science</i>	1990	2.91
9	<i>Industrial and Labor Relations Review</i> <sup>a</sup>	1947	2.68
10	<i>Personnel Psychology</i> <sup>a</sup>	1948	2.48
11	<i>Journal of International Business Studies</i> <sup>a</sup>	1970	2.42
12	<i>Human Relations</i> <sup>a</sup>	1947	2.17
13	<i>Management Science</i>	1954	2.13
14	<i>Long Range Planning</i> <sup>a</sup>	1968	1.89
15	<i>Harvard Business Review</i> <sup>a</sup>	1922	1.76
16	<i>Psychological Bulletin</i>	1904	1.64
17	<i>Academy of Management Executive</i>	1990	1.62
18	<i>Research in Organizational Behavior</i> <sup>a</sup>	1979	1.43
19	<i>Journal of Personality and Social Psychology</i>	1965	1.37
20	<i>Journal of Vocational Behavior</i>	1971	1.35
21	<i>Journal of Organizational Behavior</i>	1977	1.17
22	<i>American Economic Review</i>	1911	1.13
23	<i>Journal of Management Studies</i>	1964	1.11
24	<i>California Management Review</i> <sup>a</sup>	1958	1.07
25	<i>Journal of Financial Economics</i>	1974	0.86
26	<i>Organizational Studies</i>	1981	0.86
27	<i>Industrial Relations</i> <sup>a</sup>	1961	0.80
28	<i>Journal of Occupational Psychology</i>	1975	0.76
29	<i>American Psychologist</i>	1946	0.76
30	<i>Quarterly Journal of Economics</i>	1886	0.76
31	<i>Journal of Finance</i>	1946	0.74
32	<i>American Sociological Review</i>	1936	0.68
33	<i>Annual Review of Psychology</i>	1950	0.66
34	<i>Journal of Marketing</i>	1936	0.64
35	<i>Journal of Political Economy</i>	1892	0.61
36	<i>Sloan Management Review</i> <sup>a</sup>	1970	0.57
37	<i>Research in Personnel &amp; Human Resource Management</i>	1983	0.49
38	<i>Journal of Labor Economics</i>	1983	0.47
39	<i>Group and Organization Studies</i>	1976	0.45
40	<i>Management International Review</i>	1961	0.43
41	<i>Journal of Economic Literature</i>	1963	0.43
42	<i>Journal of Marketing Research</i>	1964	0.41
43	<i>Journal of Business Venturing</i>	1985	0.41
44	<i>Organizational Dynamics</i> <sup>a</sup>	1972	0.41
45	<i>Journal of Behavioral Decision Making</i>	1988	0.41
46	<i>Psychological Review</i>	1894	0.39
47	<i>American Journal of Sociology</i>	1895	0.37
48	<i>Journal of Human Resource [Management]</i>	1966	0.37
49	<i>Human Resource Management</i>	1962	0.35
50	<i>Journal of Experimental Social Psychology</i>	1965	0.33
51	<i>Journal of Business Ethics</i>	1982	0.33
52	<i>British Journal of Industrial Relations</i>	1963	0.33

Table 4. Continued

Rank	Journal	First publication	Proportion of citations
53	<i>Journal of Consumer Research</i>	1973	0.31
54	<i>Human Resource Planning</i>	1978	0.29
55	<i>Journal of Labor Research</i>	1980	0.27
56	<i>Journal of Business Research</i>	1973	0.27
57	<i>Review of Economics and Statistics</i>	1919	0.27
58	<i>Annual Review of Sociology</i>	1975	0.25
59	<i>Journal of industrial Economics</i>	1952	0.25
60	<i>Journal of Economic Perspectives</i>	1987	0.25
61	<i>MIS Quarterly</i>	1977	0.25
62	<i>Journal of Law, Economics, and Organization</i>	1985	0.25
63	<i>Business Horizons</i>	1958	0.25
64	<i>Research Policy</i>	1972	0.23
65	<i>Psychological Reports</i>	1955	0.23

<sup>a</sup>Journals that include source articles.

off for analysis provided the best basis for judging the impact of the journals on the current developments in the field of management.

## DISCUSSION

We believe our paper has made several significant contributions to the management literature. First, we provide a novel methodology for determining the most appropriate order of citation studies. As Egghe (1988) suggested, the 2-year order selected by Garfield (1972) for his Impact Factor may not be appropriate for academic specialties. As we show, the time period to be analyzed should incorporate the distribution of the citations, with the optimal order (age) for measure of central tendency of the distribution.

A second contribution of this study is its breadth. While some previous studies using the revealed preference methodology limited source journals to relatively few, our study uses the citations from 17 management journals. Therefore, our results provide a comprehensive view of the direct influences of developing management research.

Finally, our analysis relies upon a simple measure of a journal's contribution to the current literature. This simple measure, the citation proportion, does not alter the distribution of citations (as other journal impact factors do) and allows

for a simple interpretation of total acknowledged journal influence on scholarship.

## CONCLUSION

The internationalization of the world economy brought about by the growth of multinational corporations, free trade agreements (e.g., NAFTA, European Community), and international trade agreements (e.g., GATT) has heightened the degree of competition in all industries.<sup>13</sup> To cope in an environment where competition is fierce for both market share and factors of production (labor, capital, and technology), successful companies have implemented strategic planning in all phases and levels of operations, from hiring practices to new product development. Our results suggest that recent management research from all subfields of management reflects the importance of this strategic focus, as evidenced by the greatest fraction of citations 4 years old or younger, from *Strategic Management Journal*, the leading publication.

Since scholars engage in research to make a contribution (to the body of literature and/or to current managerial practices) they must select

<sup>13</sup> Prahalad and Hamel (1994) provide a more detailed discussion of the forces impacting the nature and degree of competition and their impact on the field of management.

appropriate publication outlets to achieve this goal. One indication that research has made a contribution is to have that research used—either in practice or to inspire future research. Our journal rankings are based on usage of a journal's recent publications. This information provides a timely mechanism for scholars to select the research outlet which will have the greatest likelihood of being scrutinized by one's peers and, therefore, impact future research. It should be understood, however, that journal rankings are but one input used by scholars<sup>14</sup> in selecting an appropriate research outlet. Due to the applied nature of the field of management, making the most significant impact would require a management scholar to follow a journal selection strategy which diversifies his publication portfolio to ensure that his research can impact both the practice and theory of management. These rankings used in conjunction with information regarding a journal's circulation and intended readership can help a scholar select journals which support the likelihood of impact on future academic research and business practice.

For both the academic and the practitioner, time is the most scarce resource. Keeping abreast of recent developments in both theory and practice is extremely difficult given the large number of publication outlets. The rankings presented in this paper are useful in that they focus on which journal's recent research is being used and therefore having the most impact on the field. Thus academics can spend their available time examining only those journals which are making the greatest contribution to the field. The proportion of citations originating from the top three journals (*Strategic Management Journal*, *Academy of Management Journal*, *Journal of Applied Psychology*) comprise almost 30 percent of the citations 4 years old or younger; the top seven journals comprise over 50 percent (also including *Organizational Behavior and Human Decision Processes*, *Academy of Management Review*, *Administrative Sciences Quarterly*, and *Journal of Management*).

Department heads in management engage in a number of activities which can be aided by the

results of our research. Given requirements to maintain or earn accreditation, competition to attract and keep productive researchers is important. Using journal rankings such as ours aids in the evaluation of the quality of the research output. In addition, our methodology, which shows that an article is likely to receive almost 30 percent of its citations in very good journals within the first 4 years after publication, and over half within 7 years, may be used to evaluate and reward the performance of serious scholars. By focusing on how many times and where a scholar's recent as well as lifetime research has been cited, we obtain additional objective input into the tenure and promotion process. However, we should be aware of the findings by Park and Gordon (1996) that in most business schools serious scholarship does not increase the likelihood of obtaining tenure in strategic management (perhaps due to the potential threat offered to less accomplished senior faculty who are evaluators).

Management department faculty are often in competition with other departments within their business colleges for research funding. Publishing in highly cited journals and being cited often may provide support for a department head's claim for the need for additional funding. Relatedly, university libraries must make difficult journal subscription decisions. Since budgets available for journal subscriptions have been shrinking, our journal rankings, which are based on usage (citations), provide a reasonable basis for comparing rival journals to provide the resources to perform quality research, particularly access to journals which seem to be used as an important input in the progression of management literature. In addition, our rankings highlight an overlap between management literature and related social sciences (i.e., psychology, sociology, economics, etc.). Decisions regarding the selection or cancellation of journal subscriptions should incorporate input from related fields rather than relying on an individual department or college. The burden for funding such shared resources should likewise be shared.

Since authors are subjected to evaluations based on publication placement, there is a competition among journals to attract the highest-quality submissions. Our journal rankings may provide a gauge against which journals and editors can determine how well they are faring in competition

<sup>14</sup> Scholars incorporate a multitude of factors (i.e., match between research topic and journal purpose, desired audience, probability of acceptance, cost, likelihood of inspiring future research, etc.) in selecting a journal to submit research.

for the best manuscripts. They also provide some basis for measuring the reviewers' ability to select the best manuscripts for publication.

We believe that our results provide valuable insights into the field of management and its development. In addition, our results should be useful for individual management scholars, practitioners, management departments, university libraries, and management journal editors.

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## APPENDIX: CITATION DISTRIBUTION DETERMINED BY THE GENERALIZED GAMMA DENSITY FUNCTION

We first define the citation of a scholarly work as the probability that it will be cited within a specified time period. Let  $T$  indicate the time to citation of an individual work, where  $T$  is identically independently distributed (i.i.d.). The random variable  $T$  has a continuous probability function,  $f(t)$ , where  $t$  is a realization of  $T$ . The cumulative probability is

$$F(t) = P(T < t) \quad (3)$$

where  $F(t)$  is the cumulative distribution of  $T$ . The conditional probability that a scholarly work will be cited in the interval from  $T=t$  to

$T=t+\Delta t$ , given that it is not cited before time  $t$ , is given by

$$\lambda(t, t + \Delta t) = P(t < T < t + \Delta t \mid T > t) \quad (4)$$

or

$$\lambda(t, t + \Delta t) = \frac{F(t + \Delta t) - F(t)}{1 - F(t)} \quad (5)$$

Dividing this ratio by  $\Delta t$  and taking the limit as  $\Delta t \rightarrow 0$ , we get the citation rate, denoted by  $\lambda(t)$ . Hence:

$$\lambda(t) = \lim_{\Delta t \rightarrow 0} \frac{F(t + \Delta t) - F(t)}{\Delta t} \cdot \frac{1}{1 - F(t)} \quad (6)$$

$$\lambda(t) = \frac{f(t)}{1 - F(t)} \quad (7)$$

The citation rate,  $\lambda(t)$ , is the probability of citation in the next instant  $\Delta(t)$ , conditional upon its not having been cited at time  $t$ . Equation 7 can be written as follows:

$$f(t) = \lambda(t) (1 - F(t)) \quad (8)$$

which expresses the density function in terms of the citation rate and the cumulative density function. Clearly, all three functions  $f(t)$ ,  $F(t)$ , and  $\lambda(t)$  are related, and each depends upon the same distributional parameters. Therefore, having the estimated parameters for any one of the functions allows the determination of the other two.

The equation of the generalized gamma density function is<sup>15</sup>

$$f(t) = \frac{\lambda \rho}{\Gamma(\theta)} (\lambda t)^{(\rho\theta-1)} e^{(-\lambda t)^\rho}, t \geq 0 \quad (9)$$

where  $f(t)$  is the density function,  $\rho$  and  $\theta$  are shape parameters,  $\lambda$  is the scale parameter, and  $\Gamma$  is the mathematical gamma function. For  $\theta > 0$ ,  $\rho > 0$ , and  $\lambda > 0$ , a family of distribution is defined by the three-parameter generalized gamma density function for various values of the parameters (see Kalbfleisch and Prentice, 1980).

<sup>15</sup> Among other topics, this model has been used to examine long-distance telephone call duration by Cameron and White (1990), the shape of unemployment duration by Swaim and Podgursky (1992), and the distribution of income by McDonald (1984).

This density function represents a positively skewed curve that starts at the origin and tends to have a sharp peak at the mode. The model nests several commonly used distributional models. Special cases include the exponential model (where  $\theta = \rho = 1$ ), as well as the Weibull (where  $\theta = 1$ ) and gamma (where  $\rho = 1$ ) distributions. The log-normal is also a limiting case as  $\theta \rightarrow \infty$ .<sup>16</sup> Each of these distributions is used to investigate which distribution provides the best fit of the data. For estimation, it is convenient to simplify Equation 10 by letting  $w = (\log t - \beta)/\sigma$ ,  $\rho = 1/\sigma$ , and  $\lambda = e^{-\beta}$ . Then the density for log  $t$  becomes:

$$f(\log t) = \frac{1}{\sigma\Gamma(\theta)} e^{(w\theta - e^w)} \quad (10)$$

and its log-likelihood function can be written as<sup>17</sup>

$$L = -n\log\sigma - n\log\Gamma(\theta) + n\sum w_i - \sum e^{w_i} \quad (11)$$

When the estimation is made by the maximum likelihood technique, the model expresses the proportional contribution of cited works with an elapsed period of  $t$  as a nonlinear function of the elapsed time (i.e., the period between the cited article and the article citing it).

<sup>16</sup> Taking the limit as  $\theta \rightarrow \infty$ , the generalized gamma distribution corresponds to a log-normal distribution with parameters  $\mu$  and  $\sigma$ . The relationship between the parameters are  $\mu = (\theta\lambda^{-\rho} - 1)/\rho$  and  $\sigma^2 = \lambda^{-\rho}/\rho^2$ . See McDonald (1984).

<sup>17</sup> In order to estimate the proposed model, we used the log of time duration. Midpoint values were used rather than the endpoint values (i.e., instead of using 0,1,2 . . . we used 0.5, 1.5, 2.5, and so on). This was done since we cannot take the log of zero. To determine whether the midpoint methodology created any bias, we also estimated the model using the endpoints, but eliminating the observations with an endpoint of zero (this resulted in eliminating 80 of approximately 24 000 observations). No significant differences were found between the two models.