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ABSTRACT

This study develops a set of empirically and theoretically sound citation-based bibliometric indicators of scientific research performance and applies them in an exploratory comparative study of the University of Tennessee-Knoxville's (UTK's) Nutrition Department with three of its peer programs at the University of Florida, the University of Georgia, and Virginia Polytechnic Institute and State University over a five-year period (1992-1996). A search of the bibliometric literature revealed much criticism of the use of citation analysis, little consensus about the solutions, and even less empirical data applicable to departmental level studies. Therefore, for the purposes of this study, self-citations were not excluded from the data, equal publication credit was given for multi-authored papers, and the two-year citation window was used in the calculation of bibliometric indicators and impact measures. The overall conceptual approach used was a limited version of Martin and Irvine's (1981, 1983) methodology of multiple converging indicators of scientific performance, using only bibliometric indicators, drawing on the citation data from the Institute for Scientific Information's "Science Citation Index-Expanded," and the "Journal Citation Reports." A set of eight empirically sound and theoretically justifiable indicators was developed and applied in this study. Of the four peer Nutrition programs evaluated, the UTK Nutrition Department ranked second in both overall rankings and in the Actual Impact Group of indicators, and ranked third in the Publication Output and Benchmark Groups of Indicators. Forty-three tables and figures are included. Appendixes contain: an annotated bibliography of selected papers relating to journal impact factors; evaluation of bibliometric indicators from the nine bibliometric studies analyzed in the literature review for possible use in this study; evaluation of the nutrition programs from each UTK peer institution for use in this study; data worksheet forms; and journal set data for each nutrition program, by year, 1992-1996. (Contains 56 references.) (Author/AEF)

IR

DEVELOPING COMPARATIVE BIBLIOMETRIC INDICATORS FOR EVALUATING THE RESEARCH PERFORMANCE OF FOUR ACADEMIC NUTRITION DEPARTMENTS, 1992-1996: AN EXPLORATORY STUDY

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Eric George Ackermann
May 2001

ABSTRACT

The goal of this study is to develop a set of empirically and theoretically sound citation-based bibliometric indicators of scientific research performance and apply them in an exploratory comparative study of the University of Tennessee-Knoxville's Nutrition Department with three of its peer programs at the University of Florida, the University of Georgia, and Virginia Polytechnic Institute and State University over a five-year period (1992-1996). A search of the bibliometric literature revealed much criticism of the use of citation analysis, little consensus about the solutions, and even less empirical data applicable to departmental level studies. Therefore for the purpose of this study, self-citations were not excluded from the data, equal publication credit was given for multi-authored papers, and the two-year citation window was used in the calculation of bibliometric indicators and impact measures. The overall conceptual approach used was a limited version of Martin and Irvine's (1981, 1983) methodology of multiple converging indicators of scientific performance, using only bibliometric indicators, drawing on the citation data from the Institute for Scientific Information's *Science Citation Index- Expanded,* and the *Journal Citation Reports*. A set of eight empirically sound and theoretically justifiable indicators was developed and applied in this study. Of the four peer Nutrition programs evaluated, the UTK Nutrition Department ranked second in both the overall rankings and in the Actual Impact Group of indicators, and ranked third in the Publication Output and Benchmark Groups of indicators.

To the Graduate Council:

I am submitting herewith a thesis written by Eric Ackermann entitled "Developing Comparative Bibliometric Indicators for Evaluating the Research Performance of Four Academic Nutrition Departments, 1992-1996: An Exploratory Study." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Information Sciences.

Elizabeth S. Aversa

Elizabeth S. Aversa, Major Professor

We have read this thesis
and recommend its acceptance:

Pat L Fisher

Douglas Raber

Accepted for the Council:

Interim Vice Provost and
Dean of The Graduate School

DEDICATION

To my wife Liz and my mother Joyce,

both of whom always believed in me

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There are many people to whom I am grateful for making my time at the University of Tennessee- Knoxville, so rewarding. I have benefited greatly from knowing the faculty and graduate students in the School of Information Sciences, and hope that these relationships will endure. I am particularly grateful to my Thesis Committee, Elizabeth Aversa, Pat Fisher, and Doug Raber for their support and encouragement. Whatever merits this thesis possesses is due primarily to their guidance and suggestions, whereas its faults and shortcomings are mine alone.

The last but greatest debt is owed to my wife (and best friend) Liz. That our love and friendship survived the long separations and endless hours of thesis work is a due in no small part to her efforts. Without her I would have never gotten this far.

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CHAPTER 1

INTRODUCTION

Background

The goal of the College of Human Ecology at the University of Tennessee-Knoxville (UTK) is to become one of the top twenty-five of its kind in the country. To this end, Dr. Jim Moran, Dean of the College of Human Ecology, asked Dr. Elizabeth Aversa, the Director of the School of Information Sciences, to help him devise bibliometric measures for evaluating his component departments and comparing them to their peers nationwide (J. Moran, personal communication, June 23, 2000). A preliminary bibliometric study of the Nutrition Department, one of the units in UTK's College of Human Ecology, was conducted during the Summer Term of 2000, and forms the basis of this study (Ackermann 2000). Nutrition is a science-based discipline focused on understanding the relationships among nutrients, between diet and certain diseases such as cancer and obesity, and how this understanding can be used to promote healthy living (Moran 2000). As a science-based discipline, the primary research publication product for the Nutrition field is the scholarly scientific journal article (Van Raan and van Leeuwen 1998).

Research Problem

"My goal is simple. It is the complete understanding of the universe, why it is as it is and why it exists at all." – Stephen Hawking (Institute for Scientific Information 2000; Khalid, 2000)

The goal of this study is to develop empirically supported and theoretically justifiable publication- and citation-based bibliometric measures for the comparative evaluation of scientific research performance of the UTK Nutrition Department and three of its counterparts from peer, benchmark institutions as well as to the Nutrition field as a whole. The emphasis of this study is on interdepartmental productivity comparisons between departmental units rather than on intradepartmental comparisons of individual performance, which are suitable for internal purposes such as tenure review and promotion. Though the data for these measures will be drawn from the print journal publication efforts of a program's research faculty over a five-year period (1992-1996), it is the Nutrition Department itself, not the individual faculty researcher, that will be the basic unit of comparison (cf. Kim and Kim 2000; Cronin and Overfelt 1994). Once completed, this study will provide some of the baseline bibliometric data for the ongoing comparison and ranking of the UTK Nutrition Department's current and future research performance with similar departments at peer institutions as well as with the entire Nutrition discipline.

Terminology

For the purposes of this study, *bibliometrics* or *bibliometry* refers to "the measurement of scientific publications and of their impact on the scientific community, assessed by the citations they attract," providing a "portfolio of indicators that can be combined to give a useful picture of recent research activity" (Garfield 1989, 94). In this context, a *bibliometric indicator* is a partial or incomplete measure of a specific aspect of scholarly scientific publishing (Martin and Irvine 1983; Martin 1996), and is sometimes used interchangeably with *bibliometric measure* or *bibliometric method* in the literature (e.g., Garfield 1989). A *citation* (or *cite*) is when one document (the *citing document*) formally references (or *cites*) another document (the *cited document*) as an information source, or to support a position or interpretation, etc. (Institute for Scientific Information 1999; MacRoberts and MacRoberts 1989). A *self-citation* (or *self-cite*) is when the citing document and the cited document share one or more of the same authors (Phelan 1999; Noyons, Moed, and Luwel 1999), and a document's *citedness* is the number of times it has been cited by other citing documents. *Papers* or *articles* are original journal research articles, technical notes, and reviews articles, excluding letters, editorials, meeting abstracts, and news items (Institute for Scientific Information 1999). *Citation lag* is the time between an article's publication in a scholarly print journal and when it receives its maximum number of citations (the *citation peak*). Fast moving fields can have a relatively short citation lag measured in months, while for slower moving fields the citation peak can be at three to five years (or more) after publication (Garfield 1989).

Research refers to both basic "curiosity driven" and long-term, specific application or goal oriented "strategic" research (Rinia, van Leeuwen, van Vuren, and van Raan 1998), while *science* includes natural science, mathematics, as well as engineering (e.g., electronics) and multidisciplinary fields such as nutrition and food. *Academic department* or *departments* include not only those discipline-specific organizational units traditionally associated with a particular university, such as the Department of Physics at the University of Tennessee, but also *research centers, academic institutes,* or *research groups*, often multi-disciplinary, affiliated with a specific university or consortium of universities, such as the Inter-university Centre for Micro-Electronics in Leuven, Belgium and the Max-Planck-Institut fur Radioastronomie in Bonn, Germany. *Research performance* and *research productivity* both refer to the published output or product of research activity, as distinct from measuring "scientific progress" (Moravcsik 1973; cf. Martin and Irvine 1983) which is beyond the scope of this study. *Research program* is often used synonymously with academic department, research center, and research group. Unless otherwise noted, a *field* or *research field* is synonymous with a Subject Category from the Institute for Scientific Information's (ISI's) *Journal Citation Reports (JCRs)* that contains at least one journal that published at least one paper authored or co-authored by at least one member of one of the four departments under study. The *Nutrition field* is composed of the Nutrition and Dietetic, and the Biochemistry and Molecular Biology subject categories (Moran 2000).

In reference to the findings, *actual* results are those achieved by the members of a group under study. *Expected* results are those that the unit under study would achieve if it were performing at the contemporary *world* or *world-wide* level (Bourke and Butler 1995). Since the approximately 80% of the source data for the ISI's *Science Citation Index* is from the results of Western scientific research (Moed, de Bruin, and van Leeuwen 1995), *world* or *world-wide* in reality refers to the research journal publications from Western countries such as the United States, Japan, and Australia (Moed, de Bruin, and van Leeuwen 1995; van Raan 1996; van Raan and van Leeuwen 1998). Note that in the literature, *world* and *world-wide* can be used to refer to other European countries as well, though it is not always possible to tell from the context which sense is meant.

Scope and Limits

Ideally, a study of research productivity and performance at the departmental level would include not only bibliometric indicators, but input measures such as the number of researchers, amount of time each researcher can spend actually doing research, the amount and sources of research funding, and the number of support staff (Martin and Irvine 1983; Koenig 1983; Zachos 1991). The assessment would also include other performance output indicators such as peer review results, number of 'discoveries' or major scientific contributions, and formal recognition in the form of prizes, medals, membership in prestigious scientific academies, patents, etc. (Myers 1970; Martin and Irvine 1981, 1983; Garfield 1989; Clark 1957; Koenig 1983).

The measures in this study however will be limited to publication and citation based bibliometric indicators, and the methods to basic citation analysis. Publication counts are a measure of research productivity (Rinia et al. 1998; van Raan and van Leeuwen 1998: Noyons, Moed, and Luwel 1999; Martin & Irvine, 1983). Citations are measures of "quality" in terms of impact or influence on subsequent publications (Rinia, et al., 1998; van Raan & van Leeuwen, 1998; Martin & Irvine, 1983). From these two measures many other bibliometric measures such as Citations per Publication (CPP) (Rinia et al. 1998; van Raan and van Leeuwen 1998; Martin and Irvine 1983; Korevaar and Moed 1996), Citation Productivity per Researcher (CPR) (Zachos 1991; Nederhof, Meijer, Moed, and van Raan 1993) are derived (for more examples see Appendix B). Publication counts and citations are also widely used due in a large part to the relative ease of accessing the information from the ISI's citation indexes, especially through the online version *Web of Science*.

The data for this study will be limited to any publication and citation data from scholarly, referred articles appearing in the print journal literature, and authored by at least one researcher from one of the four nutrition departments being examined. These departments are the Nutrition Department at the University of Tennessee- Knoxville, the Department of Food Science and Human Nutrition at the University of Florida, the Department of Foods and Nutrition at the University of Georgia; and the Department of Human Nutrition, Foods, and Exercise at the Virginia Polytechnic Institute and State

University. The publication and citation data will be from 1992-1996, and the journal impact data from 1994-1998.

For the purposes of this study, citation analysis is a method of using publication output (or the number of publications) and the number of citations received by those publications in subsequent publications to "assess the research performance of countries [e.g. Bourke and Butler 1993; Pestana 1992], universities [e.g., Davis and Royle 1996; Nederhof et al. 1993], departments [e.g., Martin and Irvine 1983,Zachos 1991], or persons [e.g., Kim and Kim 2000; Cronin and Overfelt 1994; de Arenas, Valles, Arenas 1999]" (Noyons, Moed, and Luwel 1999, 115). This study will focus on using citation analysis to examine the research performance of academic science departments, specifically in the Nutrition field.

It should be noted in passing that there are other bibliometric methods available for studying the scientific literature, such as co-citation analysis, co-word analysis, or citation (or scientific literature) mapping. Though useful and highly informative (e.g., Noyons, Moed, and Luwel 1999), they are very labor and time intensive which unfortunately puts them beyond the scope of this study. (For an excellent treatment of these techniques, see Small 1999 and White and McCain 1998).

CHAPTER 2

REVIEW OF THE LITERATURE

Background

The continuing reduction of funding available for research has led to a growing need for more selectivity in the allocation of resources. Measures of past performance, though providing no guarantees, are still some of the most reliable means for deciding between competing social and scientific interests. Recently, policy makers and research managers have shown a growing interest in the use of indicators for assessing scientific output (Garfield 1989; Martin and Irvine 1983), and promoting research quality (van Raan 1996). Ideally, these indicators can be generated routinely (Garfield 1989; Martin 1996) and derived from criteria originating within the scientific community (Martin and Irvine 1983). This administrative interest is driven by both the need for greater accountability and the increasing criticism of the peer review system (Garfield 1989; Martin 1996).

Need for Funding Selectivity

Before the1960s, funding was generally unrestricted with allocation primarily based on criteria established by the scientific community and evaluated by the peer review system (Garfield 1989; Martin and Irvine 1981, 1983). By the early 1960s changes within the scientific community required greater funding selectivity. Big (and increasingly Expensive) Science continued to grow, with many new fields emerging, creating in turn more opportunities and demands for funding. Research became more multidisciplinary and collaborative, spawning extensive projects requiring increased coordination. This period also saw the rise of "strategic research," as well as rising economic constraints requiring increasingly difficult funding choices be made between competing research proposals (Garfield 1989; Martin and Irvine 1983; Martin 1996).

Peer Review System

Traditionally scientific evaluation was conducted by the peer review system (Garfield 1989; van Raan, 1996). However, this system has come under increasing strain and criticism for a number of reasons. For instance, it is increasingly difficult to get impartial reviewers in an environment of growing concentration of research facilities into fewer units (Garfield 1989; Martin 1996) and increased competition and rivalry for recognition and funding (Martin and Irvine 1983; van Raan 1996; Chubin and Hackett 1990). The peer review system is increasingly perceived as an "old boy network" that favors established fields, and the protection of colleagues' declining research areas over emerging new ones (Garfield 1989; van Raan 1996; Chubin and Hackett 1990). There is also increasing recognition of the "halo effect" or the tendency to fund higher status and more visible programs (Garfield 1989) by an over-reliance on institutional or individual reputation (Martin and Irvine 1981, 1983; Martin 1996), or by an unwarranted extension of a university's overall prestige to all of its constituent departments (Koenig 1983).

Others complain of inconsistent reviewer assessment criteria and interpretation (Garfield 1989; Seglen 1997) based in part on a tendency of reviewers to interpret the research efforts of others through their own research activities and interests (Martin and Irvine 1983). Such inconsistent performance is made worse by a growing lack of consensus about the nature of doing "good science", who its practitioners are, and where the "best" lines of inquiry are, especially in relation to newer research areas (Garfield 1989; Seglen 1997; Chubin and Hackett 1990). Part of the problem is due to an underlying tendency of most research scientists to conform to conventional and accepted patterns of belief (Martin and Irvine 1981, 1983). In addition, little thought is given to the actual cost of review process in terms of administrative support and scientists' time, a factor often ignored or minimized (Garfield 1989). Also overlooked is the reality that most if not all reviewers cannot "guarantee the originality and accuracy of the manuscripts they review" because they have neither the time nor the resources nor in some cases the expertise to replicate or even substantially recalculate or reanalyze the data (Chubin and Hackett 1993, 87). Hence the end-product of peer review is ultimately the result of expert perceptions formed by a complex interaction of social and intellectual processes often not related to issues of quality (Martin & Irvine 1983; Chubin and Hackett 1990).

Bibliometric Indicators

For all its faults, the peer review process is, and probably will remain, an essential part of the assessment of quality in science (Garfield 1989; Martin and Irvine 1983; van Raan 1996; Rinia et al. 1998). Improvements to the system are needed, however, and among those suggested is the use of quantitative, objective scientific indicators to compliment the qualitative peer review process (van Raan 1996; Martin 1996). Of the various indicators available, the mostly widely used are those derived from the bibliometric study of publication counts and citations (Garfield 1989; Martin and Irvine 1983).

Publication Counts

The analysis of publication counts measures the total volume of research output in terms of journal articles, which is the accepted medium of reporting the results of scientific research by scientists (Garfield 1989; Martin and Irvine 1983; Martin 1996). The assumption is that each published scientific paper contributes to the advancement of scientific knowledge (Martin and Irvine 1983). There is also some empirical evidence that publication counts of individuals tend to correlate to a reasonable degree with other measures of scientific achievement, such as peer ranking and funding (Garfield 1989). At the level of individual assessment, publication counts can be as useful and perhaps more accurate than citation counts (Phelan 1999).

The use of publication counts is not without its critics. Martin and Irvine (1983) and Seglen (1992) pointed out that each individual paper does not necessarily make an equal contribution to science, as only about 15% of the scientists publish approximately 50% of the papers (Seglen 1992). Publication counts provide no indication of the quality of research output (Garfield 1989; Bayer and Folger 1966). Studies by Rinia et al. (1998) and Martin and Irvine (1983) found no evidence that publication counts of institutions and research groups correlate with either peer review ratings or other citation-based bibliometric indicators (see also van Raan and van Leeuwen 1998; Noyons, Moed, and Luwel 1999). The use of publication counts also ignores the importance in scientific communication of other, non-journal publications, both formal (e.g., technical reports) and informal (e.g., pre-prints) (Garfield 1989; Seglen 1997; Moravcsik 1973). Publication practices also vary among journals and research areas, institutions, and countries (Garfield 1989). A reliance of publication counts to measure research productivity may possibly encourage undesirable publication practices by authors, such as gratuitously conferring co-authorship, and the unnecessary division of a paper into "Least Publishable Units" (Garfield 1989; Schoonbaert and Roelants 1996). It also begs the question of how to assign publication credit to multiple authors of single papers in an environment that increasingly produces only multi-authored papers (Schoonbaert and Roelants 1996).

Citation Analysis

The reliance on publication counts alone brings with it the problem of quantity vs. quality (Bayer and Folger 1966; Hagstrom 1971). Publication counts over emphasizes the relative importance of the quantity of publications while saying nothing about the publication's "intrinsic quality and external impact" (Schoonbaert and Roelants 1966, 740; Martin and Irvine 1983). One solution is to use a system of weighting to account for the relative merit of each publication. Unfortunately, these weighting systems are usually devised in a very subject manner without "adequate theoretical basis for the choice of weights" (Martin and Irvine 1983). The use of citation analysis to provide a measure of quality (i.e., impact or influence) for evaluating scientific publications avoids this problem by using readily available, empirical data on the number of citations received by a given publication. It assumes that a publication's impact is on subsequent publications, with each instance of such influence showing up as a reference in the influenced (or impacted) paper (Martin and Irvine 1983).

Background

The use of citation analysis evolved out of a concern that publication counts alone did not account for another, perhaps more important, aspect of the scientific enterprise, the quality (or utility or the usefulness) of the research (Bayer and Folger 1996; Hagstrom 1971; Martin and Irvine 1983).

The origins of citation analysis, for all practical purposes, is tied to the development of the citation indexing database created by the Institute for Scientific Information (ISI), consisting of the reference lists extracted from a large number of scholarly journals (Seglen 1997). Citation analysis began in earnest with ISI's publication in 1961 of the *Science Citation Index (SCI)* (MacRoberts and MacRoberts 1989). It was designed as literature research tool, organized to show each reference, listed alphabetically by the first author's last name, the number of times it was cited in the previous year, and by whom (Seglen 1997). Over the years, the *SCI* was retrospectively expanded to 1945, and ISI added quarterly updates, five-year accumulations, the *Social Science Citation Index (SSCI),* the *Arts and Humanities Citation Index (AHCI),* CD-ROM (Schoonbaert and Roelants 1996) and on-line versions (*Web of Science)* covering 1970-present (Web of Science 2000). The total coverage by 1990 was 18,000,000 source publications with over 217,000,000 citations (Schoonbaert and Roelants 1996), with an annual processing rate by 1998 of approximately 12,000,000 references for 4500 journals (Institute for Scientific Information, 1999; Schoonbaert and Roelants 1996).

Assumptions

Citation analysis assumes that "an intellectual link exists between the citing source and reference article" (Garfield 1989, 96; Smith 1981), and that cited references are a record of their influence on an author's work. Such a view is based on a normative theory of science developed by Merton in 1957 (as cited in MacRoberts and MacRoberts

1989) in which "bibliographies are lists of influences," and scientists will "cite the work that they have found useful in pursuing their own research" (MacRoberts and MacRoberts 1989, 342). According to Merton's 1968 study (as cited in Case and Higgins 2000), citations are part of the rewards system in science, and come in the "form of social recognition, even when critical in nature" (p. 635). Citation analysis also assumes that a failure to cite is a rarity, and that most papers cite properly and accurately (MacRoberts and MacRoberts 1989; Smith 1981).

It is also assumed that citations can function as an indicator of scientific quality (Seglen 1997; Smith 1981) and importance, and the value of a publication are related to its explicit use as a citation in later papers (Schoonbaert and Roelants 1996). McAllister, Anderson, and Narin (1980) reported correlations of 0.5 to 0.8 between high citation counts and other recognized quality measures such as honorific awards like the Noble Prize (Garfield 1989) and the National Medal of Science (Myers 1970), academic position, and membership in scientific academies (Myers 1970; Phelan 1999). Citation frequencies of researchers have also been found to correspond to the overall peer ratings of departments or institutes to which they belong (Myers 1970; Garfield 1989).

For these reasons, the results of citation analysis have become highly influential within the scientific community. It has had an increasing effect on scientific reputations as well as individual bids for tenure, promotion, and research funding (Schoonbaert and Roelants 1996). However, citation analysis, like publication counts, is not without its critics, and many of the criticisms of publication counts apply to citation analysis as well.

Criticisms

The criticisms of citation analysis fall into five general categories: citation motivation and practice, citation database limitations, field dependent factors, consumer perceptions, and journal impact factors. Although each category has generated quite a bit of literature in its own right, especially journal impact factors, this paper will briefly address only the main issues within each category.

Citation motivation and practice

Citation motivation is more complex that just giving intellectual credit (MacRoberts and MacRoberts 1989; Case and Higgins 2000). Citation motivation can be idiosyncratic, driven by self-interest such as "hat-tipping" (paying homage) and attempts to curry favor with mentors, editors, or grant agencies (Case and Higgins 2000; Garfield 1989; Smith 1981).

Citations can be perfunctory as well, as was demonstrated by Moravcsik and Murugesan's (1975) study of a random sample of high energy physics papers publishing in the journal *Physical Review*. They found that slightly more than 40% of the references were to acknowledge papers that had done work in the same general research area, and not necessarily due to their contribution to the advancement of science (Moravcsik and Murugesan 1975). They note that such a high percentage of perfunctory citations raises "serious doubts about the use of citations as a quality measure" (Moravcsik and Murugesan 1975, 90).

Seglen (1997) found that among practicing scientists, the "primary criterion for reference selection" is the "utility within research rather than pure scientific quality" (p. 1050). Smith (1981) however noted that not all items used are necessarily cited, and "not all items cited were used" (p. 87). She also observed that citations do not always reflect the relative merit ("quality, significance, impact") of the cited item, but other factors as well, such as ease of accessibility in terms of its form, origins, language, and age (Smith 1981, 87-88).

Various citation practices can cause problems as well. For example, incorrect work can be highly cited (Garfield 1989; Martin 1996) as evidenced by Moravcsik and Murugesan's (1975) finding that 13-16% of their sample's references were negational, disputing the correctness of the reference. Authors can also create erroneous citations by depending on secondary sources rather than reading the original works (Case and Higgins 2000). Such papers can make a positive impact however by stimulating further research to confirm or deny the conclusions found in the erroneous papers (Martin 1996). Moravcsik and Murugesan (1975) noted that "a paper can be wrong on several levels," not just incorrect when written. They also pointed out that "all scientific papers turn out to be 'wrong' eventually in the sense that they are replaced by something better: (p. 92; see also Moravcsik 1973). Usually though, in the sciences erroneous papers are simply ignored (Garfield 1989).

Certain works, such as methodological papers and review articles, tend to be disproportionately used and cited (MacRoberts and MacRoberts 1989; Garfield 1989;

Martin 1996) due in part to lack of journal space preventing the citation of all the sources drawn upon by a researcher (Seglen 1997). There is no reason however to consider this type of article inferior or of less importance than other types of articles. Though they do not advance knowledge directly, methodological papers and review articles do so indirectly by providing "a foundation upon which other scientists can advance knowledge" (Phelan 1999, 123).

Self-citation, which can run from 10-30% (MacRoberts and MacRoberts 1989; Seglen 1997), may artificially inflate the citation rate (Garfield 1989), and lead to a form of cronyism where authors cite their own friends and colleagues thereby reducing the value of citation analysis (Phelan 1999; Martin 1996). There is some empirical evidence to the contrary, however. In their study of cancer research Lawani and Bayer (1983) observed that their results remained unchanged "whether or not self-citations are included ($p<0.001$)" (p. 64). The argument against the inclusion of self-citations also ignores the fact that the more papers a researcher has published in a specific area, "the larger the reservoir grows for justifiable self-citation" (Schoonbaert and Roelants 1996, 744). Phelan (1999) finds that due to the cumulative nature of focused individual research, self-citation is "not only a natural and acceptable procedure, it is also a useful and informative one" (p. 123). It is only a potential problem when evaluating individual researchers. Otherwise self-citation is probably not an important problem at more aggregated levels of study (Phelan 1999).

As for the related problem of 'cronyism,' Phelan (1999) thinks that fact that "academic leaders cite each other extensively, however, simply reinforces that fact that a large number of citations tends to indicate a scholar's position in the field's hierarchy." It is actually a "manifestation of the power relations existing within a field. That citation counts reflect this reality is not a methodological shortcoming" (Phelan 1999, 127). Martin (1996) found no evidence that cronyism existed, except as a "modern legend" (p. 357). However, these positions do not address the underlying problem of the influence that such scholarly hierarchies can have on peer review processes, which are instrumental in determining research direction, grant funding, as well as who gets published in which journal (Daniel 1993; Chubin and Hackett 1990).

The focus on citations to formally published papers ignores the informal influences on an author's work, such as conference discussions, pre-prints, and in-house shop talk (MacRoberts and MacRoberts 1989). In addition, there can be an "obliteration phenomena" at work, where theories and techniques become so assimilated into current scientific knowledge that their originators cease to be credited (Garfield 1989; Moravcsik 1973; Smith 1981).

Citation database limitations

The criticisms concerning the database limitations are particularly important considering that the ISI citation databases are the only source for citation data (Garfield 1989). The main problems concern information retrieval and the database's publication coverage. Retrieval accuracy can be affected by the presence of author homographs (different authors having the same name), inconsistent use of initials, inconsistent spelling of foreign names, and citing errors (Garfield 1989; MacRoberts and MacRoberts 1989; Seglen 1997). The homograph problem can be a particularly vexing when dealing with inconsistently anglicized versions of East Asian names. These problems of author identification (misspelled names, homographs, and institutional addresses) are not always, in themselves, intractable. The solutions, while tedious and time consuming, are not impossible. They do however require the examination of every paper and institutional affiliation of every author being considered, as well as accepting that 'data cleaning' cannot be done exclusively by computer (Phelan 1999).

As for the database's publication coverage, it only covers the journal literature (van Raan 1996). The coverage also changes over time at an estimated annual rate of approximately 10% (Schubert, Glanzel, and Braun 1989) as some journals are dropped and others added, and the expansion of publication types in 1977 to include conference proceedings (Garfield 1989; MacRoberts and MacRoberts 1989; Seglen 1997). In all fairness though, it is simply not feasible for the ISI database coverage to be completely comprehensive (Schoonbaert and Roelants 1996). Space and economics preclude the inclusion of hundreds of low impact journals into the citation database (Garfield 1996). Also the lack of coverage may not be as serious a problem as the critics maintain. For example, the Australians found strong relationships between publication in all journals and publication in ISI covered journals at both the university and departmental levels of comparison, especially in the natural sciences (Phelan 1999). Nederhof, Meijer, Moed, and van Raan (1993) discovered in their study of a Dutch agricultural university that ISI covered journals accounted for over 80% of the citations in the natural and biosciences departments. Therefore, Phelan (1999) thinks that for the vast majority of research fields, the ISI data is "likely to provide an excellent indication of total research activity" (p. 126; see also Korevaar and Moed 1996).

The coverage of the citation database is also unequal, varying between research fields, with some being better represented than others, e.g., 90% for chemistry vs. 30% for biology (Seglen 1997; Schoonbaert and Roelants 1996). However it is important to note that the fluctuating coverage reflects ISI's attempts to select and maintain database coverage of the top 10% of the journals that provide 90% of the significant literature. To do so requires a periodic adjustment to the number of journals covered (Schoonbaert and Roelants 1996) to reflect the changes in science over time (Phelan 1999). By adding journals as they begin to attract substantial citations, ISI is actually creating a current and dynamic journal set that more accurately reflects contemporary academic interests, while also making it more suitable for use in studies focused on a single point in time as well as for those examining change over time. This means, for example, that an institution with a higher ranking in a dynamic journal set indicates that it is receiving more recognition in research areas that are currently important (Phelan 1999). It may also be equally reflective of the state of contemporary of scientific politics as much as the objective, rational evaluation of scientific research (Chubin and Hackett 1990; Daniel 1993).

Other critics point out that the database also has a bias in favor of journals using the English language and the Roman alphabet (Garfield 1989; MacRoberts and MacRoberts 1989; Seglen 1997). However, practically speaking, this is only a problem in studies examining highly specialized fields or that are assessing the importance of regionally specific research in non-English speaking countries (Phelan 1999).

Field dependent factors

There are inconsistencies within the ISI citation database caused by field dependent factors or factors relating to a specific discipline or research area. Of particular concern are the varying citation (and publication) practices between research fields and over time (Moravcsik 1973; Garfield 1989; MacRoberts and MacRoberts 1989). The size of the research field can potentially effect the probability of being cited, with larger or broader research fields being more likely to be cited than smaller or narrower ones (Garfield 1989; Seglen 1997). The rate at which papers become obsolete varies with field, with lower cited papers become obsolete quicker than higher cited ones (Garfield 1989). It can also be difficult to place a newer, multi-disciplinary research area into one of the current disciplinary or research-based publication groups (Garfield 1989). There is also the problem of citation lag, which varies between research fields. Some critics see this variation in citation lags as disproportionately rewarding the faster, "hotter" research fields with faster citation peaks, often measured in months and penalizing fields with a longer, slower citation peaks measured in years (Schoonbaert and

Roelants 1996). For these reasons alone, the results of citation analysis cannot be compared across different research fields (Moravcsik 1973; Seglen 1997; Martin 1996).

Consumer perceptions

For researchers familiar with the strengths and weakness of citation analysis, the evaluation of research quality means that citations measure 'impact' rather than 'quality' (cf. van Raan 1996). Impact, when defined as the actual influence of a paper on the surrounding research activity during a specified period of time, is easier to operationalize in a bibliometric study than is 'quality', a more elusive and difficult to define concept (Phelan 1999; Martin and Irvine 1983; Martin 1996; Garfield 1989; Korevaar and Moed 1996; Smith 1981).

Yet consumers of bibliometric studies, such as university administrators and government officials, are more than willing to make a strong conceptual link between citation analysis and the assessment of research quality, which reflects their primary interest in bibliometric analysis. The problem revolves around the different understandings or perceptions of indicator precision held by bibliometric researchers and consumers. Consumers tend to have greater confidence in the precision of the bibliometric indicators than do researchers, reflecting their focus on broad results rather than on the details of measurement, which is of primary interest of bibliometric researchers (Phelan 1999). Phelan (1999) recommends that given the complexities of measurement and the emotionally charged label 'research quality,' it would be better to emphasize to consumers the concept of visibility or impact rather than quality.

Journal impact factors

One of the most controversial aspects of citation analysis was (and continues to be) the creation and use of ISI's journal impact factor (for more detail, see Appendix A). Journal impact factors (JIFs) were originally created as indicators of journal citedness, and as a means of comparing journals of differing sizes (Garfield 1996). JIFs were designed to neutralize the advantage of larger journals with their greater pool of potentially citable articles over smaller ones (Schoonbaert and Roelants 1996; Institute for Scientific Information 1999). They are defined as "ratios obtained from dividing citations received in one year by papers published in the two previous years. Thus, the 1995 impact factor counts the citations in 1995 journal issues to "items" [i.e., "original research and review articles, as well as notes"] published in 1993 and 1994" (Garfield 1996, 1; Institute for Scientific Information 1999, 14). If the coverage were for one year, it would be biased in favor of rapidly changing fields, whereas coverage of greater than two years would make the JIFs less current (Garfield 1999). The results are published annually in ISI's *Journal Citation Reports* (Seglen 1997; Schoonbaert and Roelants 1996; Institute for Scientific Information 1999).

While originally intended as a way to compare journals, the use of the JIF has evolved, especially in Europe, to include the assessment of the quality or impact of not only journals, but also research groups and individual authors (Seglen 1997; Garfield 1999). This change in use has caused problems, especially in the evaluation of individual author impact because the journal comparison involves a relatively larger population of articles and citations, far more than the vast majority of authors usually produce (Garfield 1999).

A particularly controversial use of the JIF is as a surrogate measure or substitute for actual citation counts. This use of the JIF is based on the assumption that journal is representative of its articles (Seglen 1997). Using the JIF as a surrogate is a relatively simple and inexpensive alternative to citation counts, which could be especially useful for large corporations and universities working with huge datasets (Schoonbaert and Roelants 1996). However, the use of JIFs as citation surrogates would only work if the frequency of article citation rates formed a Gaussian (normal) distribution around the population mean (i.e., the journal impact factor). Actual journal article citedness is very skewed with only about 15% of the articles accounting for approximately 50% of the citations (Seglen 1997; Schoonbaert and Roelants 1996; Phelan 1999). In addition, Nederhof et al.'s (1993) study found the JIF to be a poorer predictor of actual impact than the use of actual impact data.

The use of the JIF as a surrogate, however, can say something about the relative value of an individual paper accepted by a high impact journal for publication. This acceptance by the journal's peer reviewers and editorial board can be seen as an acknowledgement of the paper's worth and accreditation (Schoonbaert and Roelants

1996). This position has some empirical support from McAllister, Anderson, and Narin's (1980) study of scientific journals, which found correlations between a journal's impact factor and its peer assessment ranging from 0.4 to 0.9. Also, absolute citation counts ignore the greater weight that citations in higher prestige journals should get (Garfield 1989; cf. Davis and Royle 1996). Although Garfield (1996) warns against the use of the JIF in place of actual article citation counts as a dangerous expedient, especially in faculty evaluation, he acknowledges that JIFs could be used as surrogates in unusual circumstances.

There are other criticisms of the journal impact factor. For instance, the way that JIFs are determined could possibly cause inflated results. This is due to the inclusion of citations from all types of documents in the numerator, while only journal articles, technical notes, and reviews used in the denominator (Seglen 1997; Institute for Scientific Information 1999). However, the addition of all documents types, most of which were not intended to be cited, would unfairly lower the JIF of journals that publish mainly currently citable source documents, such as *The Lancet* and the *New England Journal of Medicine* (Schoonbaert and Roelants 1996). In addition, several studies have shown the current source document types in the *SCI* account for 69-95% of the publications and their citations (Moed and van Leeuwen 1995; Bourke and Butler 1993).

Another criticism is that the JIF, based on citations up to two years after publication, penalizes journals with longer publication lags, and those in slower moving research fields in which maximum potential citation peaks are not reached until three to five years after publication (Seglen 1997). It may be however that this problem with the two year 'citation window' is not as significant as it seems. Garfield (1999) found that when journals within the same disciplinary categories are examined, their impact rankings based on one year, seven year or fifteen year JIFs do not differ significantly.

There are also some fears that authors will shun journals with lower JIFs in favor of those with higher ones regardless of actual distinctions between quality, scientific suitability, and editorial fairness (Seglen 1997). However, Garfield (1996) points out that the JIF was never intended as a substitution for the editorial judgment necessary to select the best papers. In the final analysis, says Garfield (1996), "impact simply reflects the ability of journals and editors to attract the best papers available" (p. 1).

Conclusions about citation analysis

No system of counting result or ranking can be made fool proof. "In the absence of other reliable methods based on purely quantitative methods, this bibliometric approach is arguably the next best thing to the direct assessment of the intrinsic quality of the publication" (Schoonbaert and Roelants 1996, 740).

In general, most of the criticism of citation analysis does not reject it for a lack of objectivity, but rather because it does not take into account enough of the particular context of individual cases. Unfortunately, excessive concern with contextual details of individual cases can lead to the continuous creation of refining parameters, each calibrated by discipline-specific coefficients (e.g., weighted or relative JIFs) to correct discipline-related inequities, as well as the inclusion of things like the 'fractional citation counting' (giving each author of a single paper a fraction of the credit). Such an approach would soon make any ranking formula unworkable (Schoonbaert and Roelants 1996).

Also, one should keep in mind that much of the criticism of the ISI's citation indexes and its *Journal Citation Reports* appear to be based on relatively limited bodies of evidence. The ISI has always acknowledged their limits, and warned against the indiscriminate use of their products, especially for individual judgments (Schoonbaert and Roelants 1996; Institute for Scientific Information 2000).

Bibliometric methods should never be accepted as autonomously conclusive (Schoonbaert and Roelants 1996). The use of multiple bibliometric indicators in conjunction with other imperfect indicators, such as the results of peer reviews (Garfield 1989; van Raan 1996; Martin 1996; Phelan 1999), can reduce much of the negative emotional response to citation analysis (Schoonbaert and Roelants 1996; Martin 1996), as well as improve the overall accuracy of research assessment (Martin and Irvine 1983; Martin 1996). Several important limitations of citation analysis to remember are that citation patterns vary between disciplines, not all specific research topics are equally popular at any given time, and the presence of English language bias in the citation data (Schoonbaert and Roelants 1996).

It is also important to remember that bibliometric indicators, though reasonably objective in their creation, still require some degree of interpretation of their meaning, leaving them open to being manipulated into supporting existing power structures by maintaining or bolstering their influence over research, funding, journal editorship, and publishing (Daniels 1993; Chubin and Hackett 1990). In addition, bibliometric indicators appear to work best when examining entities with large numbers of citations, which means that the examination of individual cases needs to be done with the greatest care (Phelan 1999).

Bibliometric Studies of Academic Science Departments

Availability of Published Studies

Compared to the published literature analyzing the method and theory of citation analysis, the number of studies applying citation and publication based bibliometric indicators is relatively meager. Of those available, only nine were found that evaluated departmental level (or the equivalent) research productivity. Only one published bibliometric study evaluated nutrition and food research, while the other eight examined academic science departments in such fields as experimental psychology, mathematics, and condensed matter physics. All nine studies were European in origin, with six produced by a group of researchers in the Netherlands associated with the Centre for Science and Technology Studies (CWTS) (see Table 1). None of the references consulted for this study gave any indications why there are so few published departmental level bibliometric studies available. Part of the answer may be in the desire of the studied departments to keep the results confidential (e.g., see Van Leeuwen, Rinia, and van Raan 1998).

Table 1. Nine bibliometric studies of academic science departments, research groups, and institutes, by type of research unit, location, and study source.

Type of Research Unit	Location	Source of Study
Agricultural university departments	Netherlands	CWTS (Nederhof, Meijer, Moed, and Raan 1993)
Experimental psychology departments	United Kingdom United States Netherlands	CWTS (Nederhof and Noyons 1992)
High energy physics: electron accelerator research centers	United Kingdom	SPRU (Martin and Irvine 1981)
Mathematics departments	Greece Belgium	BIU (Zachos 1991) CWTS (Korevaar and Moed 1996)
Micro-electronic research center	Belgium	CWTS & AWI (Noyons, Moed, and Luwel 1999)
National condensed matter physics programs	Netherlands	CWTS (Rinia, van Leeuwen, van Vuren, and van Raan 1998)
Nutrition and food research institute	Netherlands	CWTS (van Raan and van Leeuwen 1998)
Radio astronomy research centers	United Kingdom Germany Netherlands	SPRU (Martin and Irvine 1983)

Note(s):
For purposes of this study, *academic departments* includes not only those discipline-specific organizational units traditionally associated with a particular university, such as the Department of Physics at the University of Tennessee, but also *research centers, academic institutes,* or *research groups*, often multi-disciplinary, affiliated with a specific university or consortium of universities such as the Inter-university Centre for Micro-Electronics in Leuven, Belgium and the Max-Planck-Institut fur Radioastronomie in Bonn, Germany.

Table 1. (continued)

Source of Study: The associated agency responsible for the conducting the study, followed by the reference to its published version.
CWTS: Centre for Science and Technology Studies, University of Leiden, Netherlands.
AWI: Science and Innovation Administration, Belgium.
BIU: Bibliographic Information Unit, University of Ioannina, Greece.
SPRU: Science Policy Research Unit, University of Sussex, United Kingdom.

Sources(s):

Korevaar, J.C., and H.F. Moed. 1996. Validation of bibliometric indicators in the field of mathematics. *Scientometrics* 37, no. 1: 117-130.

Martin, B.R., and J. Irvine. 1981. Internal criteria for scientific choice: An evaluation of research in high-energy physics using electron accelerators. *Minerva* 19: 408-432.

Martin, B.R., and J. Irvine. 1983. Assessing basic research, Some partial indicators of scientific progress in radio astronomy. *Research Policy* 12: 61-90.

Nederhof, A.J., R.F. Meijer, H.F. Moed, and A.F.J. van Raan. 1993. Research performance indicators for university departments: A study of an agricultural university. *Scientometrics* 27: 157-178.

Nederhof, A.J., and E.C.M. Noyons. 1992. Assessment of the international standing of university departments' research: A comparison of bibliometric methods. *Scientometrics* 24: 393-404.

Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http://sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Zachos, G. 1991. Research output evaluation of two university departments in Greece with the use of bibliometric indicators. *Scientometrics* 21, no.2: 195-221.

Brief Comparison of Available Studies

The early CWTS studies (Nederhof and Noyons 1992; Nederhof et al. 1993) used relatively small data sets to focus on several of aspects relating to a department's research performance, such as comparative national and international standing (Nederhof and Noyons 1992). These early studies suffered from little or no literature review or analysis, generally incomplete reporting, and overall poor presentation. For instance, the Nederhof and Noyons (1992) study was so badly presented as to render it virtually valueless. In contrast, the later CWTS studies (Korevaar and Moed 1996; Rinia et al. 1998; van Raan and van Leeuwen 1998; Noyons, Moed, and Luwel 1999) were a vast improvement, using large data sets originally developed for other related projects, better research design and execution, as well as much improved presentation. These studies also shared the goal of discovering the specific relationship that their bibliometric indicators had with other indicators, especially peer review ratings.

The Zachos (1991) study of two Greek mathematics departments also suffered from the lack of a literature review as well. However, it is an excellent example of how multiple indicators, bibliometric and otherwise, can be used to provide a more complete evaluation of departmental research performance.

In many respects, the one of the earliest studies in the group, Marin and Irvine's (1983) examination of four radio astronomy research centers, is one of the best, building on their previous work (Martin and Irvine 1981). It has a good introduction, an excellent literature review and analysis, and a well-conceived and executed study with generalized (and generalizable) results.

A common theme that unites these various studies is a focus on the nature and behavior of a variety of bibliometric indicators rather than an interest in evaluating the research output of departments *per se*. This emphasis tends to make these studies exploratory rather than explanatory in nature. These studies also tend to address two associated issues rather frequently, the problems of self-citation and allotting publication credit to multi-authored papers.

Evaluation of the Bibliometric Indicators Used

The nine studies under consideration together generated twenty-six different publication and citation-based indicators. The evaluation criteria for determining the suitability of any of these indicators for this study involved the clarity and precision of description, the ease of calculation, the suitability for application to the circumstances of this study, and the interpretation of a particular indicator. The clarity and precision of the description of an indicator is required to insure that it is measuring what one thinks it is measuring, while the ease of calculation is important due to the time, staffing, and data source constraints of this study. The application of an indicator in a study will allow a determination of its suitability for the research conditions of this project, while its interpretation will indicate what information it can and cannot be expected to deliver.

Of particular value are those indicators that, in addition to meeting the aforementioned criteria, also indicate show a strong correspondence or correlation with other methods of evaluating research quality, particularly peer review. For example, Van Raan (1993, cited in van Raan and van Leeuwen 1998) considers the combination of bibliometric indicators and peer review ratings to represent the best method for evaluating research performance. McAllister, Anderson, and Narin's (1980) study reported correlations of 0.7 to 0.9 between departmental publication and citation rates and their peer rankings. There are also other studies that report findings that support the linkage between citations and peer review ratings such as the Rinia et al. (1998) evaluation of Dutch research into condensed matter physics, Koenig's (1983) study of pharmaceutical research performance, Clark's (1975) study of psychology, and Lawani and Bayer's (1983) study of cancer research.

Types of bibliometic indicators

Upon examination, these twenty-six indicators can be grouped into three general types, primary indicators, secondary indicators, and incidental indicators, based on their description, method of calculation, application, interpretation, and correlation with other non-bibliometric indicators (for more detail concerning the evaluation procedure, see Appendix B). A *primary indicator* is a partial measure of a specific aspect of research performance, and empirically correlates with at least one other indicator, such as peer review results. A *secondary indicator* is mainly used as a basis for calculating primary indicators, and on occasion, can be used as a primary indicator in its own right. An *incidental indicator* appears to have no explicitly useful or practical purpose in the study in which it appears. Of the twenty-six indicators under evaluation, seven are primary indicators, three are secondary indicators, and sixteen are incidental indicators. Since the latter seem to have no discernable practical use, only the ten primary and secondary indicators will be considered for use in this study (see Table 2).

Problem of Self-Citations

One of the problems that all the studies had to resolve is what to do with self-citations (or self-cites). Self-citations were handled in a variety of ways by the studies examined. For instance, Zachos (1991) separately counted and reported self-citations, in-house citations, and "foreign" citations. Van Raan and van Leeuwen (1998), Rinia et al. (1998), Noyons, Moed, and Luwel (1999) used both indicators that included self-cites, and some that did not. Nederhof et al. (1993) appeared to have left the self-cites in the data.

The crux of the self-citation issue seems to lay in the oft implied notion that the primary motive driving self-citation is self-aggrandizement, with the resulting distortion of the citation database (MacRoberts and MacRoberts 1989; Seglan 1997). There seems to be little empirical evidence however to support this assumption, and some research (Case and Higgins 2000) that indicates that an author's motivation to self-cite does not vary appreciably from the motivation to cite others. To remove automatically all self-

Table 2. Primary and secondary bibliometric indicators used in nine studies, by indicator, definition, and interpretation.

Indicator	Definition	Interpretation
Primary		
C	Total citations.	General impact measure.
CPP	Average citations per journal publication.	Actual impact normalized for size of publication output.
CPP/FCSm	Citations per paper compared to the average citation rate of all the journals in a field/sub-field.	Comparison of actual to expected field/ sub-field impact
CPP/JCSm	Citations per paper compared to the average citation rate of a specified journal set.	Comparison of actual to expected journal impact.
JCSm/FCSm	Average citation rate of the journal set compared to the average citation rate of all the journals in the same field/sub-field.	Impact of a journal set on its field.
HCP	Highly cited papers (or key papers), top 1% papers that equal or exceed a given citation threshold.	Number of high impact "discoveries"produced by a research group.
PPR	Publications per researcher.	Research output normalized for department size.
Secondary		
FCSm	Average citation rate of all the journals in a field/sub-field.	Average field impact.
JCSm	Average citation rate of all the journals in a specific journal set.	Average journal impact.
P	Total number of publications	Research or publication output.

Table 2. (continued)

Note(s):

Impact is a limited, partial measure of research quality in terms of influence on contemporary or future research.

Publications refer to original research papers, review papers, and technical notes.

Source(s):

Korevaar, J.C., and H.F. Moed. 1996. Validation of bibliometric indicators in the field of mathematics. *Scientometrics* 37, no. 1: 117-130.

Martin, B.R., and J. Irvine. 1981. Internal criteria for scientific choice: An evaluation of research in high-energy physics using electron accelerators. *Minerva* 19: 408-432.

Martin, B.R., and J. Irvine. 1983. Assessing basic research, Some partial indicators of scientific progress in radio astronomy. *Research Policy* 12: 61-90.

Nederhof, A.J., R.F. Meijer, H.F. Moed, and A.F.J. van Raan. 1993. Research performance indicators for university departments: A study of an agricultural university. *Scientometrics* 27: 157-178.

Nederhof, A.J., and E.C.M. Noyons. 1992. Assessment of the international standing of university departments' research: A comparison of bibliometric methods. *Scientometrics* 24: 393-404.

Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http:// sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Zachos, G. 1991. Research output evaluation of two university departments in Greece with the use of bibliometric indicators. *Scientometrics* 21, no.2: 195-221.

citations appears to unnecessarily penalize researchers working in new fields or in currently unfashionable fields, where there is not a large amount of relevant citable literature available. It also seems to unfairly penalize the efforts of veteran researchers who have built up a body of related work upon which they, like science in general, can then build upon for future research and development (Schoonbaert and Roelants 1996; Phelan 1999). While self-citation may be more of an issue at the level of assessing the individual researcher for tenure and promotion, it seems an unnecessary concern at the department level of aggregation (or higher) (Phelan 1999; see also van Raan 2000).

Problem of Multi-Authored Papers

The second problem of concern in these bibliometric studies is how to assign publication credit to all the authors of a multi-authored paper. Multi-authored publications were handled in a variety of ways by the studies examined. For example, Zachos (1991) counted them proportionally, adjusting "publication and citation counts" and giving "a fraction to every co-author" (p. 198). The other studies either credited one paper to each author, or did not state how the credit was distributed. Though no consensus seems to exist on this topic, it appears that the most equitable way to handle this situation for the foreseeable future is to assign one paper's credit to each author. Though it risks giving excessive credit to people only tangentially related to the project, it has the virtue of not penalizing those participants unfortunate enough not to be first authors, as well as keeping the evaluation process relatively simple by not adding another layer of calculation and fractional reporting.

Conclusions

As can be see from the previous discussion, there are very few published reports of the assessing the research productivity of academic departments using citation-based bibliometric indicators, and almost none specifically evaluating a nutrition department. This study could help remedy this situation by adding a needed example of using bibliometric indicators to evaluate both an academic science department, as well as a department in the Nutrition research field. It would also be a non-European example potentially useful for comparative study.

As for which indicators to use, based on a review of the available literature, it appears that the most useful indicators for a departmental level bibliometric study will one or more of those listed in Table 2. It also seems that one can probably safely ignore the self-citation phenomena, which would be of greater concern to evaluations of individual research performances. Also, at the risk of over-rewarding some people, the assignment of one paper's publication credit to each author of a multi-authored paper is probably in the long run the least complicated and more equitable solution to the multi-authorship problem.

CHAPTER 3

METHODOLOGY

"If we knew what we were doing, it wouldn't be called research, would it?"
– Albert Einstein (Institute for Scientific Information 2000; Khalid 2000)

Overall Approach

The goal of this study is to develop bibliometric indicators that are theoretically justifiable and supported by empirical findings and apply them to the evaluation of research of four academic research programs. To that end, this study will use a version of Martin & Irvine's (1981, 1983) methodology of multiple converging partial indicators. Although not as widely used as one would think (Martin 1996), it has several distinct advantages. First, a multi-indicator approach more accurately reflects the multi-faceted nature of most basic scientific research, with each indicator revealing a piece of the overall picture (see also Hagstrom 1971). By focusing on bibliometric indicators that correlate with other indicators, the results of this study could be meaningfully combined in the future with peer ratings (Lawani and Beyer 1983; McAllister, Anderson, and Narin 1980; Hagstrom 1971), esteem indicators (e.g., medals, prizes, invitations to give prestigious lectures), number of PhDs awarded, and other partial measure of scientific performance (Koenig 1983; Myers 1970; Garfield 1989; Phelan 1999).

Secondly, a multi-indicator approach tends to facilitate the acceptance by the scientific community of the results of non-peer review measures, which in turn are often easier and less time consuming to obtain than the more traditional peer review evaluations (Martin 1996). Finally, the use of multiple indicators "minimizes the risk that scientists will in some way 'play the game' and manipulate the indicators to their advantage" without actually improving their research (Martin 1996: 360). For the purposes of this study however, the multi-indicator approach will be limited to the use of citation-based bibliometric indicators of research productivity (i.e., publications and citations) based on the scientific article, the main medium for communicating nutrition research results (van Rann and van Leeuwen 1998).

Level of Analysis

For this study, the department will be the level of analysis and data aggregation. There are several reasons for choosing the department as the level of analysis. Van Raan (1996; van Raan 1993, cited in van Raan and van Leeuwen 1998) shows that in most cases, the department seems to be the lowest level of aggregation capable of yielding statistically useful bibliometric results. It absorbs a large amount of basic research funding (Martin and Irvine 1983) as well as matches the administrative, structural, and evaluative imperatives of research universities, making it an important focal point for research productivity assessment (van Raan 2000).

Resources

In terms of resources, there are three possible options for producing a bibliometric study. The first option is to buy the study from ISI, which will produce it to virtually any specification (Institute for Scientific Information 2000). The drawback is both the initial expense, plus the ongoing cost of any updates purchased in support of annual reports and budget requests. The second option is to buy the data from ISI and conduct the analysis in house (Institute for Scientific Information 2000). Though less expensive initially than buying the study outright, there are other costs to consider, including the cost of long-term storage, routine maintenance, data cleaning (e.g., standardizing addresses, names, etc), database design and development, and the cost of buying and processing the data for annual updates (Moed and van Leeuwen 1995; van Raan 1996; Bourke and Butler 1993). The third option, which will be used in this study, is the Do It Yourself approach, taking best advantage of what is readily available or easily obtainable at any major academic library. The cost is low, requiring only access to the *Web of Science* database, copies of ISI's *Journal Citation Reports*, connectivity, computer, and software such as MicroSoft Office 2000. This option is particularly useful to chronically cash-strapped organizations, such as many academic libraries, and special libraries at many national laboratories, that cannot afford the first two alternatives. The cost is primarily finding someone in the organization with the time, expertise, knowledge of the source institutions and the people involved, as well as a willingness to do it.

Research Design

Measurement Specifications

"Not everything that can be counted counts, and not everything that counts can be counted." – Albert Einstein, from a sign hanging in his Princeton office (Institute for Scientific Information 2000; Khalid 2000)

Assumptions

Since there is an apparent lack of consensus or empirical evidence in the published literature about how to handle self-citations, credit for multi-authored papers, and the proper length of citation windows, for the purposes of this study certain assumptions will be made concerning self-citations, multi-author publication credit, and citation windows. Unlike many other studies (e.g., Noyons, Moed, and Luwel 1999; Zachos 1991), there will be no attempt to remove any self-citations from the citation data. For a multi-authored paper, each author will be given publication credit for authoring one paper. A two-year citation window will be assumed, allowing the use of ISI's impact factors as found in the *Journal Citation Report (JCR)*. The two-year citation window used by ISI has the added virtue of simplifying future calculations by utilizing sufficiently accurate (*pace* Moed and van Leeuwen 1995) and readily available data.

Measurement objectives, types, and categories

In general, this study is attempting to measure two things: research output and research impact. Research output is the amount of journal article productivity, while research impact is the influence these papers have on contemporary and future scientific research. Bibliometric indicators are often used to measure research output and impact, and can be thought of as being specific instances or examples of four general types of measures: absolute, relative, comparative, and benchmark (see Table 3).

Each type of measure possesses a certain amount of meaning or understanding about the item being measured. The degree of potential explanatory power tends to increase from the absolute measures with the lowest explanatory potential, to the relative measures with greater explanatory potential, and finally to the comparative measures with the highest explanatory potential. Benchmark measures derive meaning or explanatory power from being used in conjunction with the other three measures. (For an example of the relationship between measurement objectives, measurement types, and indicator types using the bibliometric indicators from this study, see Table 3.)

Absolute measures are total counts of like items, such as journal publications or citations. They lack any integral context or framework for potentially providing meaning, and by themselves offer little or no explanatory power (van Raan 2000). *Relative measures* result from the comparison of absolute measures at the same level of aggregation. They contain a limited context that allows the assessment of meaning for a specific study group, but little or no explanatory power beyond it. Relative measures can also include absolute measures that were converted to a percentage of a study group population. *Comparative measures* are relative measures compared to a benchmark or standard value or measure. They possess an integral context extending beyond the

Table 3. Bibliometric indicators selected for use in this study, classified by measurement objective, indicator type, and measurement type.

Measurement Objective	Indicator Type	Measurement Type	Bibliomeric Indicator
Publication output or productivity	Secondary	Absolute	P (Total publications)
Publication impact or influence	Primary	Absolute	C (Total actual impact)
		Relative	CPP (Average impact per publication)
		Comparative	CPP/FCSm (Average impact on research field(s))
			CPP/JCSm (Average impact on the journal set)
			JSCm/FCSm (Average journal set impact on the research field(s))
	Secondary	Benchmark	FCSm (Average impact of the research field(s))
			JCSm (Average impact of the journal set)

Note(s):
Publications refer to original research papers, review papers, and technical notes.

originating group to a larger population, and provide a framework for assessing meaning in relation to a higher level of aggregation. Comparative measures can also include any absolute or relative measures that were converted to a percentage of a higher level of aggregation than the study group. *Benchmark* or *standard measures* are the average or mean values of an aspect of a larger population against which absolute and relative values are compared (van Raan 2000). They provide a context that, when joined with an absolute or relative measure, converting those measures into comparative measures possessing the greatest potential explanatory power.

To assess the meaning of the bibliometric indicators from the literature that are also comparative measures often involves their evaluation in relation to an average baseline result, or expected value, usually set at 1.0 (e.g., van Leeuwen and Tijssen 1993; Rinia et al. 1998; van Raan and van Leeuwen 1998). Though a useful way of indicating general, relative comparisons (e.g., below average vs. average vs. above average), it should be noted that this evaluative method is too restrictive in terms of creating meaning or providing potential interpretive value. For example, how much more potentially significant or meaningful is a bibliometric indicator with a value of 1.10 to one with a value of 1.45, or 2.01? They are all above 1.0, and therefore are by definition above average results. Therefore, the results of such comparisons should be treated with some caution as there appears to be little or nothing in the literature about the typical range of such indices, which would help shed some light on their relative significance or meaning.

Selection of bibliometric indicators

Eight bibliometric indicators will be used in this study, five primary and three secondary indicators (see Table 3). Only two of the primary indicators (C and CPP) and one of the secondary indicators (P) from the literature will be used unaltered. Three other primary indicators (CPP/FCSm, CPP/JCSm, and JCSm/FCSm) and two secondary indicators (FCSm and JCSm) will be used in a modified form, while two primary indicators (HCP and PPR) from the literature review will not be used.

The reasons that the secondary indicators FCSm and JCSm needed to be modified for use in this study are found in how and why they were created. Both FCSm and JSCm were benchmark measures created to avoid using ISI's Journal Impact Factor (JIF) (Korevaar and Moed 1996; van Raan 1996; Nederhof and Noyons 1992). The main difference between ISI's JIF and the FCSm and JCSm indicators is the use of a longer citation window of three to five years in the calculation of the latter two indicators rather than the two-year window used in the calculation of ISI's JIFs, which was considered too short to capture the maximum number of citations for a given publication set (Rinia et al. 1998; van Raan and van Leeuwen 1998; Korevaar and Moed 1996). Since this study is using the ISI impact factors, FCSm and JCSm, as well as the three indicators dependent on their values, CPP/FCSm, CPP/JCSm, and JCSm/FCSm, were calculated to reflect the two-year citation window used by ISI.

The remaining two primary indicators from the literature HCP (Highly Cited Papers) and PPR (Papers Per Researcher) were excluded from use in this study for several reasons. In the case of the HCP indicator, it was due to the lack of sufficient evidence for its generalizability beyond the two studies in which it was used (Martin and Irvine, 1981, 1983). The link between the HCP indicator and the presence of key papers in a discipline is rather weak, and the citation thresholds appear to be excessively dependent on a specific data set. The PPR indicator, though a useful way to normalize total output by the number of the researchers in a department, suffers from the difficulty of securing accurate "counts of staff members who are expected to produce [research] results" (Phelan 1999: 133). Since these staff counts can vary year to year, the time required to gather the information for this study from four different nutrition departments for a five-year period was considered prohibitive.

Derivation of each selected bibliometric indicator

Indicator P

Definition. For the purposes of this study, **P** is the total number of scientific, scholarly publications (articles, notes, and reviews) published by a given Nutrition program in any of the scholarly, scientific print journals covered by the ISI's *Web of Science* citation database and listed in its *JCR*s over a given period of time (van Raan 2000).

Calculation. For the purposes of this study,

$$P = \Sigma_P$$

where Σ_P is the is the total number of all the publications (articles, notes, and reviews) published in a given year by any researcher(s) officially affiliated with one of the Nutrition programs in the study. For example, the P published by the University of Florida's (UFL's) Food Science and Nutrition Program in 1994 is 40 (see Table 7, p. 71).

Data Source(s). For the purposes of this study, the publication data used to calculate P is drawn from the *SCI-E* section of ISI's *Web of Science* citation database. The data is drawn for each year of the study 1992-1996, and for each Nutrition program used in this study.

Interpretation. For the purposes of this study, P is considered to be an indicator of the scientific productivity (van Raan and van Leeuwen 1998), or research output (van Raan 2000) of each Nutrition program in terms of print journal publications.

Indicator C

Definition. For the purposes of this study, **C** is the total number of citations (including self-citations) received over a two year period (including the year of publication) for all of a given Nutrition program's scholarly, scientific publications (**P**) in any of the scholarly, scientific print journals covered by the ISI's *Web of Science* citation database and listed in its *JCR*s (van Raan and van Leeuwen 1998; van Raan 2000).

Calculation. For the purposes of this study,

$$C = \Sigma_C$$

where Σ_C is the total number of all the citations received over a two year period (including the year of publication) by all the publications (P) published by any researcher(s) officially affiliated with one of the Nutrition programs in the study. For example, the C for the 40 publications (P) published by the UFL's Food Science and Nutrition Program in 1994 is 28 (see Table 7, p. 71).

Data Source(s). For the purposes of this study, the publication data used to calculate C is drawn from the *SCI-E* section of ISI's *Web of Science* citation database. The data is drawn for each year of the study 1992-1996, and for each publication from each Nutrition program used in this study.

Interpretation. For the purposes of this study, C is considered to be an indicator research quality or significance of a Nutrition program's P in terms of its impact or influence on subsequent scientific, scholarly research and publication (van Raan and van Leeuwen 1998; van Raan 2000).

Indicator FCSm

Definition. For the purposes of this study, **FCSm** or **Field Citation Score mean**, is the world-wide or international mean citation rate for a two year period (including the year of publication) of all the publications P published by all of the scholarly journals in the ISI's *JCR*'s journal category for the field(s) in which a given Nutrition programs is actively researching and publishing (van Raan 2000).

Calculation. For the purposes of this study,

$$FCSm = \Sigma_{JIF}/\Sigma_J$$

where Σ_{JIF} is the sum of all the JIFs for all the journals from each ISI Subject Category that corresponds to a field in which the Nutrition program actively researched and published in a given year, and Σ_J is the total number of all the journals from each ISI Subject Category that corresponds to the field in which the Nutrition program actively researched and published in a given year. For example, the FCSm for the UFL's Food Science and Nutrition Program for 1994 is calculated using the data from the 1996 *JCR*, with $\Sigma_{JIF} = 2041.255$ and $\Sigma_J = 914$. The FCSm then is 2041.255/914 or 2.23 (see Table 7, p. 71).

Note that FCSm is calculated for each year of the study using a two-year citation window for each journal in the field(s) in which the Nutrition program of interest is researching and publishing. Because the ISI calculates its JIF for each journal using a two-year citation window as well, FCSm can be derived by using the relevant JIFs from the JCR two years later than the particular year under study. For example, in the calculation above of the FCSm for the UFL's Food Science and Nutrition Program for 1994, the JIF data was drawn from the 1996 *JCR*.

Data Source(s). For the purposes of this study, the journal publication data used to calculate the FCSm for each of the four Nutrition departments for each year was drawn from ISI's *JCR* for two years later. That is, the data used to calculate the FCSm for the year 1992 was taken from the 1994 *JCR*; to calculate the 1993 FCSm, the data was taken from the 1995 *JCR*; to calculate the 1994 FCSm, the data was taken from the 1996 *JCR*;

to calculate the 1995 FCSm, the data was taken from the 1997 *JCR*; and to calculate the 1996 FCSm, the data was taken from the 1998 *JCR*.

Interpretation. For the purposes of this study, FCSm provides a world-wide or international reference value for the comparison of average expected impact for the field(s) in which a given Nutrition program used in this study is active (van Raan and van Leeuwen 1998; van Raan 2000).

Indicator JCSm

Definition. For the purposes of this study, **JCSm** or Journal Citation Score mean, is the world-wide or international mean citation rate for a two year period (including the year of publication) of all the publications P published by all of the scholarly journals in a dynamic journal set composed of all the journals that contain at least one paper authored or co-authored by a member of a given Nutrition program in the same year.

Calculation. For the purposes of this study,

$$JCSm = \Sigma_{JIFjs}/\Sigma_{Jjs}$$

where Σ_{JIFjs} is the sum of all the JIFs for all the journals in the journal set in which at least one member of a given Nutrition program published at least one publication in a given year, and Σ_{Jjs} is the total number of all the journals in the journal set in which at least one member of a given Nutrition program published at least one publication in a given year. For example, the JCSm for the UFL's Food Science and Nutrition Program for 1994 is calculated using the JIF data from the 1996 *JCR*, with $\Sigma_{JIFjs} = 61.053$ and $\Sigma_{Jjs} = 23$. The JCSm then is 61.053/23 or 2.65 (see Table 7, p. 71).

Note that the JCSm indicator is calculated using a two-year citation window for each journal in the field(s) in which the Nutrition program of interest is researching and publishing. Because the ISI calculates its JIF for each journal using a two-year citation window as well, JCSm can be derived by using the relevant JIFs from the JCR two years later than the particular year under study. For example, in the calculation above of the JCSm for the UFL's Food Science and Nutrition Program for 1994, the JIF data was drawn from the 1996 *JCR*.

Data Source(s). For the purposes of this study, the journal publication data used to calculate the JCSm for each of the four Nutrition departments for each year was drawn from ISI's *JCR* for two years later. That is, the data used to calculate the JCSm for the year 1992 was taken from the 1994 *JCR*; to calculate the 1993 JCSm, the data was taken from the 1995 *JCR*; to calculate the 1994 JCSm, the data was taken from the 1996 *JCR*; to calculate the 1995 JCSm, the data was taken from the 1997 *JCR*; and to calculate the 1996 JCSm, the data was taken from the 1998 *JCR*.

Interpretation. For the purposes of this study, JCSm provides a world-wide or international reference value for the comparison of average expected impact for a journal set in which a given Nutrition program used in this study publishes (van Raan and van Leeuwen 1998; van Raan 2000).

Indicator CPP

Definition. For the purposes of this study, **CPP** is the average number of citations (including self-citations) per publication (P) (van Raan 2000) received for all of a given Nutrition program's scholarly, scientific publications in any of the scholarly, scientific print journals covered by the ISI's *Web of Science* citation database and listed in its *JCR*s.

Calculation. For the purposes of this study,

$$CPP = \Sigma_C / \Sigma_P$$

where Σ_P is the total number of all publications (P) published by any researcher(s) officially affiliated with one of the Nutrition programs in the study, and Σ_C is the total number of citations received by those same publications (P) over a two year period including the year of publication. For example, the CPP for the UFL's Food Science and Nutrition Program for 1994 is calculated with $\Sigma_C = 28$ and $\Sigma_P = 40$. The CPP is then 28/40 or 0.70 (see Table 7, p. 71).

Data Source(s). For the purposes of this study, the publication and citation data used to calculate CPP is drawn from the *SCI-E* section of ISI's *Web of Science* citation database. The data is drawn for each year of the study 1992-1996, and for each publication from each Nutrition program used in this study.

Interpretation. For the purposes of this study, CPP is considered to be an indicator of the average actual impact of each publication by a given a Nutrition program in terms of that publication's impact or influence on subsequent scientific, scholarly research and publication (van Raan and van Leeuwen 1998).

Indicator CPP/FCSm

Definition. For the purposes of this study, **CPP/FCSm** is the average number of citations (including self-citations) per publication (CCP) received for all of a given Nutrition program's scholarly, scientific publications in any of the scholarly, scientific print journals covered by the ISI's *Web of Science* citation database and *JCR*s, compared with the **FCSm** or **Field Citation Score mean**, the world-wide or international mean citation rate for a two year period of all the publications P published by all of the scholarly journals in the ISI's *JCR*'s journal category for the field(s) in which the particular Nutrition program is actively researching and publishing.

Calculation. For the purposes of this study,

$$CPP/FCSm = \frac{\Sigma_C/\Sigma_P}{\Sigma_{JIF}/\Sigma_J}$$

where Σ_P is the total number of all publications (P) published by any researcher(s) officially affiliated with one of the Nutrition programs in the study; Σ_C is the total number of citations received by those same publications (P) over a two year period including the year of publication; Σ_{JIF} is the sum of all the JIFs for all the journals from each ISI Subject Category that corresponds to a field in which the Nutrition program actively researched and published in a given year; and Σ_J is the total number of all the journals from each ISI Subject Category that corresponds to a field in which the Nutrition program actively researched and published in a given year. For example, the CPP/FCSm for the UFL's Food Science and Nutrition Program for 1994 is calculated with $\Sigma_C = 28$, $\Sigma_P = 40$, $\Sigma_{JIF} = 2041.255$, and $\Sigma_J = 914$. The CPP is then (28/40)/(2041.255/914) or 0.70/2.23 or 0.31 (see Table 7, p. 71)

Note that the FCSm portion of the CPP/FCSm indicator is calculated using a two-year citation window for each journal in the field(s) in which the Nutrition program of interest is researching and publishing. Because the ISI calculates its JIF for each journal using a two-year citation window as well, the FCSm can be derived by using the relevant JIFs from the JCR two years later than the particular year under study. For example, in the calculation above of the FCSm for the CPP/FCSm for the UFL's Food Science and Nutrition Program for 1994, the JIF data was drawn from the 1996 *JCR*.

Data Source(s). For the purposes of this study, the data for calculating CPP/FCSm is drawn from the same sources as for the CPP and the FCSm indicators (see page and page respectively.)

Interpretation. For the purposes of this study, CPP/FCSm is considered to be an indicator of the impact of a given Nutrition program's research on the field(s) in which it is actively researching and publishing. If the CPP/FCSm result is > 1.0, then the Nutrition program's work has a higher citation rate than the field-based world average (van Raan and van Leeuwen 1998; van Raan 2000).

Indicator CPP/JCSm

Definition. For the purposes of this study, **CPP/JCSm** is the average number of citations (including self-citations) per publication (CCP) received for all of a given Nutrition program's scholarly, scientific publications in any of the scholarly, scientific print journals covered by the ISI's *Web of Science* citation database and *JCR*s, compared with the **JCSm** or **Journal Citation Score mean**, is the world-wide or international mean citation rate for a two year period (including the year of publication) of all the publications P published by all of the scholarly journals in a dynamic journal set composed of all the journals that contain at least one paper authored or co-authored by a member of a given Nutrition program in the same year.

Calculation. For the purposes of this study,

$$\text{CPP/JCSm} = \frac{\Sigma_C/\Sigma_P}{\Sigma_{JIFjs}/\Sigma_{Jjs}}$$

where Σ_P is the total number of all publications (P) published by any researcher(s) officially affiliated with one of the Nutrition programs in the study; Σ_C is the total number of citations received by those same publications (P) over a two year period including the year of publication; Σ_{JIFjs} is the sum of all the JIFs for all the journals in the journal set in which at least one member of a given Nutrition program published at least one publication in a given year., and Σ_{Jjs} is the total number of all the journals in the journal set in which at least one member of a given Nutrition program published at least one publication in a given year. For example, the CPP/JCSm for the UFL's Food Science and

Nutrition Program for 1994 is calculated with Σ_C= 28, Σ_P= 40, Σ_{JIFjs}= 61.053 and Σ_{Jjs}= 23. The CPP/JCSm then is (28/40)/(61.053/23) or 0.70/2.65 or 0.26 (see Table 7, p. 71).

Note that the JCSm portion of the CPP/JCSm indicator is calculated using a two-year citation window for each journal in the field(s) in which the Nutrition program of interest is researching and publishing. Because the ISI calculates its JIF for each journal using a two-year citation window as well, the JCSm can be derived by using the relevant JIFs from the JCR two years later than the particular year under study. For example, in the calculation above of the JCSm for the UFL's Food Science and Nutrition Program for 1994, the JIF data was drawn from the 1996 *JCR*.

Data Source(s). For the purposes of this study, the data for calculating CPP/JCSm is drawn from the same sources as for the CPP and the JCSm indicators (see page and page respectively.)

Interpretation. For the purposes of this study, CPP/JCSm is considered to be an indicator of the impact of a given Nutrition program's research on the journals in all the field(s) in which it is actively researching and publishing. If the CPP/JCSm result is > 1.0, then the Nutrition program's work has a higher citation rate than the journal-based world average (van Raan and van Leeuwen 1998; van Raan 2000).

Indicator JCSm/FCSm

Definition. For the purposes of this study, **JCSm/FCSm** is the **JCSm** orJournal Citation Score **m**ean, the world-wide or international mean citation rate for a two year period (including the year of publication) of all the publications P published by all of the scholarly journals in a dynamic journal set composed of all the journals that contain at least one paper authored or co-authored by a member of a given Nutrition program in the same year, compared with the **FCSm** or **Field Citation Score mean**, the world-wide or international mean citation rate for a two year period of all the publications P published by all of the scholarly journals in the ISI's *JCR*'s journal category for the field(s) in which the particular Nutrition program is actively researching and publishing (Korevaar and Moed 1996).

Calculation. For the purposes of this study,

$$\text{JCSm/FCSm} = \frac{\Sigma_{JIFjs}/\Sigma_{Jjs}}{\Sigma_{JIF}/\Sigma_{J}}$$

where Σ_{JIFjs} is the sum of all the JIFs for all the journals in the journal set in which at least one member of a given Nutrition program published at least one publication in a given year., and Σ_{Jjs} is the total number of all the journals in the journal set in which at least one member of a given Nutrition program published at least one publication in a given year; Σ_{JIF} is the sum of all the JIFs for all the journals from each ISI Subject Category that corresponds to a field in which the Nutrition program actively researched and published in a given year; and Σ_{J} is the total number of all the journals from each ISI Subject Category that corresponds to a field in which the Nutrition program actively researched and published in a given year.. For example, the 1994 FCSm/JCSm for the UFL's Food Science and Nutrition Program is calculated with $\Sigma_{JIF} = 2041.255$, $\Sigma_{J} = 914$,

Σ_{JIFjs} = 61.053, and Σ_{Jjs} = 23. The FCSm/JCSm then is (2041.255/914)/(61.053/23) or 2.23/2.65 or 0.84 (see Table 7, p. 71).

Note that both the JCSm and the FCSm parts of the JCSm/FCSm indicator is calculated using a two-year citation window for each journal in the field(s) in which the Nutrition program of interest is researching and publishing. Because the ISI calculates its JIF for each journal using a two-year citation window as well, both the JCSm and the FCSm can be derived by using the relevant JIFs from the JCR two years later than the particular year under study. For example, in the calculation above of the FCSm for the CPP/FCSm for the UFL's Food Science and Nutrition Program for 1994, the JIF data was drawn from the 1996 *JCR*.

Data Source(s). For the purposes of this study, the data for calculating FCSm/JCSm is drawn from the same sources as for the FCSm and the JCSm indicators (see page and page respectively.)

Interpretation. For the purposes of this study, JCSm/FCSm is considered to be an indicator of the impact of a given Nutrition program's journal set on the field(s) in which it is actively researching and publishing (Korevaar and Moed 1996;). For example, if the JCSm/FCSm result is > 1.0, then the Nutrition program's journal set has a higher mean citation rate than that of all the papers "published in the fields to which the journals belong" (van Raan 2000, 317).

Journal set

The decision to use a dynamic journal set rose from the problems experienced using a designated journal set in the preliminary study of the UTK Nutrition Department (Ackermann 2000). Early in the data collection phase of that study, it quickly became apparent that the designated journal set was not functioning as intended. It simply was not capturing all of the relevant data. If only the designated data set had been used, forty-one of the ninety-six publications (43%) and 343 of the 470 citations received (73%) by the UTK Nutrition Department during the five-year period under study would have been missed (Ackermann 2000).

To remedy this problem, it was decided to use a dynamic journal set for this study. A *dynamic journal set* is composed of all the journals that contain at least one paper authored or co-authored by a member of a particular department in a given year. It has a composition that varies from year to year, reflecting the contemporary state of research productivity of a given department, capturing any changes in its publishing habits (Bourke and Butler 1993). Each dynamic journal set (referred hereafter as the *journal set*) then will form the journal sources from which publication (P) and citation (C) data will be gathered, as well as providing the journals from which the impact data will be drawn from the *Journal Citation Reports* (see Appendix E for the journal set data used in this study.)

Peer Institutions

Three of the eight bibliometric indicators are ratios that contain built in comparisons of a department's actual impact (CPP) with either an expected field-specific impact (FCSm) or a journal set-specific expected impact (JCSm), or compares a department's journal set impact with its expected field impact (JCSm/FCSm). In all three of these cases, the comparisons are international averages for a given field or journal set. While this can be a useful measure, it is a high-level abstraction that is derived from the scholarly journal output of a large number of different kinds of research units that vary widely in attributes such as size of research staff, funding, as well as the size and type of supporting or parent institution.

Hence, it may be equally useful to compare research performance with a more compatible group of peer or benchmark institutions that share many of the same or similar features, such as size, level of funding, geographic location, etc. The UTK Office of Institutional Research and Assessment has compiled a list of ten peer institutions for use by the University of Tennessee-Knoxville in comparative performance evaluations (Office of Institutional Research and Assessment 2000) (see Table 4). Using these peer institutions will allow comparison to be made between the UTK Nutrition Department and similar programs in similar academic environments, thereby enhancing the accuracy and usefulness of the bibliometric assessment results (Martin and Irvine 1983; Martin 1996; Zachos 1991).

Table 4. Peer, benchmark institutions used by the University of Tennessee-Knoxville for comparative performance evaluation purposes.

University of Florida
University of Georgia
University of Kentucky
University of Maryland at College Park
University of North Carolina at Chapel Hill
University of Oklahoma
University of South Carolina
University of Texas at Austin
University of Virginia
Virginia Polytechnic Institute and State University

Source(s):
Office of Institutional Research and Assessment. UTK's peer institutions. <http://web.utk.edu/~oira/peers.html>. 24 July 2000.

Although the peer institutions are reasonably comparable at the university level, it was not immediately evident that they all would be suitable for use in this study. In order to have an accurate and meaningful comparison at the department level, each of the peer institutions selected for use in this study must have a nutrition department, program, or research unit possessing approximately the same characteristics as the UTK Nutrition Department. To this end, each of the peer institutions was evaluated and rated using information gathered from each of their respective websites (for more detail, see Appendix C). Of the ten UTK peer institutions evaluated, two had no nutrition programs at all, and of the remaining eight institutions, the top three were selected for use in this study (see Table 5). Each of these three peer programs has an Extension Service component.

Data Collection Methods

The source for publication and citation data for each nutrition department for the five year period 1992-1996 is ISI's *Science Citation Index- Expanded (SCI-E)*, part of the Web of Science (2000) online database. The database was searched using the address data field in order to avoid as much as possible the problems associated with author identification such as homographs, misspelled names, etc. (MacRoberts and MacRoberts, 1989; Garfield 1989; Seglen 1997). It was found that a search argument composed of the most unique elements in a department's institutional address was the most effective

Table 5. Selected UTK peer institutions in alphabetical order, by institution and department (or program) name.

Peer Institution	Department (or Program)
University of Florida	Department of Food Science and Human Nutrition
University of Georgia	Department of Foods and Nutrition
Virginia Polytechnic Institute and State University	Department of Human Nutrition, Foods, and Exercise

Source(s):
University of Florida: http://fshn.ifas.ufl.edu/academic.htm; http://fshn.ifas.ufl.edu/research.htm; http://fshn.ifas.ufl.edu/faculty.htm

University of Georgia: http://www.fcs.uga.edu/fdn/graduate; http://www.fcs.uga.edu/fdn/people/index.php3?FDN+faculty

Virginia Polytechnic Institute and State University:
http://www.chre.vt.edu/Admin/HNFE;
http://www.chre.vt.edu/Admin/HNFE/fac/Davis/current_research.htm;
http://www.chre.vt.edu/jhwms/hnfegrad/faculty.html

(Ackermann 2000). For example, the search argument for the UTK Nutrition Department is "nutrition same tenn* same knoxville."

The source of the impact data for the five-year period 1994-1998 is ISI's *Journal Citation Reports (JCR)*. These reports are published annually, and are based on citation data for papers published two years previously (i.e., a two-year citation window) to allow time for the papers to be read, absorbed, and (possibly) cited by the scientific community. The data from these sources will be recorded on data worksheet forms designed for this study (see Appendix D).

Data Analysis Methods

"Knowledge is the process of piling up facts; wisdom lies in their simplification."
– Martin Luther King, Jr. (Institute for Scientific Information 2000; Khalid 2000)

The primary methods of data analysis will be descriptive, using tables and charts to find any patterns over time in the behavior of the bibliometric indicators.

Limitations

There are several limitations to this methodology that need to be kept in mind. The citation data is reported by calendar year, whereas most academic and government institutions run on a fiscal year, with the two rarely being synonymous. Due to the two-year publication lag between the *JCR* updates, which reflects the nature of how citations accumulate, the most recent bibliometric indicators will always be at least two years behind the current year. For example, if the 1998 *JCR* is the most current edition available, then the indicator values can only be current through 1996.

There are minor differences between the journal title abbreviations used in the *JCR* and in the *SCI-E*. For example, the *Journal of American Dietetic Association* is abbreviated in the *SCI-E* as J Amer Diet Assn (Web of Science 2000), while listed in the *JCR* as J Am Diet Assoc (Institute for Scientific Information 1995). Unless otherwise indicated, the form used by the *SCI-E* will be the one used in this study.

Only data from the citing journals are included in this study, whereas data from cited journals are not. This is due to the lack of impact and subject category data for cited journals in the *JCR*. For example, in the preliminary study (Ackermann 2000), two such journals were found containing publication and citation data from the UTK Nutrition Department, but were excluded from the study: the *American Journal of Physiology, Endocrinology, and Metabolism*; and the *Journal of Parenteral and Enteral Nutrition.*

The publication and citation data is drawn only from the relevant *printed* scholarly scientific literature currently found in the ISI citation databases. Since the ISI databases do not yet draw their data from electronic scholarly scientific journals, none will be included here.

CHAPTER 4

DATA ANALYSIS AND EVALUATION

Introduction

Data was gathered for all eight bibliometric indicators, and the findings organized into data summaries (see Table 6 and Table 7). For purposes of analyzing these findings, each indicator was placed into one of three groups according to what that indicator was measuring. The indicator groups were the Publication Output Group, the Benchmark Impact Group, and the Actual Impact Group. Within each indicator group, the findings were analyzed to discover any patterns for the five-year period from 1992-1996, and then were placed in rank order comparisons based on aggregate five-year findings. The Publication Output Group contains only one indicator P. Two indicators, FCSm and JCSm, form the Benchmark Impact Group. The remaining five indicators are in the Actual Impact Group: C, CPP, CPP/FCSm, CPP/JCSm, and JCSm/FCSm. Note that the order in which the indicators are given above, P, FCSm, JCSm, C, CPP, CPP/FCSm, CPP/JCSm, and JCSm/FCSm, will be the same order in which they will appear in the data summary tables.

Publication Output Group

The pattern analysis of the publication output of the four Nutrition departments or programs under study reveled a mixed pattern of publication rates, three (UGA, UTK,

Table 6. Data summary of bibliometric indicators for publication output (P), benchmark impact (FCSm, JCSm), and actual impact (C, CPP, CPP/FCSm, CPP/JCSm, JCSm/FCSm) by Nutrition department or program, 1992-1996.

Department or Program	Year				
	1992	1993	1994	1995	1996
INDICATOR **P**: PUBLICATION OUTPUT					
Univ.Florida	43.00	38.00	40.00	42.00	37.00
Univ.Georgia	21.00	37.00	29.00	36.00	33.00
Univ.Tenn-K	17.00	18.00	18.00	25.00	18.00
Virginia Tech	9.00	7.00	8.00	10.00	11.00
INDICATOR **FCSm**: MEAN IMPACT ON RESEARCH FIELD(S)					
Univ.Florida	1.67	2.08	2.23	1.78	1.96
Univ.Georgia	2.15	2.19	2.59	2.31	1.95
Univ.Tenn-K	1.78	1.35	2.16	1.92	2.01
Virginia Tech	1.88	0.91	0.86	1.61	2.06
INDICATOR **JCSm**: MEAN IMPACT ON JOURNAL SET					
Univ.Florida	5.34	4.08	2.65	2.71	3.09
Univ.Georgia	2.84	3.71	3.55	3.21	2.84
Univ.Tenn-K	2.94	2.94	3.92	4.25	3.24
Virginia Tech	3.31	1.14	1.15	1.40	2.91
INDICATOR **C**: TOTAL ACTUAL IMPACT					
Univ.Florida	30.00	36.00	28.00	43.00	41.00
Univ.Georgia	29.00	16.00	26.00	21.00	19.00
Univ.Tenn-K	23.00	12.00	5.00	26.00	13.00
Virginia Tech	9.00	3.00	2.00	9.00	4.00
INDICATOR **CPP**: AVERAGE IMPACT PER PUBLICATION					
Univ.Florida	0.70	0.95	0.70	1.02	1.11
Univ.Georgia	1.38	0.43	0.90	0.58	0.58
Univ.Tenn-K	1.35	0.67	0.28	1.04	0.72
Virginia Tech	1.00	0.43	0.25	0.90	0.36
INDICATOR **CPP/FCSm**: AVERAGE IMPACT ON RESEARCH FIELD(S)					
Univ.Florida	0.42	0.46	0.31	0.57	0.57
Univ.Georgia	0.64	0.20	0.35	0.25	0.30
Univ.Tenn-K	0.76	0.50	0.13	0.54	0.36
Virginia Tech	0.53	0.47	0.29	0.56	0.17

Table 6. (continued)

Department or Program	Year				
	1992	1993	1994	1995	1996
INDICATOR **CPP/JCSm**: AVERAGE IMPACT ON JOURNAL SET					
Univ.Florida	0.13	0.23	0.26	0.38	0.36
Univ. Georgia	0.49	0.12	0.25	0.18	0.20
Univ.Tenn-K	0.46	0.23	0.07	0.24	0.22
Virginia Tech	0.30	0.38	0.22	0.64	0.12
INDICATOR **JCSm/FCSm**: AVERAGE JOURNAL SET IMPACT ON FIELD(S)					
Univ.Florida	3.19	1.96	1.19	1.52	1.58
Univ.Georgia	1.32	1.69	1.37	1.39	1.46
Univ.Tenn-K	1.65	2.18	1.81	2.21	1.61
Virginia Tech	1.76	1.25	1.34	0.87	1.41

Note(s):
Field or *research field* is all the ISI Subject Categories that contain at least one journal that published at least one paper by at least one researcher from one of the departments or programs under study.

Source(s):

Institute for Scientific Information. 1995. *1994 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia: Institute for Scientific Information Press.

Institute for Scientific Information. 1996. *1995 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia: Institute for Scientific Information Press.

Institute for Scientific Information. 1997. *1996 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia: Institute for Scientific Information Press.

Institute for Scientific Information. 1998. *1997 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia: Institute for Scientific Information Press.

Institute for Scientific Information. 1999. *1998 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia: Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table 7. Data summary for each Nutrition department or program by bibliometric indicators for publication output (P), benchmark impact (FCSm, JCSm), and actual impact (C, CPP, CPP/FCSm, CPP/JCSm, JCSm/FCSm), 1992-1996.

	Year				
Indicator	1992	1993	1994	1995	1996
DEPT. OF FOOD SCIENCE & HUMAN NUTRITION, UNIV. OF FLORIDA					
P	43.00	38.00	40.00	42.00	37.00
FCSm	1.67	2.08	2.23	1.78	1.96
JCSm	5.34	4.08	2.65	2.71	3.09
C	30.00	36.00	28.00	43.00	41.00
CPP	0.70	0.95	0.70	1.02	1.11
CPP/FCSm	0.42	0.46	0.31	0.57	0.57
CPP/JCSm	0.13	0.23	0.26	0.38	0.36
JCSm/FCSm	3.19	1.96	1.19	1.52	1.58
DEPT. OF FOODS & NUTRITION, UNIVERSITY OF GEORGIA					
P	21.00	37.00	29.00	36.00	33.00
FCSm	2.15	2.19	2.59	2.31	1.95
JCSm	2.84	3.71	3.55	3.21	2.84
C	29.00	16.00	26.00	21.00	19.00
CPP	1.38	0.43	0.90	0.58	0.58
CPP/FCSm	0.64	0.20	0.35	0.25	0.30
CPP/JCSm	0.49	0.12	0.25	0.18	0.20
JCSm/FCSm	1.32	1.69	1.37	1.39	1.46
DEPT. OF NUTRITION, UNIVERSITY OF TENNESSEE-KNOXVILLE					
P	17.00	18.00	18.00	25.00	18.00
FCSm	1.78	1.35	2.16	1.92	2.01
JCSm	2.94	2.94	3.92	4.25	3.24
C	23.00	12.00	5.00	26.00	13.00
CPP	1.35	0.67	0.28	1.04	0.72
CPP/FCSm	0.76	0.50	0.13	0.54	0.36
CPP/JCSm	0.46	0.23	0.07	0.24	0.22
JCSm/FCSm	1.65	2.18	1.81	2.21	1.61
DEPT. OF HUMAN NUTRITION, FOODS, & EXERCISE, VIRGINIA TECH					
P	9.00	7.00	8.00	10.00	11.00
FCSm	1.88	0.91	0.86	1.61	2.06
JCSm	3.31	1.14	1.15	1.40	2.91
C	9.00	3.00	2.00	9.00	4.00
CPP	1.00	0.43	0.25	0.90	0.36
CPP/FCSm	0.53	0.47	0.29	0.56	0.17
CPP/JCSm	0.30	0.38	0.22	0.64	0.12
JSm/FCSm	1.76	1.25	1.34	0.87	1.41

Table 7. (continued)

Note(s):
Field or *research field* is all the ISI Subject Categories that contain at least one journal that published at least one paper by at least one researcher from one of the departments or programs under study.

Source(s):

Institute for Scientific Information. 1995. *1994 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia: Institute for Scientific Information Press.

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Institute for Scientific Information. 1998. *1997 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia: Institute for Scientific Information Press.

Institute for Scientific Information. 1999. *1998 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia: Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

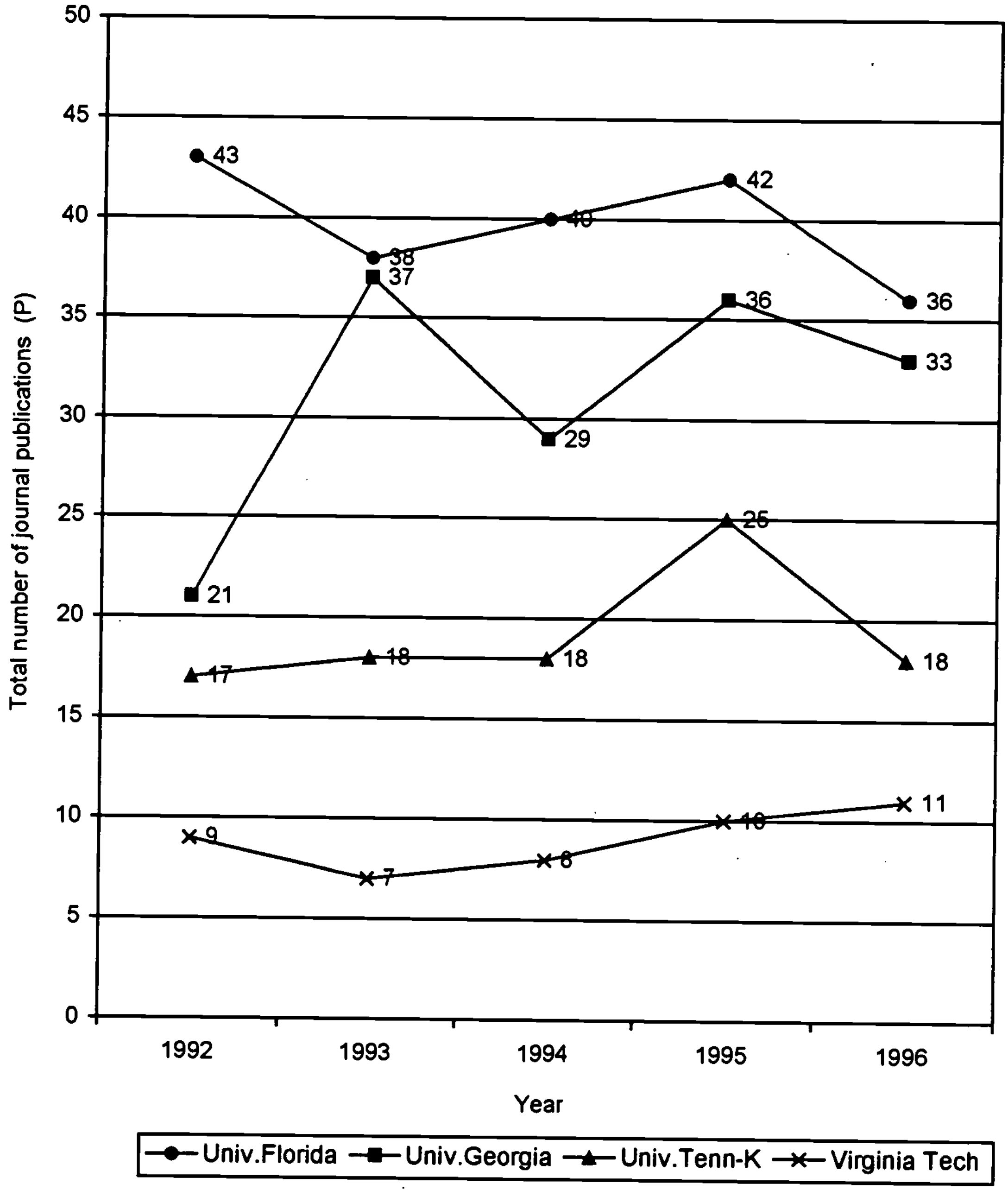


Figure 1. P or publication output or the total number of journal publications for each Nutrition program, 1992-1996.

and VT) ending with a higher yearly total in 1996 than in 1992 (see Table 6, Table 7, and Figure 1). The exception was UFL, which ended with a lower publication rate in 1996 than in 1992. All four departments experienced their greatest increase in publications between 1993 and 1995, followed by a decrease in 1996 for the programs at UFL, UGA and UTK. VT's program had the steadiest pattern, characterized by a slight decrease in total publications from 1992 to 1993, followed by a slow, steady increase from 1993 to 1996. The most volatile pattern was shown by UGA, which was characterized by sharp upswings in 1993 and 1995, and sharp downswings in 1994 and 1996. An examination of the rank order of the four Nutrition programs based on the five-year aggregate findings shows that UFL ranked first with 40% of the total publications (N= 200), followed by UGA with 31% (N= 156), UTK with 20% (N= 96), and VT with 9% (N= 45) (see Table 8).

Benchmark Impact Group

The five-year pattern for the Benchmark Impact Group will examined separately for each of the two indicators in the group, FCSm and JCSm. Patterns will be analyzed first for both indicators, followed by the rank order comparisons for each Nutrition program by indicator. From 1992 to 1993, the FCSm indicator for both UTK and VT declined while the FCSm for UFL and UGA increased (see Table 6, Table 7, and Figure 2). From 1993 to 1994 saw the FCSm for UFL, UGA, and UTK increase to its highest point, while the

Table 8. Rank order of Nutrition departments or programs by publication output (P), mean impact (FCSm, JCSm), and actual impact (C, CPP, CPP/FCSm, CPP/JCSm, JCSm/FCSm) for the aggregate five-year period 1992-1996.

Department in Rank Order	Five-year Aggregate Total (N)	Mean	Percent	Department in Rank Order	Five-year Aggregate Total (N)	Mean	Percent
INDICATOR **P**: PUBLICATION OUTPUT				INDICATOR **CPP**: AVERAGE IMPACT PER PUBLICATION			
Univ. Florida	200.00	40.00	40%	Univ. Florida	4.48	0.90	29%
Univ. Georgia	156.00	31.20	31%	Univ. Tenn-K	4.06	0.81	27%
Univ. Tenn-K	96.00	19.20	20%	Univ. Georgia	3.87	0.77	25%
Virginia Tech	45.00	9.00	09%	Virginia Tech	2.94	0.59	19%
Total	497.00	99.40	100%	Total	15.35	3.07	100%
INDICATOR **FCSm**: MEAN IMPACT OF THE RESEARCH FIELD(S)				INDICATOR **CPP/FCSm**: AVERAGE IMPACT ON RESEARCH FIELD(S)			
Univ. Georgia	11.19	2.24	30%	Univ. Florida	2.33	0.47	28%
Univ. Florida	9.72	1.94	26%	Univ. Tenn-K	2.29	0.46	27%
Univ. Tenn-K	9.22	1.84	24%	Virginia Tech	2.02	0.40	24%
Virginia Tech	7.32	1.46	20%	Univ. Georgia	1.74	0.35	21%
Total	37.45	7.48	100%	Total	8.38	1.68	100%
INDICATOR **JCSm**: MEAN IMPACT OF THE JOURNAL SET				INDICATOR **CPP/JCSm**: AVERAGE IMPACT ON THE JOURNAL SET			
Univ. Florida	17.87	3.57	30%	Virginia Tech	1.66	0.33	30%
Univ. Tenn-K	17.29	3.46	28%	Univ. Florida	1.36	0.27	25%
Univ. Georgia	16.15	3.23	26%	Univ. Georgia	1.24	0.25	23%
Virginia Tech	9.91	1.98	16%	Univ. Tenn-K	1.22	0.24	22%
Total	61.22	12.24	100%	Total	5.48	1.09	100%
INDICATOR **C**: TOTAL ACTUAL IMPACT				INDICATOR **JCSm/FCSm**: AVERAGE JOURNAL SET IMPACT ON FIELD(S)			
Univ. Florida	178.00	35.60	45%	Univ. Tenn-K	9.46	1.89	29%
Univ. Georgia	111.00	22.20	28%	Univ. Florida	9.44	1.89	29%
Univ. Tenn-K	79.00	15.80	20%	Univ. Georgia	7.23	1.45	22%
Virginia Tech	27.00	5.40	07%	Virginia Tech	6.63	1.33	20%
Total	395.00	79.00	100%	Total	32.76	6.56	100%

Note(s):
Field(s) or *research field(s)* is all the ISI Subject Categories that contain at least one journal that published at least one paper by at least one researcher from one of the departments or programs under study.

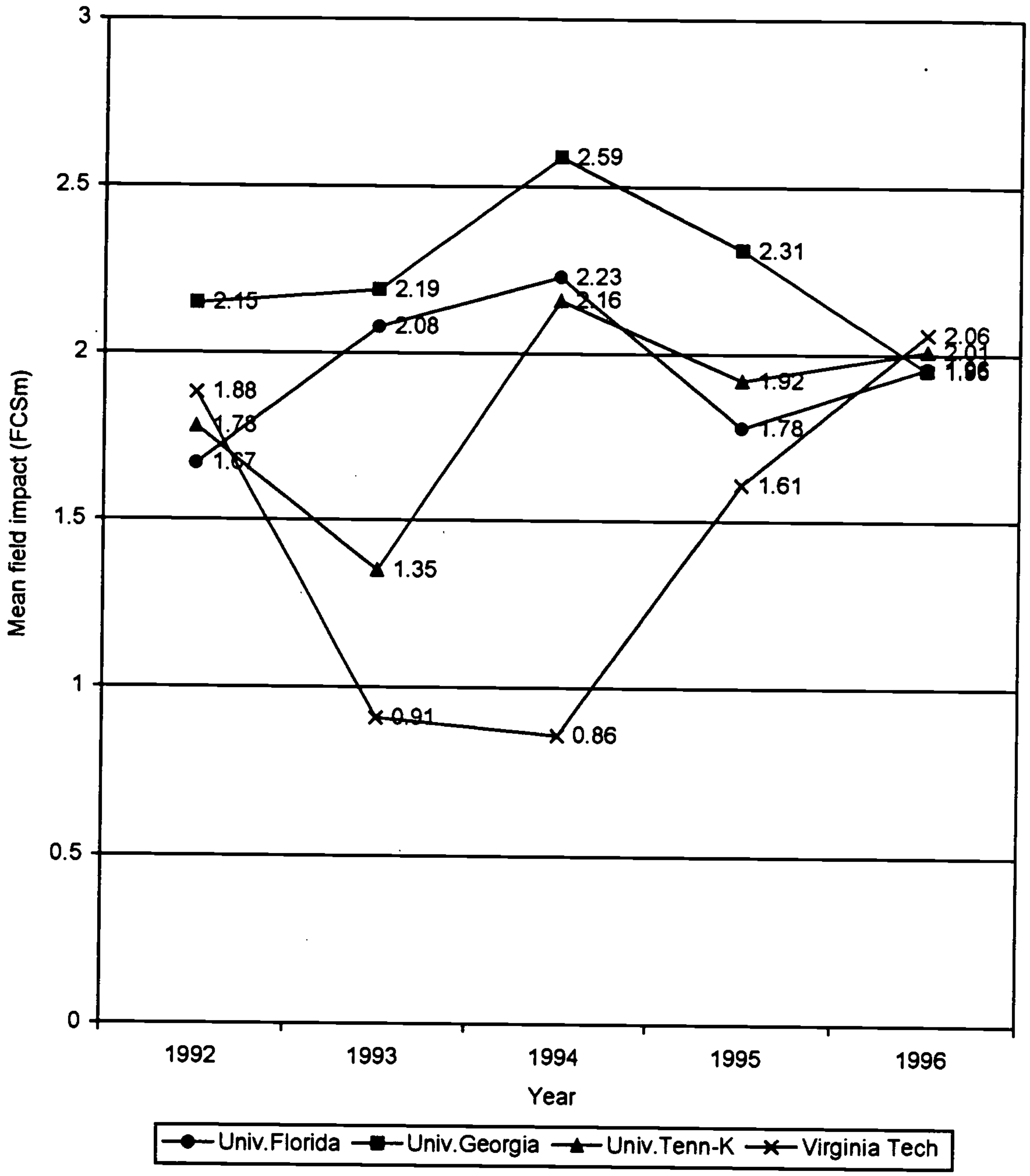


Figure 2. FCSm or mean impact of journal publications of the research field(s) for each Nutrition program, 1992-1996. Field(s) = all ISI Subject Categories that contain at least one journal that published at least one paper by at least one researcher.

FCSm for VT decreased to its lowest point. During the two years from 1994 to 1996, UGA's FCSm declined to its lowest point, ending below its 1992 value, while both UFL's and UTK's FCSm declined then recovered, ending slightly above their respective 1992 values. VT's FCSm showed a sharp increase to end slightly higher than its 1992 value. The rank order of the Nutrition departments by FCSm ran from UGA with 30% (N= 11.19) of the aggregate value, followed by UFL with 26% (N= 9.72), UTK with 24% (N= 9.22), and VT with 20% (N= 7.32) (see Table 8).

The JCSm indicator for UFL experienced a steep, continuous decrease from 1992 to 1994, followed by a slight increase through 1996, ending lower than its 1992 value (see Table 6, Table 7, and Figure 3). The JCSm for UGA increased from 1992 to 1993, followed by a steady decline to 1996, ending with the same value as in 1992. The JCSm for UTK increased overall from 1993 to 1996, ending above its 1992 value. VT's JCSm dropped precipitously from 1992 to 1993, then increased steadily to 1996, ending below its 1992 values. UFL lead in the rank order by JCSm for the four Nutrition programs with 30% (N= 17.87) of the aggregate value, followed by UTK with 28% (N= 17.29), UGA with 26% (N= 16.15), and VT with 16% (N= 9.91) (see Table 8).

Actual Impact Group

The Actual Impact Group consists of five indicators: C, CPP, CPP/FCSm, CPP/JCSm, and JCSm/FCSm. As was done with the indicators in the Expected Impact

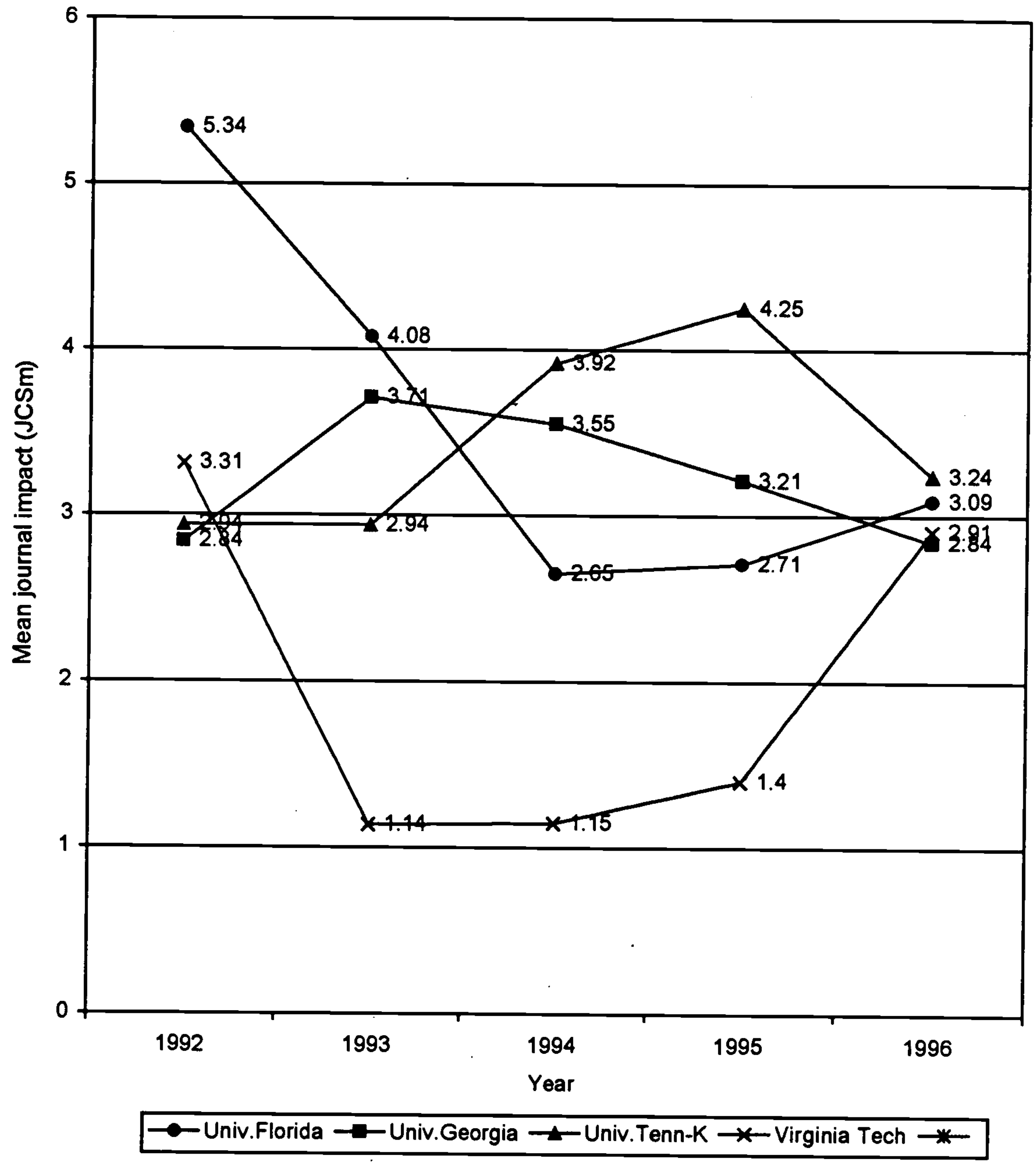


Figure 3. JCSm or mean impact of the journal set in which a Nutrition program publishes, 1992-1996.

Group, the five-year pattern will be examined separately for each indicator in the group, followed by the rank order comparisons for each Nutrition program by indicator.

The patterns for C for all four Nutrition departments was characterized by a general decline in its overall values from 1992 to 1996, ending with values below those of 1992, despite having an upswing year in either 1994 or 1995 (see Table 6, Table 7, and Figure 4). The exception was UFL, which experienced an overall net increase in C from 1992-1996. The rank order by C value for the departments has UFL first with 45% (N= 178) of the total citations received, followed by UGA in second place with 28% (N= 111), UTK in third place with 20% (N= 79), and VT in last place with 7% (N= 27) (see Table 8).

The indicator CPP had a pattern similar to that for C (see Table 6, Table 7, and Figure 5). All the Nutrition departments except UFL experienced a general, overall decline from 1992 to 1994, with UTK and VT experiencing a recovery from 1994 to 1995 (1993 –1994 for UGA), and with all three (UGA, UTK, and VT) ending with values in 1996 below the 1992 mark. The exception was UFL, which experienced an overall increase, ending the five-year period with a CPP well above that for 1992. The rank order by CPP value shows UFL with the highest part of the aggregate value at 29% (N=4.48), followed by UTK with 27% (N=4.06), UGA with 25% (N= 3.87), and VT with 19% (N= 2.94) (see Table 8).

The CPP/FCSm indicator was below average (<1.0) for all the departments for the entire period (see Table 6, Table 7, and Figure 6). All four programs (UFL, UTK, VT,

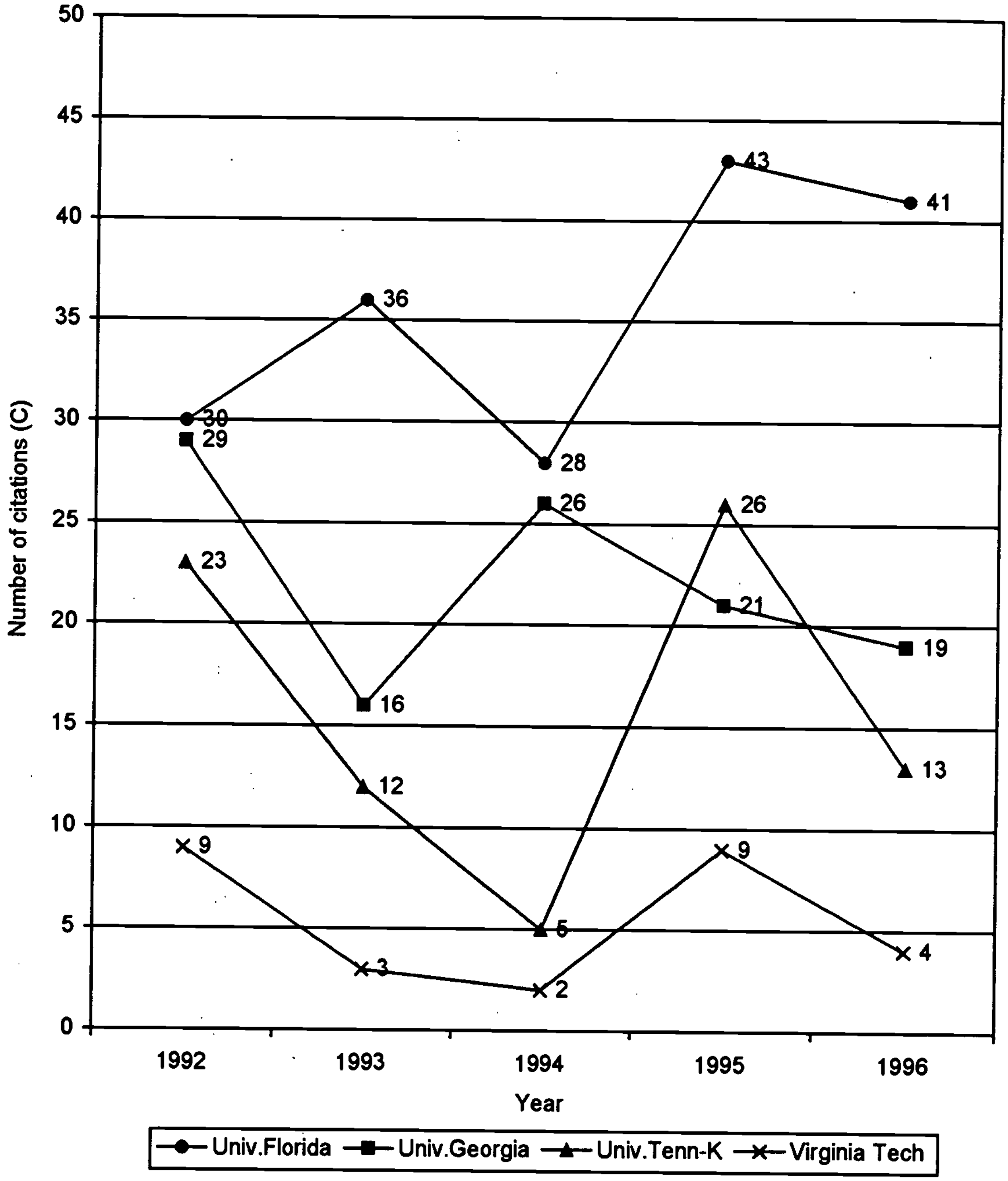


Figure 4. C or total number of citations to journal publications for each Nutrition program, 1992-1996.

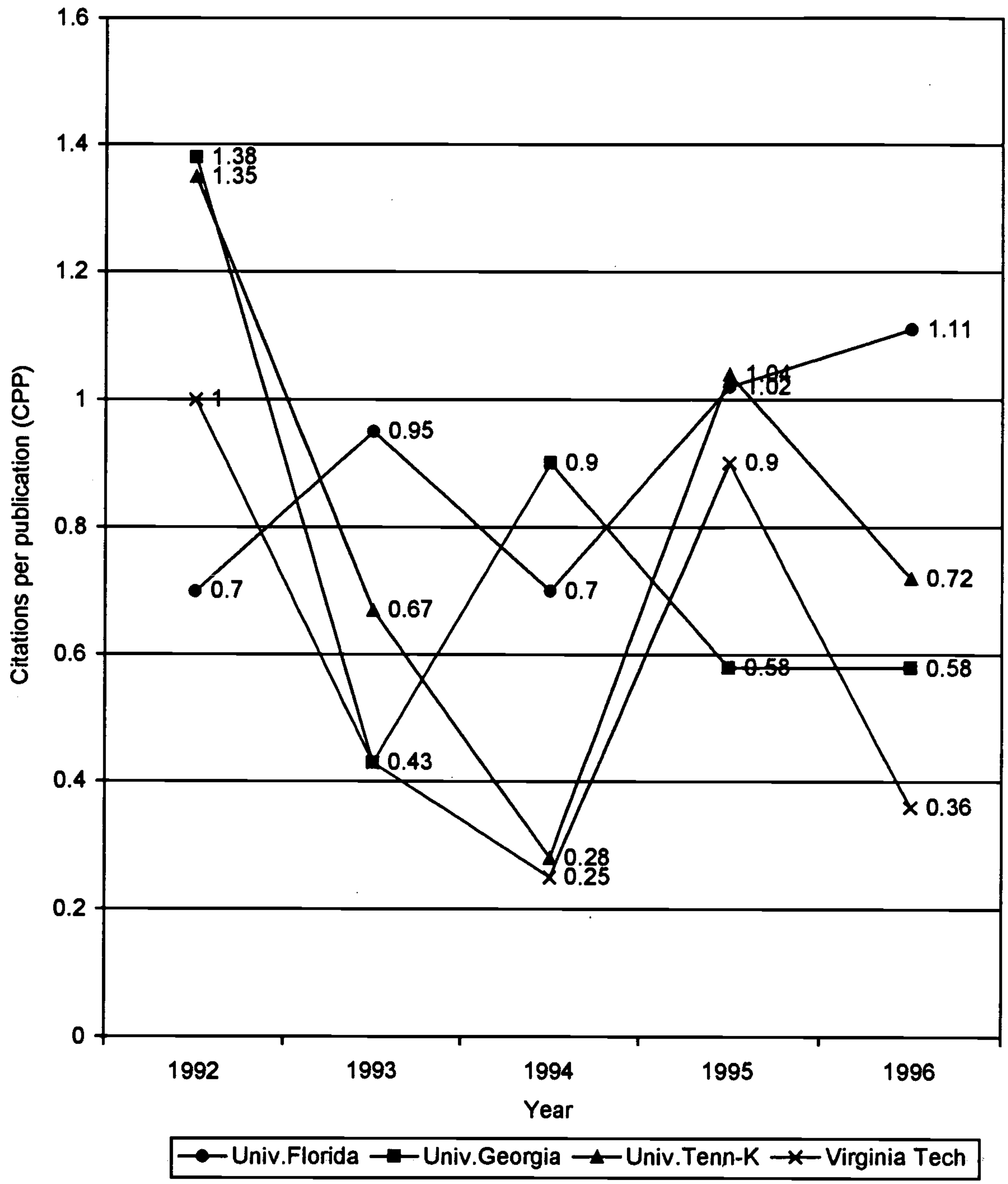
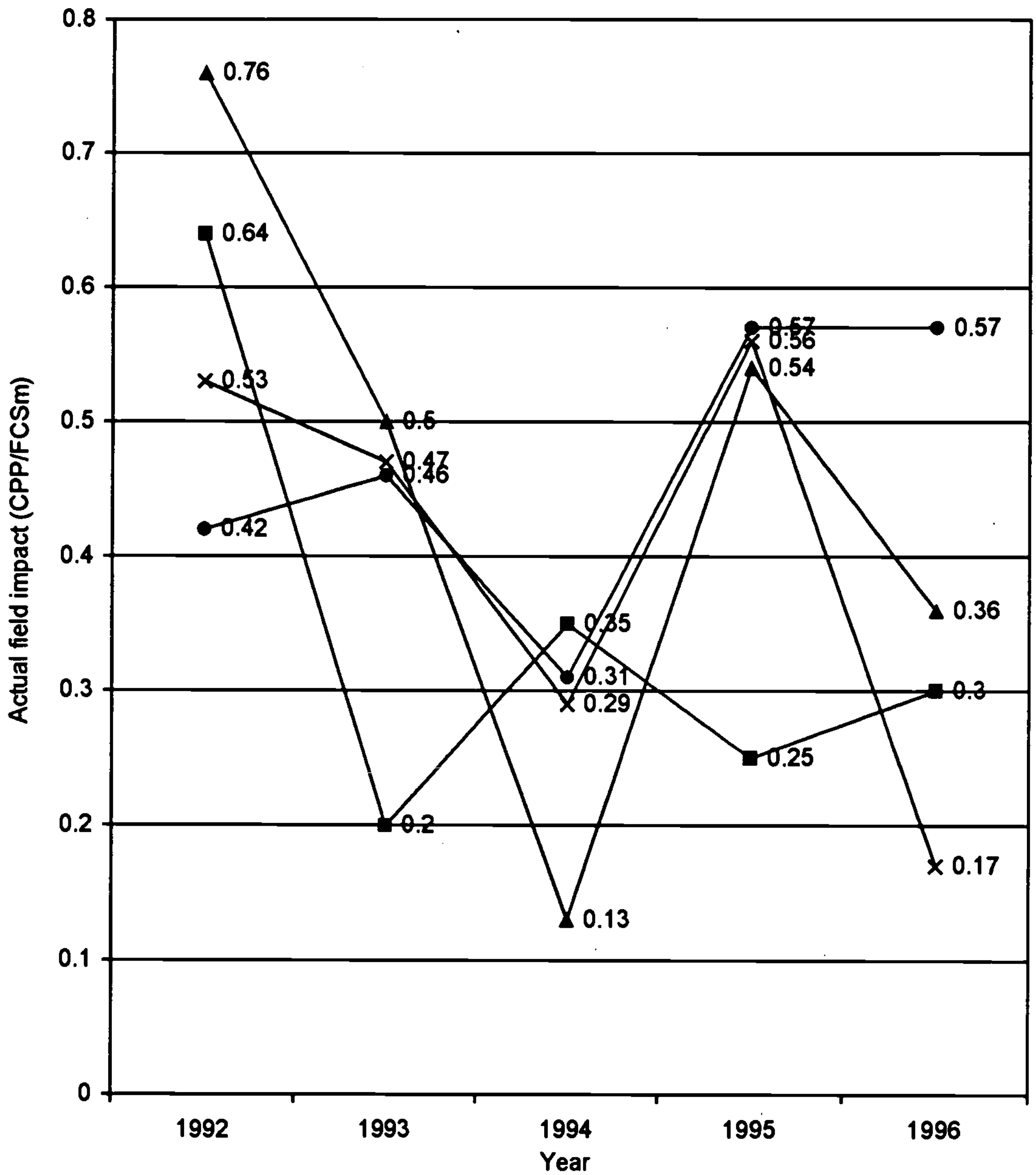


Figure 5. CPP or average actual impact of journal publications for each Nutrtion program, 1992-1996. CPP = citations per publication.



Note(s): Field= all the ISI Subject Categories that contain at least one journal that published at least one paper by at least one researcher.

—●— Univ.Florida —■— Univ.Georgia —▲— Univ.Tenn-K —×— Virginia Tech

Figure 6. CPP/FCSm or average impact of journal publications from each Nutrition program on the field(s) in which it researches, 1992-1996. For comparative purposes, the mean expected impact = 1.0. Hence, <1.0 is below average, >1.0 is above average.

and UGA) had a uniform decline in CPP/FCSm value from 1992 to 1994, followed by an upswing from 1994 to 1995. From 1995 to 1996, the CPP/FCSm value for UFL remained steady through 1996, while that for VT and UTK decreased and UGA increased, with all the programs still ending with 1996 values lower than those did for 1992. The exception was UFL, which posted higher values for 1996 than for 1992. The rank order of Nutrition departments by CPP/FCSm value had UFL in first place with 28% (N= 2.33) of the aggregate value. The CPP/FCSm values for the remaining three departments were within 7% of each other: UTK with 27% (N= 2.29), VT with 24% (N= 2.02), and UGA with 21% (N= 1.74) (see Table 8).

The indicator CPP/JCSm had a general pattern very similar to that for CPP/FCSm. All values were below average (<1.0), with sharp increases from 1994 to 1995, followed by declines, ending in 1996 with values less than those for 1992 (see Table 6, Table 7, and Figure 7). UFL's CPP/JCSm was the exception again, showing an overall increase from 1992 to 1996, ending above its 1992 value. VT led the CPP/JCSm rank order with 30% (N= 1.66) of the aggregate value. The remaining three departments in rank order were, UFL with 25% (N= 1.36), followed by UGA with 23% (N= 1.2.4) and UTK with 22% (N= 1.22).

The last actual impact indicator, JCSm/FCSm, was above average (>1.0) for each department for the 1992-1996 period, with the sole exception of VT in 1995 (see Table 6, Table 7, and Figure 8). UFL's JCSm/FCSm experience the most precipitous decline

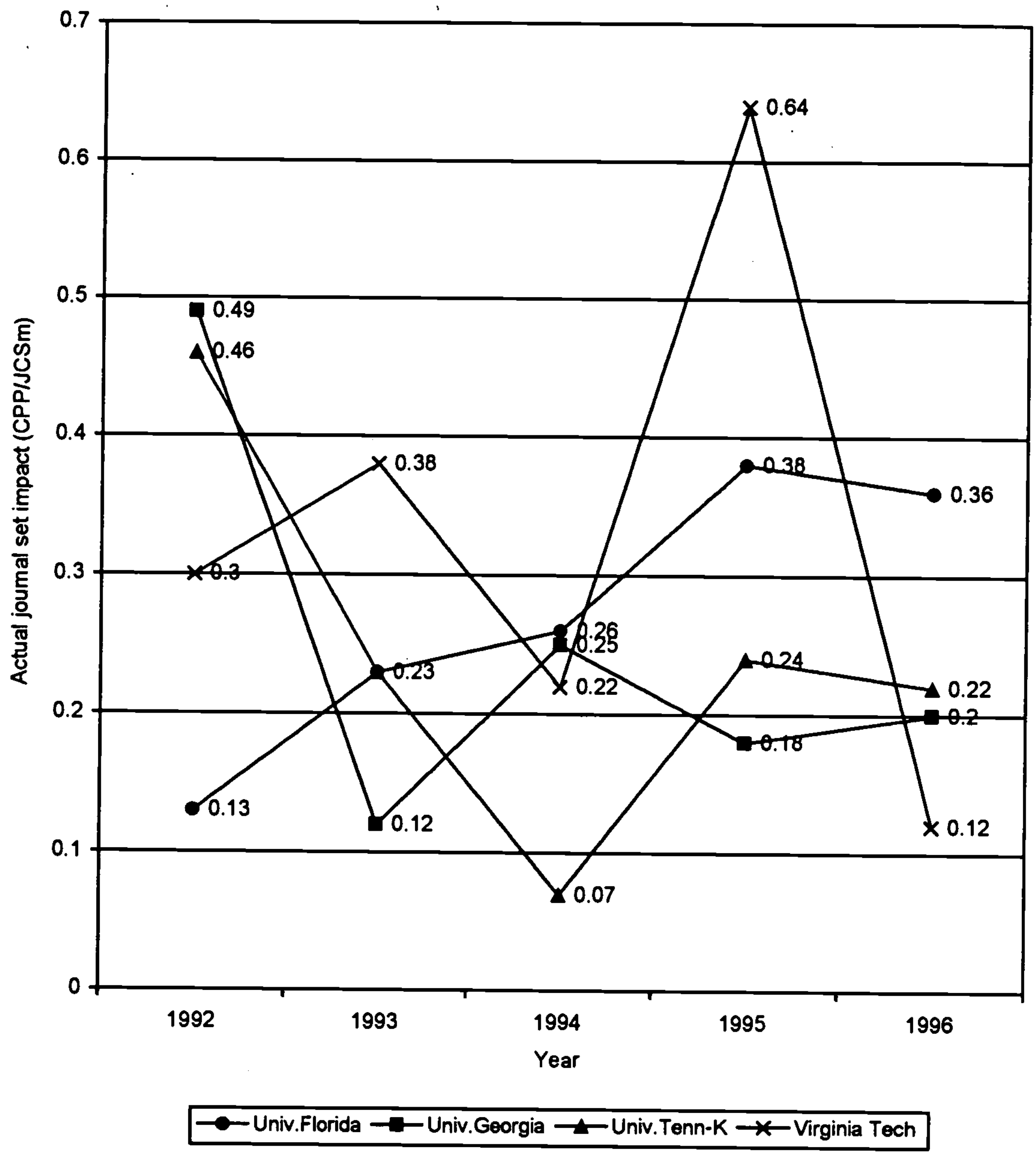
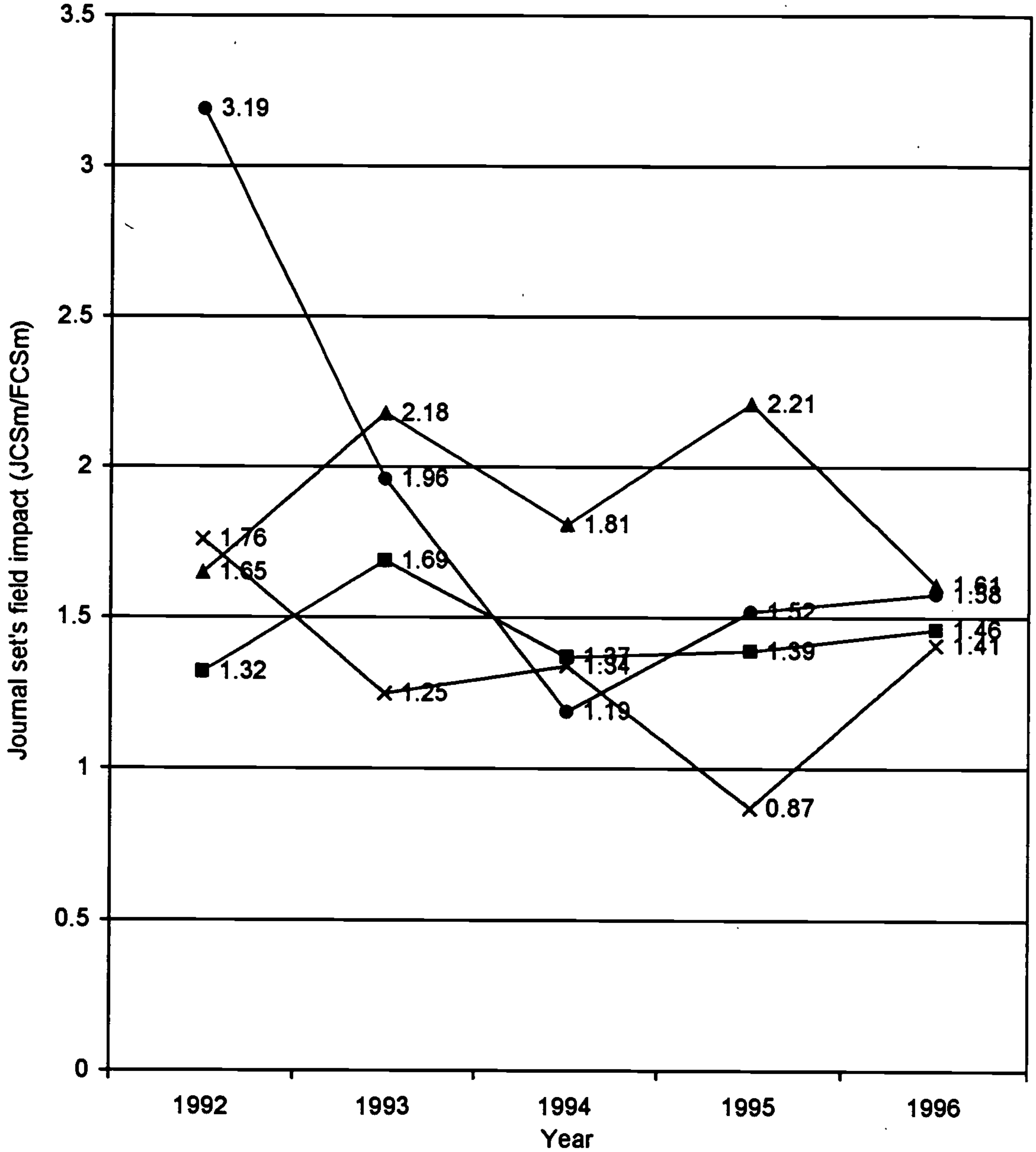


Figure 7. CPP/JCSm or average impact of journal publications from each Nutrition program on the journal set in which it publishes, 1992-1996. For comparative purposes, the mean expected impact = 1.0. Hence, <1.0 is below average, >1.0 is above average.



Note(s): Field= all the ISI Subject Categories that contain at least one journal that published at least one paper by at least one researcher.

Univ.Florida — Univ.Georgia — Univ.Tenn-K — Virginia Tech

Figure 8. JCSm/FCSm or average journal set impact for journals published in the field(s) for each Nutrition program, 1992-1996. For comparative purposes, the mean expected impact = 1.0. Hence , <1.0 is below average and >1.0 is above average.

from 1992 to 1994, after which it rallied slightly for the remaining two years, ending well below its 1992 value. UGA's values rose slightly from 1992 to 1993, then dropped in 1994, rising through 1996, but ending above its 1992 value. UTK experienced an increase in its JCSm/FCSm values from 1992 to 1993, a decline from 1993 to 1994, followed by an increase from 1994 to 1995, and ending in 1996 slightly below its 1992 value. VT's JCSm/FCSm was above average for the entire five-year period, with the exception of 1995. Even so VT's values underwent a steady decline from 1992 to 1995, followed by a recovery from 1995 to 1996, ending below its 1992 value. The rankings by JCSm/FCSm showed UTK and UFL tied with the highest percentage of the aggregate value at 29% (N= 9.46 and N= 9.44 respectively). UGA was ranked second with 22% of the aggregate value (N= 7.23), followed by VT with 20% (N= 6.63) (see Table 8).

Summary of Findings

In general, the Publication Output Group ended with a higher number of total publications in 1996 than it began with in 1992. The FCSm indicator from the Benchmark Impact Group had 1996 values only slightly above or slightly below their 1992 values. The JCSm indicator values tended to end with 1996 values at or below their 1992 beginning values. The indicators in the Actual Impact Group shared a similar pattern of value changes for UGA, UTK, and VT, with decreases from 1992 to 1994, increases from 1994 to 1995, followed by decreases again from 1995 to 1996, all ending below the 1992 values. For four of the five indicators (C, CPP, CPP/FCSm, and

CPP/JCSm), UFL was the exception, ending with 1996 values greater than those for 1992.

The overall rank order results, when averaged by department, ranged approximately between one and four. UFL had the highest average ranking of 1.4, followed by UTK with 2.5, UGA with 2.6, and VT with 3.5. This rank order remains the same when examining just the Actual Impact Group of indicators. The rank order changes slightly to UFL, UGA, UTK, and VT when examining the Publication Output Group and the Benchmark Group of indicators. These average rank order results should be treated with caution however as they were created from values for indicators that are only somewhat related, not directly comparable entities.

Discussion of Findings

The overall rank order of UFL, UTK, UGA, and VT may be in part reflective of the relative differences in the size of the researcher staff available in each program. The UFL program has the largest staff with 32 researchers, followed by UGA and VT with 24 researchers each, and UTK with 17 (see Appendix C). However, the differences in staffing cannot explain everything as UTK, with the smallest research staff of the four Nutrition programs, handily out performed VT and surpassed UGA (albeit slightly), two programs possessing larger research staffs. Also, if staff size alone was a major determinant of performance rank order, then VT's and UGA's programs, each staffed with the same number of researchers, should have consistently ranked more closely together than they actually did (see Table 8).

It is interesting to note that for four of the five Actual Impact Group indicators, C, CPP, CPP/FCSm, and CPP/JCSm, UFL was the only program that did not experience an overall decline from 1992 to 1996 (see Table 6 and Figures 4-7). This means that the UFL Nutrition program produced publications that had a greater impact on the fields in which it conducted research and on the journals in which it published than did the other three Nutrition programs used in this study. As for the fifth indicator of actual impact JSCm/FCSm, the four Nutrition programs in this study showed mixed results. Two programs, UFL and VT saw an overall decline in the impact of the journals in which they published their research results, whereas UGA experienced an increase and UTK remain about the same. That is, on the average, researchers from two (UFL and VT) of the four programs were getting their research published in journals with lower impact factors in 1992 than they were in 1996. One program, UGA, was getting its research published in higher impact journals, while the impact of the journals that published the UTK research remained relatively unchanged overall.

It is also interesting to note that the rank order for the P and C indicators are the same (see Table 8). This suggests that the quantity of publications (P) produced by a given Nutrition department may have a degree of influence on the quantity of citations (C) that its publications receive. That is, the greater a Nutrition program's P, the greater its C. At one level, this relationship may simply be the result of probability, with the greater the number of publications given a Nutrition department produces, the greater the number of citable papers that exist in the literature to be cited, hence the greater the possibility of being cited.

There is some indication in the literature that the benchmark indicators FCSm and JCSm can have a certain predictive quality. That is, by implication they provide a comparative expected value against which an actual result, such as CPP, is compared (van Raan and van Leeuwen 1998). Therefore, it can be assumed that FCSm functions as a predictor of CPP/FCSm or the actual impact on a given program's research field(s), and JCSm as the predictor of CPP/JCSm or the actual impact on the journal set in which a given program publishes. For example, in this study, if one used the five-year average value of FCSm to predict the CPP/FCSm rankings, the results should find UGA ranked first, followed by UFL, UTK, and VT. Similarly, using the five-year average values of the JCSm indicator to predict the CPP/JCSm rankings, the results should be UFL ranked first, followed by UTK, UGA, and VT (see Table 8). The data from this study, however, does not lend much support to this assumption. Of all the rankings predicted by both the FCSm and JCSm indicators using five-year data averages, only one ranking occurred as predicted, UGA's JCSm prediction of a third ranking for its CPP/JCSm (see Table 8 and 9). When examined on a year-by-year basis, the predictive capabilities of FCSm and JCSm do not seem to improve. The FCSm rank order predicted the CPP/FCSm rank order correctly only three times, ranking UFL fourth in 1992, UGA and UFL first and second respectively in 1994, and UTK second in 1996. The JCSm indicator preformed even more poorly by only correctly predicting two rankings for CPP/JCSm, which were a third rank for UTK in 1993 and a second rank for UGA in 1994 (see Table 9).

Table 9. Rank order prediction of field impact (FCSm vs. CPP/FCSm) and journal set impact (JCSm vs. CPP/JCSm), by year and by five-year average, 1992-1996.

Comparison by year of:									
FCSm (predicted rank order) vs. CPP/FCSm (actual rank order)									
1992		1993		1994		1995		1996	
FCSm	CPP/ FCSm	FCSm	CPP/ FCSm	FCSm	CPP/ FCSm	FCSm	CPP/ FCSm	FCSm	CPP/ FCSm
UGA	UTK	UGA	UTK	**UGA**	**UGA**	UGA	UFL	VT	UFL
VT	UGA	UFL	VT	**UFL**	**UFL**	UTK	VT	**UTK**	**UTK**
UTK	VT	UTK	UFL	UTK	VT	UFL	UTK	UFL	UGA
UFL	**UFL**	VT	UGA	VT	UTK	VT	UGA	UGA	VT
JCSm (predicted rank order) vs. CPP/JCSm (actual rank order)									
1992		1993		1994		1995		1996	
JCSm	CPP/ JCSm	JCSm	CPP/ JCSm	JCSm	CPP/ JCSm	JCSm	CPP/ JCSm	JCSm	CPP/ JCSm
UFL	UGA	UFL	VT	UTK	UFL	UTK	VT	UTK	UFL
VT	UTK	UGA	UFL	**UGA**	**UGA**	UGA	UFL	UFL	UTK
UTK	VT	**UTK**	**UTK**	UFL	VT	UFL	UTK	VT	UGA
UGA	UFL	VT	UGA	VT	UTK	VT	UGA	UGA	VT

Comparison by five-year average of:			
FCSm (predicted rank order) vs. CPP/FCSm (actual rank order)		JCSm (predicted rank order) vs. CPP/JCSm (actual rank order)	
FCSm	CPP/FCSm	JCSm	CPP/JCSm
UGA	UFL	UFL	VT
UFL	UTK	UTK	UFL
UTK	VT	**UGA**	**UGA**
VT	UGA	VT	UTK

Note(s):

The **bold** entries represent correctly predicted rank orders.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

"I never thought that others would take them more seriously than I did."
- Albert Einstein, talking about his theories
(Institute for Scientific Information 2000; Khalid 2000)

Conclusions of the Study

The goal of this study was to develop a set of empirically derived and theoretically sound citation-based bibliometric indicators of scientific research performance and apply them in an exploratory study comparing the University of Tennessee-Knoxville's Nutrition Department with three of its peer programs at the University of Florida, the University of Georgia, and Virginia Tech over a five-year period (1992-1996). A set of eight bibliometric indicators were developed and used in this evaluation: P, FCSm, JCSm, C, CPP, CPP/FCSm, CPP/JCSm, and JCSm/FCSm (see Table 3.)

Based on the findings of this study, the UTK Nutrition Department was ranked third in publication or research output (P), third in the average impact of its published papers on its research field(s) (FCSm), and second in the average impact of its publications on the journal set in which it published (JCSm) (see Table 8). In terms of the actual impact of its publications, UTK's Nutrition Department ranked third in total citations received by all its published journal articles (C), second in the average impact of its journal publications (CPP), second in the average impact of its journal publications on the field(s) in which the department conducted research (CCP/FCSm), fourth in the average impact of its journal publications had on the set of journals in which the department published (CPP/JCSm), and first in the average impact that these journals had on the field(s) in which the department conducted its research (JCSm/FCSm) (see Table 8). The overall average ranking for the UTK Nutrition Department in this study was second.

Interpretative Limitations of Bibliometric Evaluations

The important thing to remember when drawing conclusions from bibliometric evaluations of research performance is that their results are primarily *descriptive* and can offer little or nothing in the way of causal explanations. That is, they can *describe* patterns in publication and citation, the relative impact ranking between journals, and show any increases and decreases over time for various measures of departmental research performance, but cannot say much (if anything) about *why* the results are they way they are or how they came about. Such causal explanations require more intimate and detailed knowledge about each of the programs involved, such as the past and current research expertise and productivity of each researcher, projects completed, projects in progress, current funding sources, size and functionality of existing laboratory facilities, and number and quality of graduate students, than can be gleaned from the publication and citation databases. An understanding of the Nutrition discipline in general and the state of the art over the time period studied is also important for the formulation of useful and relevant causal explanations of the results of bibliometric evaluations. For example, this study demonstrated a pattern of total citations received (C) by each of the four Nutrition departments over a five-year period (see Figure 4), but cannot explain why this pattern exists or how it came about. Was the overall decline in citations received by three of the programs under study (UGA, UTK, and VT) due to the loss of key researchers by the departments through transfer or retirement, or due to the ending of a large project with no replacement yet in place, or due to natural causes such a flood, fire or earthquake? Alternatively, was the overall decline due instead to changes within the research priorities of the Nutrition field as a whole, with a shifting of emphasis to subjects not covered by the expertise extant in the departments under study? This would lead to a decline in the citation rate of journal publications that were no longer in the "hot" or even mainstream research areas. Based only the information found in this study, how is one to know which (if any) of these explanations are correct or even applicable?

These findings about the relative research performance of the four Nutrition programs under examination can be useful as a management tool for deans or department heads of these departments as well as to the Dean of UTK's College of Human Ecology in particular. In addition, the results of this study can make a useful contribution to the fields of scientometrics and infometrics by the through the development of a set of empirically and theoretically robust of bibliometric indicators.

Bibliometric Results as a Management Tool

The results of this study demonstrate the standing of the UTK Nutrition Department relative to three of its peer departments, as well as relative to all the Nutrition research units represented in the ISI citation database, in terms of the eight bibliometric measures used to evaluate research performance (see Table 8). The Dean of the UTK College of Human Ecology (CHE), as well as the deans and department heads of the other three programs, could use these results as additional inputs into the planning process in order to develop the best strategies for maximizing the department's strengths and minimizing its weaknesses. In addition, the Dean of the CHE could make use of the findings in making management decisions, such as whether or not to hire more research faculty or recruit more graduate students, and as additional data useful for helping secure additional funding from granting agencies as well as from the university administration.

The Dean may also find that the results of the four bibliometric indicators used in this study that had a strong relationship with peer review findings (CPP, CPP/FCSm, CPP/JCSm, and JCSm/FCSm) most useful for on-going ranking purposes when integrated with any current and future peer review data that he has for the UTK Nutrition Department. The findings of this study could also be utilized as the basis for developing an on-going, in-house database for tracking the current and future research performance of the UTK Nutrition Department against that of its specified peer programs as well against that of the Nutrition field as a whole.

Contributions to Scientometrics and Infometrics

This study provides a needed addition to the literature of departmental level bibliometric studies by providing both a source of comparative data and a set of bibliometric indicators of known empirical and theoretical utility for application in other studies in similar contexts. This study also may provide further empirical data on the behavior and utility of specific bibliometric indicators either previously used in the literature, or previously used in the literature but modified with ISI's impact data for use in this study.

Of particular interest in this respect are the four indicators CPP, CPP/FCSm, CPP/JCSm, and JCSm/FCSm that have the strongest empirical and theoretical rationale of those examined in this study. These indicators are all primary indicators that are shown to correlate with other measures of scientific achievement such as peer review ranking, awards, and academic positions (see Appendix B). In addition, CPP, CPP/FCSm, CPP/JCSm, and JCSm/FCSm are all contextualized (i.e., relative or comparative) measurement types that provide their own intrinsic, meaningful context that gives the strongest potential explanatory power (see pp. 43-45; van Raan 2000). In the future, these four indicators may form the basis of what will become a standard set of recognized, core indicators that must be present in every well-conducted departmental level bibliometric study.

The successful (if limited) application of Martin & Irvine's (1981, 1983) methodology of multiple converging partial indicators in this study will hopefully encourage others conducting departmental level bibliometric research performance studies to use more than two or three bibliometric indicators, thereby improving the accuracy and quality of their results (Martin, 1996).

Recommendations for Further Research

Further Subject Development

In light of the use of Martin and Irvine's (1983) methodology of multiple, converging indicators, it is worth considering what could be added to this study to explain more about the measurement of academic research performance in the Nutrition field. Some of the areas meriting further exploration would include departmental publication habits, peer review ratings, nature of each department's research activity, the inclusion of non-citation based indicators of scientific achievement, and the peer departments or programs that have been used previously for benchmarking purposes by each of the Nutrition programs under study.

Departmental publications habits

The publication habits of each Nutrition program under study could be further examined in order to accurately gauge how much of its research output is actually covered, and hence explainable by, the findings drawn from only the consideration of the traditional, scholarly print journal literature. For example, for each department or program, how much of the research is published in alternate sources such as books and monographs, in the "gray literature" (e.g., technical reports and patents), or in journals not covered by the *SCI-E*, as well as in other related areas, such as education, that may be covered in the *SSCI* or *AHCI* but not in the *SCI-E*. It would also be interesting to discover to what degree scholarly, scientific departmental publishing is moving from print to electronic outlets, such as peer reviewed (or not) electronic journals, as well as appearing in web sites created and maintained primarily by either the author, or a professional organization or society.

Peer review data

The addition of any existing peer review data available for each Nutrition department or program under study would add another indicator of research performance. In this case, the data would provide a qualitative dimension to an otherwise quantitative assessment, while remaining relevant due to the previously reported correlations with the indicators used in the study (Lawani and Beyer 1983; McAllister, Anderson, and Narin 1980; Hagstrom 1971). The addition of peer review data would also facilitate the acceptance by the scientific community of the findings from quantitative, bibliometric measures (Martin 1996).

Nature of research activities

The addition of more information about the research activities of each Nutrition department or program under study would increase the explanatory power of this study.

Of particular interested would be the inclusion of more data on research staffing, responsibilities, focus, and funding.

Research staffing and responsibilities

It would be useful to know the number of researchers available in each department for each year of the study as well as the amount of time that each was expected to actually do research as opposed to other duties such as teaching, administration, and fund-raising (Martin and Irvine 1983). The latter data would allow the calculation of a weight that could be multiplied by the number of researchers to normalize the staff size to reflect the actual number of researchers functioning as researchers (or *FR*s). For example, if Nutrition Department A has a designated research staff of 10, but requires an estimate average of 45% of their time be devoted to teaching and administrative duties, the weight would be calculated as100% (total time) – 45% (average estimated amount of time doing non-research activities) = 65% (amount of time actually conducting research). So the number of FRs in Department A is 10 (size of research staff) x 0.65 (average time spent researching) or 6.5. The use of FRs would provide a more accurate assessment of the research capabilities of a given Nutrition department in terms of its research staffing.

Research focus

Another aspect of research that would be interesting to know is the degree of focus and the changes in research subjects or topics over the time period of the study. Is a given department's research efforts narrowly focused on a small array of research topics, or is the focus broad, ranging over a diverse number of topics? An intensive, narrow focus could possible account for the strong presence (and hence potential impact) of a given department's research output in a given set of research fields and their associated journals. Conversely, a broader, more diverse research program may tend disperse the publication effort of a department, accounting for a relatively weak presence (and potential impact) in a larger set of research areas.

Research funding

It would also be useful to know the amount of research funding that each Nutrition department or program has available for each year from all sources (Martin and Irvine 1983). This would allow an evaluation of the relative influence the level of funding has on the relative research output and impact of a department or program. Such data could function as an indicator of how much research "bang" a given Nutrition department has produced for each research "buck" that it received from each of its funding sources. This in turn could perhaps serve as an indicator of their future research performance as well.

Non-citation based indicators of scientific achievement

One of the indicators of research performance missing from this study is an evaluation of other non-citation based indicators of scientific achievement obtained by the researchers of a given Nutrition program for the period under study. These non-citation based indicators include esteem indicators such as medals, prizes (e.g., Noble Prize), memberships in national academies (e.g., National Academy of Science of the United States), academic rank, endowed chairs, and invitations to given prestigious lectures (Lawani and Beyer 1983; McAllister, Anderson, and Narin 1980; Hagstrom 1971; Garfield 1989). It would be interesting to see if any of these non-citation based indicators of scientific achievement correlated with any of the bibliometric indicators used in this study. If so, then the non-bibliomentric indicators could serve to both provide not only additional qualitative information about the relative quality of a given department's research output, but also provide a degree of validation for the results of the bibliometric evaluation as well.

Departmentally determined peer programs

Finally, it would also be useful to know the peer departments or programs that have been used previously for benchmarking purposes by each of the Nutrition programs under study. If none were used, it would still be useful to discover the ones that they would use if required to submit a list of peer programs for the university president, provost, or dean. Such a list may prove to be different than the one used by the university for its evaluative purposes. It would provide a more accurate benchmarking tool since it originated within each Nutrition program or department, and based on their collective experience and understanding of both their department and the Nutrition field in general.

Further Methodological Development

The nature of the metrics or methodology of measuring research performance in this study could be further extended with the addition of citation mapping, testing of the indicators for the validity of the previously reported relationships with peer review and other non-bibliometric indicators of scientific achievement, as well as with size of research staff and amount of research funding. The stability or volatility of the patterns discovered in the findings of this study (see Figures 1-8) could be examined by extending the time frame from five to ten years. The methodology could also be extended by the use of a dynamic peer program set analogous to the dynamic journal set used by each Nutrition department under study to produce more accurate and relevant comparisons.

Citation mapping

Citation mapping is a method designed to graphically illustrate the underlying "structural and dynamic aspect of scientific research"(Noyons, Moed, and Luwel 1999, 115). Although citation maps have been created using co-citation analysis, co-word analysis, or combinations of the two (Small 1999; White and McCain 1998; Noyons, Moed, and Luwel 1999), its use in this study would be restricted to co-citation analysis.

The data for co-citation analysis are "the number of times that selected author pairs are cited together" in the publications under consideration, and the goal is to "identify influential authors and display their interrelationships from the citation record", or maps of "*writings related by use*" [emphasis original] (White and McCain 1998, 327, 329), which for this study are scholarly, scientific journal publications. These maps show spatial relationships can "help facilitate our understanding of conceptual relationships and developments" within a scientific field (Small 1999, 799). Co-citation maps use "two dimensions to depict subject relationships," under the assumption that "patterns of co-citation" define "the collective perceptions [of] citing authors" which in turn "create clusters of highly cited and co-cited works" (Small 1999, 800). By tracking the rate at which changes in these highly cited or co-cited articles occur, the rate of intellectual change in a given research field can be studied (Small 1999). Sudden changes are assumed to reflect revolutionary developments in a field.

The use of co-citation mapping then can provide a visual display showing the relationship of a given Nutrition department's publications to the research fronts or areas of "hottest" new or most popular research areas within the Nutrition field. In addition, it can show a given department's researchers in relation to other researchers from other institutions, as well as show the nature of any interdisciplinary research across research areas within or without the Nutrition field. Co-citation mapping can also show the current concentrations of research specialties, and perhaps even help predict what areas of research will emerge as the new popular or "hot" research specialties (White and

McCain 1998; Small and Greenlee 1990; van Raan 1996). As an added bonus, the results of citation mapping can provide at least partial validation the findings from the evaluation of the departments using bibliometric indicators, while the latter findings can provide some validation of the structures revealed by the citation mapping (Noyons, Moed, and Luwel 1999).

Relationships with other indicators

The methodology could be further developed by using it as a vehicle for testing the relationship between the eight bibliometric indicators used in the study and other previously reported factors such as peer review results and other awards of scientific achievement, as well as with other research indicators such as size of research staff and amount and sources of funding. In the case of examining the eight bibliometric indicators' relationship with peer review results and other awards of scientific achievement, the findings would either add to the growing both of literature providing empirical support, or provide some empirical grounds for questioning the relationships' validity. The analysis of the bibliometric indicators relationship to the size of the research staff and amount of funding for Nutrition programs would serve to both gauge the relative importance of these two factors in assessing the research performance of Nutrition programs, an issue poorly covered in the existing literature, as well as there relative potential usefulness as core evaluative indicators.

Temporal scope

Another way to develop the study's methodology is to extend its temporal scope. For instance, the time period under study could be increased to cover ten years (1988-1997) by adding data from 1998 to 1991 and for 1997. The study's timeframe cannot be moved any closer to 2001 due to a lack of available JCR data for 1998 on. The purpose of increasing the time period covered by the study would be to examine the degree of stability or volatility of the patterns discovered in the original study's findings. This in turn would allow an exploration of the question of how large a time slice is necessary to get accurate and representative patterns for evaluation Nutrition departments. For example, if the patterns seem to be relatively stable, with relatively little variation between the five and ten year patterns, then it could be assumed that a five-year study period would be sufficient for evaluating the research performance of Nutrition programs. On the other hand, relatively volatile patterns showing a high degree of variation between the patterns show by ten-year and five-year studies would indicate the need for at least ten-year period would be required for accurately evaluating Nutrition departments.

Dynamic peer program set

It would be interesting to see if the development and use of a dynamic peer program or department set analogous to the dynamic journal set would prove to be a useful for improving the comparative accuracy of the ranking of the departments or programs under study. Such a dynamic peer program set, generated for each department or program and for each year of the study would reflect the changes in the peer programs over time due to such factors as changes in a program's primary mission (e.g., from research to teaching) or research (e.g., from applied to theoretical). These dynamic peer program sets would be determined at the department or program level by each department or program using their knowledge of their own programs and the Nutrition field as a whole or as revealed by citation mapping. Using a dynamic peer program set would also have the added advantage being the same level of aggregation as the study level, thereby increasing overall comparability of the peer departments.

Summary

In this study, a set of eight empirically derived and theoretically sound citation-based bibliometric indicators of scientific research performance were developed: P, FCSm, JCSm, C, CPP, CPP/FCSm, CPP/JCSm, and JCSm/FCSm. They were used in an exploratory study comparing the University of Tennessee-Knoxville's Nutrition Department with three of its peer programs at the University of Florida, the University of Georgia, and Virginia Tech over a five-year period (1992-1996). The results of the study found that the UTK Nutrition Department ranked second in both the overall rankings and in the Actual Impact Group of indicators, and ranked third in the Publication Output and Benchmark Groups of indicators.

Though limited in their ability to provide causal explanations, the bibliometric findings from this study can help the deans and department heads form the four programs examined in the planning and management of their research units. In addition, they can use the bibliometric findings as augmentations to the traditional peer review evaluations of their unit's research performance.

The findings of this study can also provide an additional source of comparative data for further informetric and scientometric studies of departmental level research performance, of which there is little available in the literature. These findings can also provide further empirical data on the behavior of eight bibliometric indicators previously used in the literature, albeit modified for this study.

Some of the subject areas touch upon in this study that merit further exploration are each program's publication habits, its peer review ratings, the nature of its research activity, the inclusion of non-citation based indicators of scientific achievement for each program, and the incorporation of any data from previous used benchmarking programs. The methodology of this study could be further extended with the addition of citation mapping; validation of the previously reported relationships between the indicators and peer review; the addition of other non-bibliometric indicators of scientific achievement, the size of research staff, and amount of research funding; examining the stability or volatility of the patterns in the findings by extending the time frame from five to ten years; and exploring the use of a dynamic peer program set to produce more accurate and relevant comparisons.

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- Albert Einstein (Khalid 2000)

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Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Office of Institutional Research and Assessment. 2000. UTK's peer institutions. <http://web.utk.edu/~oira/peers.html>. 24 July 2000.

Pestana, A. 1992. Spanish performance in life sciences: A comparative appraisal of the scientific production of Spain and five other European countries in 1989. *Scientometrics* 24, no. 1: 95-114.

Phelan, T.J. 1999. A compendium of issues for citation analysis. *Scientometrics* 45, no. 1: 117-136.

Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Schoonbaert, D., and G. Roelants. 1996. Citation analysis for measuring the value of scientific publications: Quality assessment tool or comedy of errors? *Tropical Medicine and International Health* 1, no. 6: 739-752.

Schubert, A., W. Glanzel, and T. Braun. 1989. Scientometric datafiles, A comprehensive set of indicators on 2649 journals and 96 countries in all major science fields and subfields, 1981-1985. *Scientometrics* 16, no. 1-6: 3-478.

Seglen, P.O. 1992. The skewness of science. *Journal of the American Society for Information Science* 43, no. 9: 628-638.

Seglen, P.O. 1997. Citations and journal impact factors: Questionable indicators of research quality. *Allergy* 52: 1050-1056.

Small, H. 1999. Visualizing science by citation mapping. *Journal of the American Society for Information Science* 50, no. 9: 799-813.

Small, H., and E. Greenlee. 1990. A co-citation study of AIDS research. In *Scholarly Communications and Bibliometrics*, ed. Christine L. Borgman, 166-193. Newberry Park: Sage Publications.

Van Leeuwen, Th.N., E.J. Rinia, and A.F.J. van Raan. 1998. Bibliometric profiles of academic physics research in the Netherlands. <http://sahara.fsw.leidenuniv.nl/cwts/rep9609s.html>. 28 June 2000.

Van Leeuwen, Th.N., and , R.J.W. Tijssen. 1993. Assessing multidisciplinary areas of science and technology: A synthetic bibliometric study of Dutch nuclear energy research. *Scientometrics* 26, no. 1: 115-133.

Van Raan, A.F.J. 1996. Advanced bibliometric methods as quantitative core of peer review based evaluation and foresight exercises. *Scientometrics* 36,, no. 3: 397-420.

Van Raan, A.F.J. 2000. The Pandora's Box of citation analysis: Measuring scientific excellence- The last evil?" In *The Web of knowledge, A Festschrift in Honor of Eugene Garfield*, ed. Blaise Cronin and Helen B. Atkins, pp. 301-320. Metford, NJ: Information Today, Inc.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http:// sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

White, H.D., and K.W. McCain. 1998. Visualizing a discipline: An author co-citation analysis of information science, 1972-1995. *Journal of the American Society for*

Information Science 49, no. 4: 327-355.

Zachos, G. 1991. Research output evaluation of two university departments in Greece with the use of bibliometric indicators. *Scientometrics* 21, no.2: 195-221.

APPENDICES

APPENDIX A

ANNOTATED BIBLIOGRAPHY OF SELECTED PAPAERS RELATING TO JOURNAL IMPACT FACTORS (JIFs)

Campanario, J.M. 1996. The competition for journal space among referees, editors, and other authors and its influence on journals' impact factors. *Journal of the American Society for Information Science* 47, no. 3: 184-192.

Discovered a positive relationship between a journal's JIF and its use by "journal- related authors" (e.g., external referees, or editors of that journal).

Davis, G., and P. Royle. 1996. A comparison of Australian university output using journal impact factors. *Scientometrics* 35, no. 1: 45-58.

Use of JIF as quality indicator allowed scaling (adjusting) results for institutional size.

Garfield, E. 1989. Evaluating research: Do bibliometric indicators provide the best measures? In *Essays of an Information Scientist: Vol. 12. Creativity, Delayed Recognition, and Other Essays*. Philadelphia: Institute for Scientific Information Press. <http:// www.garfield.library.upenn.edu/essays/v12p093y1989.pdf>. 2 May 2000.

Review of bibliometric performance measures "in terms of their strengths, weaknesses and particular applications." Actually, this is an abridged version of Jean King's 1987 article "A review of bibliometric and other science indicators and their role in research evaluation" (*Journal of Information Science*, 13, 261-276).

Garfield, E. 1996. How can impact factors be improved? *British Medical Journal* 313: 411-413.

JIF misused as evaluative surrogates. It actually reflects a journal's long term ability to attract the best articles (data from medical journals).

Garfield, E. 1997. Dispelling a few common myths about journal citation impacts. *The Scientist* 11, no. 3: 11. <http://www.the-scientist.library.upenn.edu/ yr1997/feb/comm._970203.html>. 3 May 2000.

Mainly a rebuttal of notion that journal size alone determines its impact factor.

Garfield, E. 1998. The multiple meanings of impact factors. *Journal of the American Society for Information Science* 49, no. 8: 768.

Point by point rebuttal of Harder and Nisonger's criticism of JIF.

Garfield, E. 1998. The use of journal impact factors and citation analysis for evaluation of science. Paper presented at the 41st Annual Meeting of the Council of Biology Editors, Salt Lake City, UT, 4 May 1998- 17 April 1998. <http:// www. garfield.upenn.edu/papers/eval_of_science_CBE(Utah).html>. 3 May 2000.

Includes a discussion of using JIF as a surrogate for actual citation counts. In general he discourages such use, but discusses acceptable real life exception. Shows that long-term JIF favors established fields, while short-term (2-year) JIFs favor hot fields. Rebuttal of assertion that a field of study's size has any noticeable effect on its journal's JIFs.

Garfield, E. 1999. Journal impact factor: A brief review. *Canadian Medical Association Journal* 161: 979-980. <http:// www. cma.ca/cmaj/vol-161/issue-8/0979.htm

Defense of JIF. JIF created as simple means of journal comparison regardless of size. Evolved in Europe to include both author and journal impact, which are two different things. Provides thoughts on correct use of JIF. Maintains that though JIF is not a perfect measure of quality, it fits well with the perception each field has of its journals.

Harter, S.P., and T.E. Nisonger. 1997. ISI's impact factor as misnomer: A proposed new measure to assess journal impact. *Journal of the American Society for Information Science* 48, no. 12: 1146-1148.

JIF is primarily a measure of a journal's influence on the scholarly communication process, not just an indicator of journal productivity. The number of articles (size) of a journal distorts its relative impact. Smaller journals with fewer, higher quality articles have less impact on scholarly communications than large journals publishing more, lower quality articles. Recommends replacement of JIF with "article impact factor," a new measure of journal influence.

Hecht, F., B.K. Hecht, and A.A. Sandberg. 1998. The journal "impact factor": A misnamed, misleading, misused measure. *Cancer Genetics and Cytogenetics* 104: 77-81.

JIFs misused as measures of relative importance of researchers, programs, and institutions. Recommends JIF be renamed "citation rate index" to prevent future abuse.

Moed, H.F., and Th.N. van Leeuwen. 1995. Improving the accuracy of Institute for Scientific Information's journal impact factors. *Journal of the American Society for Information Science* 46, no. 6: 461-467.

ISI's JIFs inaccurate due to failure to clearly define document types. JIFs should be recalculated by document type.

Peritz, B.C. (1995). On the association between journal circulation and impact factor. *Journal of Information Science* 21, no. 1: 63-67.

Discovered low correlation between a journal's JIF and its circulation.

Schoonbaert, D., and G. Roelants. 1996. Citation analysis for measuring the value of scientific publications: Quality assessment tool or comedy of errors? *Tropical Medicine and International Health* 1, no. 6: 739-752.

Balanced, but generally positive assessment of using JIFs as quality measures in the sciences, as long as it's limitations are understood.

Seglen, P.O. 1992. The skewness of science. *Journal of the American Society for Information Science* 43, no. 9: 628-638.

The variability of citation rates between articles in scientific journals is too great to make either JIF or article citation rates a viable measure of research productivity of individuals or groups.

Seglen, P.O. 1994. Causal relationship between article citedness and journal impact. *Journal of the American Society for Information Science* 45, no. 1: 1-11.

Use of JIF to evaluate research units ("author, research group, institution, or country) can produce highly misleading results unless the size of the evaluated unit is equal in size to the world average for that unit.

Seglen, P.O. 1997. Citations and journal impact factors: Questionable indicators of research quality. *Allergy* 52: 1050-1056..

Good review of criticisms of JIF and citation analysis, including the problems of citation motives, shortcomings of the ISI database, effect of a given research field on citation rates, English language bias, North American journal bias, effects of article length and review articles, and the problems with calculating JIFs.

Sen, B.K. 1992. Documentation note: Normalized impact factor. *Journal of Documentation* 48, no. 3: 318-325.

Using a normalized JIF provides better indicator of comparative performance quality between labs doing diverse research.

Van Leeuwen, Th.N., H.F. Moed, and J. Reedijk. 1999. Critical comments on institute for scientific information journal impact factors: A sample of inorganic molecular chemistry journals. *Journal of Information Science* 25, no.6: 489-498.

Problems of using the JIFs of science journals as quality measures: different document types, journal splitting into tow, journal name changes, rate of uncitedness of papers published, and the short length of citation time period (two years) upon which the JIF is calculated

Vinkler, P. 1991. Possible causes of differences in information impact of journals from different subfields. *Scientometrics* 20, no. 1: 145-161.

Using data from chemistry journals, found differences between JIFs due to journal size, "mean number of references per article," information ageing rates, and subject subfields. Recommends use of a standardized JIF for comparisons between journals for difference subfields.

APPENDIX B

EVALUATION OF BIBLIOMETRIC INDICATORS FROM THE NINE BIBLIOMTRIC STUDIES ANALYZED IN THE LITERATURE REVIEW FOR POSSIBLE USE IN THIS STUDY

Evaluation Criteria

The following criteria were used to evaluate the twenty-six bibliometric indicators used by the bibliometric studies reviewed for this study. In Table B1, each criterion is listed followed by its possible values, and its definition.

Table B1. Selection criteria used to evaluate the bibliometric indicators used by the studies analyzed in the literature review.

Criterion	Possible Values	Definition
Definition	Accept or reject	What is the indicator?
Calculation	0 or 1	How is the indicator created?
Application	0 or 1	Does the indicator function as a primary or secondary indicator?
Interpretation	0 or 1	What does the indicator mean?
Peer Correlation	0 or 1	Does the indicator correlate with the results of peer review or evaluation? (Name statistical test used, confidence interval, etc. if given).
Other Correlation(s)	0 or 1	Do the results of the indicator correspond to one or more other indicators or methods of scientific evaluation (such as academic awards, membership in prestigious academic academies, etc).

Note(s):
Values (accept or reject): If the indicator it is not defined, or the definition is
Table B1 (continued).

not reasonably clear and understandable, then it is immediately rejected without further consideration.
Values (0 or 1): If the criteria is not defined or explained in the study (or studies) in which it is used, or done so poorly that the meaning is not clear, or the study results are conflicting, then it is given a value of 0 (zero). Otherwise, it is given a value of 1 (one).
Primary indicators function mainly as a partial measure of a specified aspect (e.g., CPP functions as a primary indicator of publication impact). Optionally, it can be used for calculating other primary measures such CPP/FCSm and CPP/JCSm.
Secondary indicators function mainly as the basis for calculating one or more other primary indicators (e.g., C is used mainly to calculate primary indicators such as CPP, CPPex, and CPP/FCSm).

Evaluation Findings

The following is an alphabetical list of all 26 bibliometric indicators encountered during the literature review of actual bibliometric studies evaluating the performance of academic departments. The rating for an **Indicator** is given in parentheses after its name. **Source(s)** lists reference(s) to the study in which the indicator was found. Any variation of an indicator (e.g., P and %P) is listed as separate indicator. Note that *world-wide* is often used to mean either *other European countries*, or *other Western countries* such as the United States, Japan, and Australia (van Raan & van Leeuwen, 1998), though it is not always possible to tell from the context in which it is used. *Study group* refers to the unit of analysis such as academic department, research center, or similar used in the source study (or studies). *NA* means that the information is *not available* or not given any of the **Source(s)**. *Journal set* refers to a group of journals usually selected by the study group as being their main publication outlet. *Publications and papers* are often used interchangeably.

Indicator: C (4)
Definition: Number of citations (including self-citations) received for all the study group's publications
Calculation: Item count
Application: Secondary indicator
Interpretation: Indicator of impact or visibility (van Raan and van Leeuwen 1998)
Peer Correlation: High; Spearman's rank correlation (r_s) at the 99% confidence level (Rinia et al. 1998); None with peer evaluation (Martin & and Irvine 1983); however, McAllister, Anderson, and Narin (1980) found a strong correlation (0.7-0.9 product-moment and Spearman's r).
Other Correlation(s): None with highly cited papers, publications/researcher, or CPP (Martin and Irvine 1983); Correlation (0.5-0.8, product-moment and Spearman's r) with honorific awards, academic position, etc. (Myers 1970; McAllister, Anderson, and Narin 1980)
Source(s):

Martin, B.R., and J. Irvine. 1983. Assessing basic research, Some partial indicators of scientific progress in radio astronomy. *Research Policy* 12: 61-90.

McAllister, P.R., R.C. Anderson, and F. Narin. 1980. Comparison of peer and citation assessment of the influence of scientific journals. *Journal of the American Society for Information Science* (May): 147-152.

Myers, C.R. 1970. Journal citations and scientific eminence in contemporary psychology. *American Psychologist* 25, no. 11: 1041-1048

Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http:// sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Indicator: Cex (2)
Definition: Number of citations (excluding self-citations) received for all the study group's publications
Calculation: (Total number of citations)-(total self-citations)
Application: Secondary indicator
Interpretation: NA
Peer Correlation: NA
Other Correlation(s): NA
Source(s):
Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: %Cex (1)
Definition: A study group's percentage of the number of citations (excluding self-citations) for all the study group's publications
Calculation: [(study group's citation count)-(self-citations)/ (total of all study groups' citations)-(self-citations)]100
Application: NA
Interpretation: NA
Peer Correlation: NA
Other Correlation(s): NA
Source(s):
Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: CPP (5)
Definition: Average number of citations (including self-citations) per paper
Calculation: C/P
Application: Primary indicator
Interpretation: Indicator of actual impact
Peer Correlation: High; Spearman's rank correlation (r_s) at the 99% confidence level (Rinia et al. 1998); Also with peer evaluation, (Martin and Irvine 1983)
Other Correlation(s): With highly cited papers and publications per researcher (Martin and Irvine 1983).
Source(s):
Korevaar, J.C., and H.F. Moed. 1996. Validation of bibliometric indicators in the field of mathematics. *Scientometrics* 37, no. 1: 117-130.

Martin, B.R., and J. Irvine. 1983. Assessing basic research, Some partial indicators of scientific progress in radio astronomy. *Research Policy* 12: 61-90.

Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http:// sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Indicator: CPPex (4)
Definition: Average number of citations (excluding self-citations) per paper
Calculation: Cex/P
Application: Secondary indicator
Interpretation: A partial measure of publication impact
Peer Correlation: High; Spearman's rank correlation (r_s) at the 99% confidence level (Rinia et al. 1998)
Other Correlation(s): NA
Source(s):

Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http:// sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Indicator: CPPex/Overall Mean (3)
Definition: Ratio of citations per publication to average number of citations from all study groups
Calculation: CPPex/Overall Mean
Application: Primary indicator of the impact of a study group
Interpretation: High impact > 1.2, Low impact < 0.8, otherwise is Average impact (between 0.8 and 1.2)
Peer Correlation: NA

Other Correlation(s): NA
Source(s):
Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: CPP/FCSm (4)
Definition: Citation rate of the study group, compared with the average citations of all the articles in a journal category for a field/sub-field as defined by *JCR*'s journal categories.
Calculation: CPP/FCSm
Application: Primary indicator of a CPP normalized to the field-based citation average
Interpretation: Impact of the study group's research on its field or subfield. If the result is > 1.0, then the study group's "work is cited more frequently than the field-based world average" (van Raan and van Leeuwen 1998)
Peer Correlation: High; Spearman's rank correlation (r_s) at the 99% confidence level (Rinia et al. 1998).
Other Correlation(s): NA
Source(s):
Korevaar, J.C., and H.F. Moed. 1996. Validation of bibliometric indicators in the field of mathematics. *Scientometrics* 37, no. 1: 117-130.

Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http:// sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Indicator: CPP/JCSm (4)
Definition: Citations per publication compared with the citation rate of the study group's journal set; called a different name in Nederhof (1993) and Zachos (1991)
Calculation: CPP/JCSm
Application: Primary indicator of a CPP normalized to the journal-based citation average
Interpretation: Impact of the study group's research on its journal set. If it is > 1.0, then it is above "the journal-based world average" (van Raan and van Leeuwen 1998)
Peer Correlation: High; Spearman's rank correlation (r_s) at the 99% confidence level (Rinia et al. 1998).
Other Correlation(s): NA

Source(s):

Nederhof, A.J., R.F. Meijer, H.F. Moed, and A.F.J. van Raan. 1993. Research performance indicators for university departments: A study of an agricultural university. *Scientometrics* 27: 157-178.

Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http:// sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Zachos, G. 1991. Research output evaluation of two university departments in Greece with the use of bibliometric indicators. *Scientometrics* 21, no.2: 195-221.

Indicator: CPR (2)
Definition: Citation productivity per researcher within a research group
Calculation: Number of citations/number of researchers
Application: NA
Interpretation: Estimate of the research impact or visibility of a research group
Peer Correlation: NA
Other Correlation(s): NA
Source(s):

Nederhof, A.J., R.F. Meijer, H.F. Moed, and A.F.J. van Raan. 1993. Research performance indicators for university departments: A study of an agricultural university. *Scientometrics* 27: 157-178.

Zachos, G. 1991. Research output evaluation of two university departments in Greece with the use of bibliometric indicators. *Scientometrics* 21, no.2: 195-221.

Indicator: FCSm (3)
Definition: Mean citation rate of all the articles in the journal category for a field/sub-field as defined by *JCR*'s journal categories [mean Field Citation Score]
Calculation: Total citations of the study group in their field or subfield/total papers in the study group's field or subfield
Application: Secondary indicator
Interpretation: Provides a world-wide reference value or expected impact score for comparison (van Raan and van Leeuwen 1998)
Peer Correlation: Low; Spearman's rank correlation (r_s) (Rinia et al. 1998)
Other Correlation(s): NA
Source(s):

Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http:// sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Indicator: HCP (4)
Definition: Highly cited papers (or key papers) of a study group that received at least 15 (or more) citations within the same one-year period.
Calculation: Item count
Application: Indicator of the number of high impact "discoveries" made by the study group
Interpretation: Each of these key papers has made a very large impact in its time on the advancement of scientific knowledge.
Peer Correlation: With peer evaluation
Other Correlation(s): NA
Source(s):

Martin, B.R. 1996. The use of multiple indicators in the assessment of basic research. *Scientometrics* 36: 343-362.

Martin, B.R., and J. Irvine. 1983. Assessing basic research, Some partial indicators of scientific progress in radio astronomy. *Research Policy* 12: 61-90.

Indicator: JCSm (3)
Definition: Average number of citations received by all articles in a specific journal during a given citation window (Korevaar and Moed 1996) [mean Journal Citation Score]
Calculation: Total citations of study group in their journal set/total papers in journal set
Application: Secondary indicator
Interpretation: Provides a world-wide reference value or expected journal impact score for comparison, allowing whether" the measured impact is above or below world average" (van Raan and van Leeuwen 1998)
Peer Correlation: Low; Spearman's rank correlation (r_s) (Rinia et al. 1998)
Other Correlation(s): NA
Source(s):

Korevaar, J.C., and H.F. Moed. 1996. Validation of bibliometric indicators in the field of mathematics. *Scientometrics* 37, no. 1: 117-130.

Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http:// sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Indicator: JCSm/FCSm (4)
Definition: Comparison of the impact of a journal to the world citation average of the field/sub-field (as defined by *JCR*'s journal categories) to which the journal belongs (Korevaar and Moed 1996).
Calculation: CPP/FCSm
Application: Primary indicator of a journal's impact on its field [a journal measure to replace ISI's journal impact factor] (Korevaar and Moed 1996).
Interpretation: If it is > 1.0, then the journal's actual impact is above the world average (or expected impact); if = 1.0, then it is the same as the expected impact; if < 1.0, then it is below the expected impact (Korevaar and Moed 1996).
Peer Correlation: High; Spearman's rank correlation (r_s) at the 99% confidence level (Rinia et al. 1998).
Other Correlation(s): NA
Source(s):

Korevaar, J.C., and H.F. Moed. 1996. Validation of bibliometric indicators in the field of mathematics. *Scientometrics* 37, no. 1: 117-130.

Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

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Indicator: Overall Mean (2)
Definition: Average number of citations from all study groups
Calculation: Total number of citations/total number of publications
Application: Secondary indicator
Interpretation: NA
Peer Correlation: NA
Other Correlation(s): NA

Source(s):
Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: P (3)
Definition: Total number of journal articles, notes, and reviews published by the study group
Calculation: Item count
Application: Secondary indicator
Interpretation: Indicator of scientific production (van Raan and van Leeuwen 1998), not of scientific progress (Martin and Irvine 1983)
Peer Correlation: None (Rinia et al. 1998; Martin and Irvine 1983)
Other Correlation(s): None with highly cited papers, publications/researcher, or CPP (Martin and Irvine 1983)
Source(s):
Martin, B.R., and J. Irvine. 1983. Assessing basic research, Some partial indicators of scientific progress in radio astronomy. *Research Policy* 12: 61-90.

Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

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Indicator: %P (1)
Definition: A study group's percentage of the total number of journal articles, notes, and reviews published by the all the study groups
Calculation: (study group's publications/total publications of all study groups)100
Application: NA
Interpretation: NA
Peer Correlation: NA
Other Correlation(s): NA
Source(s):

Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: P/cit>90 (1)
Definition: Number of publications for each study group among the 10% most frequently cited from all study groups"
Calculation: Item count
Application: NA
Interpretation: NA
Peer Correlation: NA
Other Correlation(s): NA
Source(s):
Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: %P/cit>90 (1)
Definition: Percentage of publications for each study group among the 10% most frequently cited from all study groups"
Calculation: (P/cit>90 for a study group/P90)100
Application: NA
Interpretation: NA
Peer Correlation: NA
Other Correlation(s): NA
Source(s):
Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: P/cit>10 (1)
Definition: Number of publications for each study group receiving more than 10 citations
Calculation: Item count
Application: NA
Interpretation: NA
Peer Correlation: NA
Other Correlation(s): NA
Source(s):

Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: %P/cit>10 (1)
Definition: Percentage of publications for each study group receiving more than 10 citations
Calculation: (P/cit>10 for a study group/P/cit>10 for all study groups)100
Application: NA
Interpretation: NA
Peer Correlation: NA
Other Correlation(s): NA
Source(s):
Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: Pfte (2)
Definition: Publication productivity per fte (or full-time equivalency) within a research group
Calculation: Total publications/number of man-hours for research or fte
Application: NA
Interpretation: Estimate of scientific productivity of a research group
Peer Correlation: NA
Other Correlation(s): NA
Source(s):
Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: Pnc (1)
Definition: Total count of publications not cited
Calculation: Item count
Application: NA
Interpretation: NA
Peer Correlation: NA
Other Correlation(s): NA
Source(s):

Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: %Pnc (1)
Definition: Percentage of publications not cited
Calculation: No. of uncited papers/total papers P)100
Application: NA
Interpretation: NA
Peer Correlation: NA
Other Correlation(s): NA
Source(s):
Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http:// sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Indicator: P90 (2)
Definition: The 10% most frequently cited publications from all study groups (90th percentile)
Calculation: Percentile
Application: Secondary indicator
Interpretation: NA
Peer Correlation: NA
Other Correlation(s): NA
Source(s):
Noyons, E.C.M., H.F. Moed, and M. Luwel. 1999. Combining mapping and citation analysis for evaluative bibliometric purposes: A bibliometric study. *Journal of the American Society for Information Science* 50, no. 2: 115-131.

Indicator: PPR (4)
Definition: Publication productivity per researcher within a research group
Calculation: Total publications/number of researchers
Application: NA
Interpretation: Estimate of scientific productivity of a research group
Peer Correlation: With peer evaluation (Martin and Irvine, 1983)

Other Correlation(s): With highly cited papers and CPP (Martin and Irvine 1983).
Source(s):
Martin, B.R., and J. Irvine. 1983. Assessing basic research, Some partial indicators of scientific progress in radio astronomy. *Research Policy* 12: 61-90.

Zachos, G. 1991. Research output evaluation of two university departments in Greece with the use of bibliometric indicators. *Scientometrics* 21, no.2: 195-221.

Indicator: %Selfcite (3)
Definition: Percentage of papers not cited
Calculation: (Total self-cites/total cites C) 100
Application: NA
Interpretation: An indication either of a study group's relative isolation due to its focus on currently unfashionable research topics, or as an indication of the uniqueness/newness of its research focus.
Peer Correlations: High/negative (i.e., lower self-cite percentages correspond to higher peer ratings); Spearman's rank correlation (r_s) at the 99% confidence level (Rinia et al. 1998).
Other Correlation(s): NA
Source(s):
Rinia, E.J., Th.N. van Leeuwen, H.G. van Vuren, and A.F.J van Raan. 1998. Comparative analysis of a set of bibliometric indicators and central peer review criteria: Evaluation of condensed matter physics in the Netherlands. *Research Policy* 27: 95-107.

Van Raan, A.F.J., and Th.N. van Leeuwen. 1998. Assessment of multidisciplinary, applied research using bibliometric methods in nutrition and food research. <http:// sahara.fsw.leidenuniv.nl/cwts/rcivo_a.html>. 28 June 2000.

Evaluation Results

The selection of the actual indicators from those listed above was ultimately a subjective judgement based on a particular indicator's rating, type (primary or secondary), and if it required the exclusion of self-citations in its calculation. Since it was previously decided that it was unnecessary to remove all self-citations from the data before use, all indicators requiring it (e.g., CPPex and Cex) were eliminated from further consideration. All remaining indicators with ratings of 1 or 2 were rejected for having too few desirable criteria to merit further consideration. All the remaining indicators with ratings of 4 and 5 that were classed as "primary indicators" were thought the most useful, since each included at least one correlation criterion. The remaining indicators rated with at least a 3 rating and classed as "secondary indicators" were retained, with the balance discarded. The selection results are summarized in Table B2.

Table B2. Selected bibliometric indicators, by type and rating order.

Type	Rating	Indicator
Primary	5	CPP (Average citations per paper)
	4	C (Total citations)
	4	CPP/FCSm (Citations per paper compared with the expected field's citation rate)
	4	CPP/JCSm (Citations per paper compared with expected journal set citation rate)
	4	JCSm/FCSm (Comparison of the impact of a journal to the world citation average of the field/sub-field)
	4	HCP (Highly cited papers, or key papers)
	4	PPR (Publications per researcher)
Secondary	3	FCSm (Average citation rate of the field or sub-field)
	3	JCSm (Average citation rate of the journal set)
	3	P (Total publications)

APPENDIX C

EVALUATION OF THE NUTRITION PROGRAMS FROM EACH UTK PEER INSTITUTION FOR USE IN THIS STUDY

Evaluation Criteria

The following criteria were used to evaluate and rate the relative comparability of each peer institution's Nutrition program with UTK's program (see Table C1). The higher a program or department's rating, the greater is its similarity to UTK's Nutrition Department. Data used for the evaluation was taken from the website of each institution, the URL of which was active as of 4 October 2000.

Table C1. Criteria for evaluating Nutrition departments or programs from UTK peer institutions for inclusion in this study.

Criterion	Possible Values	Definition
Program	Accept or reject	Does the peer institution have a Nutrition Department or equivalent program?
Program Type		What is the nature of the department or program?
Disciplinary	1	Traditional, discipline specific academic department.
Interdisciplinary	0	Joint venture of many departments from different disciplines.
Program Focus		What is the department or program's main teaching and research subject focus?
Traditional	1	Subjects such as foods, nutrition, and biochemistry.
Non-traditional	0	Subjects such as nutrition and public health, nutrition and medicine, or human and animal/avian nutrition.
Faculty Size/Ratio	Peer/UTK	How many faculty in the department or program? How does it compare in size to UTK faculty?
Faculty Type		What is the primary responsibility of the department or program's faculty?
Research	0	Mainly to conduct research.
Research/extension	1	To conduct both research and extension work.
Graduate Program		Does it have a graduate program in Nutrition?
None	0	
Masters	1	
Doctoral	1	
Active Research	0 or 1	Does it have an active research component?

Note(s):
Values (accept or reject): If the peer institution does not indicate the presence of a Nutrition Department or equivalent program on its website, then it is immediately rejected from further consideration.
Values (0 or 1): If the department does not have a graduate program, or has an interdisciplinary program or has a non-traditional research and teaching focus, or has

only research faculty, or if it is not a Masters or Doctorate in Nutrition Science degree (e.g., certification program, internship, degree in Dietetic Administration, Hospitality, Health Education, etc.); or if there is no indication on the website that the department is

Table C1. (continued)

actively engaged in nutrition related research, such as a list of current research projects, grants, etc., then it is given a value of 0 (zero). Otherwise, it is given a value of 1 (one).
Peer/UTK: A comparative value calculated by dividing the number of faculty in the peer institution's department or program by the number of faculty in the UTK Nutrition Department (i.e., 17). The resulting number is subtracted from the 1, and the absolute value of that result is in turn subtracted from rating.
Active Research Component refers to a list of current or very recently completed research projects, not just to a list of research interests given on the department or program's website.
Equivalent programs refers to alternate names for departments that focus on nutrition as their academic discipline, such as Nutrition Sciences, Human Nutrition, Department of Foods and Nutrition, but excluding Food Science and Technology, Food Service, and similar applied science and technology programs.

Evaluation Findings

The following is an alphabetical list of the peer institutions for the University of Tennessee-Knoxville with the results of the evaluation. Note that the total rating for each peer institution is given in parentheses after its name.

Peer Institution: University of Florida (5.12)
Program: Department of Food Science and Human Nutrition
Program Type: Disciplinary
Program Focus: Traditional
Faculty Size/Ratio: 32/1.88
Faculty Type: Research and extension
Graduate program: MS and PhD
Active research: List of research projects with active faculty investigators
Source(s): http://fshn.ifas.ufl.edu/academic.htm; http://fshn.ifas.ufl.edu/research.htm; http://fshn.ifas.ufl.edu/faculty.htm

Peer Institution: University of Georgia (5.59)
Program: Department of Foods and Nutrition
Program Type: Disciplinary
Program Focus: Traditional
Faculty Size/Ratio: 24/1.41
Faculty Type: Research and extension
Graduate program: MS and PhD
Active research: List of current research projects
Source(s): http://www.fcs.uga.edu/fdn/graduate; http://www.fcs.uga.edu/fdn/people/index.php3?FDN+faculty

Peer Institution: University of Kentucky (2.59)
Program: Department of Nutrition and Food Science
Program Type: Disciplinary
Program Focus: Traditional
Faculty Size/Ratio: 10/0.59
Faculty Type: Research
Graduate program: MS in Hospitality and Dietetic Administration
Active research: Two current projects

Source(s): http://www.uky.edu/HES/NFS/nutritiongrad-new-hosp.html; http://www.rgs.uky.edu/ca/digest/index/html; http://www.uky.edu/HES/research%20bric/faculty.htm

Peer Institution: University of Maryland at College Park (2.82)
Program: Nutrition Program, Department of Nutrition and Food Science
Program Type: Interdisciplinary
Program Focus: Non-traditional
Faculty Size/Ratio: 20/1.18
Faculty Type: Research
Graduate program: MS and PhD
Active research: Requires completion of research project by graduate students
Source(s): http://www.gradschool.umd.edu/catalog/programs/nutr.htm; http://www.agnr.umd.edu/users/nfsc/gradnutr.htm

Peer Institution: University of North Carolina at Chapel Hill (1.06)
Program: Department of Nutrition
Program Type: Interdisciplinary
Program Focus: Non-traditional
Faculty Size/Ratio: 50/2.94
Faculty Type: Research
Graduate program: MS and PhD
Active research: List of ongoing research
Source(s): http://www.sph.unc.edu/nutr/Degree/degree.html; http://www.sph.unc.edu/nutr/Research/research.html; http://www.sph.unc.edu/nutr/Divisions/biochem.html

Peer Institution: University of Oklahoma (3.41)
Program: Department of Nutritional Sciences
Program Type: Disciplinary
Program Focus: Traditional
Faculty Size/Ratio: 7/0.41
Faculty Type: Research
Graduate program: MS
Active research: List of research activities
Source(s): http://rentsv1.ouhsc.edu/ahealth/ns.htm; http://rentsv1.ouhsc.edu/ahealth/research.htm; http://rentsv1.ouhsc.edu/ahealth/fans.htm

Peer Institution: University of South Carolina (0)
Program: None to date, but one is pending
Program Type: NA
Program Focus: NA
Faculty Size/Ratio: NA
Faculty Type: NA
Graduate program: None
Active research: None
Source(s): http://www.sph.sc.edu/sphdept.htm; http://www.sph.sc.edu/news/nutrctr.htm

Peer Institution: University of Texas at Austin (3.94)
Program: Department of Nutritional Sciences
Program Type: Disciplinary
Program Focus: Traditional
Faculty Size/Ratio: 16/0.94
Faculty Type: Research
Graduate program: MA and PhD
Active research: List of faculty research interests
Source(s): http://www.utexas.edu/depts/he/nutr_science/;
http://www.utexas.edu/depts/he/nutr_science/faculty;
http://www.utexas.edu/depts/he/nutr_science/faculty/grfaculty

Peer Institution: University of Virginia (0)
Program: None
Program Type: NA
Program Focus: NA
Faculty Size/Ratio: NA
Faculty Type: NA
Graduate program: None
Active research: None
Source(s): http://www.Virginia.edu/depts.html

Peer Institution: Virginia Polytechnic Institute and State University (5.59)
Program: Department of Human Nutrition, Foods, and Exercise
Program Type: Disciplinary
Program Focus: Traditional
Faculty Size/Ratio: 24/1.41
Faculty Type: Research and Extension
Graduate program: MS and PhD

Active research: Molecular Nutrition Lab
Source(s): http://www.chre.vt.edu/Admin/HNFE; http://www.chre.vt.edu/Admin/HNFE/fac/Davis/current_research.htm; http://www.chre.vt.edu/jhwms/hnfegrad/faculty.html

Evaluation Results

The following table lists in rating order from highest to lowest the peer institutions that qualify for possible use as sources for comparison in this study (see Table C2). Note that peer institutions with the same rating are listed alphabetically.

Table C2. UTK peer institutions in rating order, by institution and department (or program) name.

Rank	Peer Institution	Department (or Program)
5.59	University of Georgia	Department of Foods and Nutrition
5.59	Virginia Polytechnic Institute and State University	Department of Human Nutrition, Foods, and Exercise
5.12	University of Florida	Department of Food Science and Human Nutrition
3.94	University of Texas at Austin	Department of Nutritional Sciences
3.41	University of Oklahoma	Department of Nutritional Sciences
2.82	University of Maryland at College Park	Nutrition Program, Department of Nutrition and Food Science
2.59	University of Kentucky	Department of Nutrition and Food Science
1.06	University of North Carolina at Chapel Hill	Department of Nutrition

APPENDIX D

DATA WORKSHEET FORMS

Figure D1. Journal Data Worksheet Form

Journal Data Worksheet for (project):				
Institution:			Year:	
Source(s):				
Journal	ISI Field	ISI JIF	P	C
Total number of journals	Total		P	C
	JCSm	CPP	CPP/FCSm	CPP/JCSm

Figure D2. Field Data Worksheet Form

Field Data Worksheet for (project):		
Institution:		Year:
Source(s):		
ISI Field	Number of Journals	Total JIF
Total		
	FCSm	JCSm/FCSm

APPENDIX E

JOURNAL SET DATA FOR EACH NUTRITION PROGRAM, BY YEAR, 1992-1996

1992 Journal Set Data

Table E1. Journal set data for the Department of Food Science and Human Nutrition, University of Florida, 1992.

Journal Title	Field Name	ISI JIF	P
Clinical Research	Medicine, Research & Experimental	57.778	1
FASEB Journal	Biochemistry & Molecular Biology	15.115	8
Abstracts of Papers of the American Chemical Society	Chemistry	8.000	5
Hepatology	Gastroenterology & Hepatology	5.569	1
Molecular Microbiology	Biochemistry & Molecular Biology	5.142	1
Biochemical Journal	Biochemistry & Molecular Biology	4.262	1
American Journal of Clinical Nutrition	Nutrition & Dietetics	2.864	1
Journal of Pediatrics	Pediatrics	2.609	1
Toxicology & Applied Pharmacology	Pharmacology & Pharmacy	2.490	1
Journal of Laboratory & Clinical Medicine	Medicine, General & Internal	2.244	1
Journal of Nutrition	Nutrition & Dietetics	1.977	6
Enzyme & Microbial Technology	Biotechnology & Applied Microbiology	1.784	1
Proceedings of the Society for Experimental Biology& Medicine	Medicine, Research & Experimental	1.675	1
Critical Reviews in Food Science & Technology	Nutrition & Dietetics	1.377	1
Journal of Agricultural & Food Chemistry	Food Science & Technology	1.342	1
Journal of Animal Science	Agriculture, Dairy & Animal Science	1.335	1

Table E1. (continued)

Journal Title	Field Name	ISI JIF	P
Journal of Food Protection	Food Science & Technology	1.292	1
International Journal of Immunopharmacology	Pharmacology & Pharmacy	1.170	1
Toxicology Letters	Toxicology	1.112	1
Journal of the American Dietetic Association	Nutrition & Dietetics	1.090	1
Journal of Food Safety	Food Science & Technology	1.047	1
Journal of Food Science	Food Science & Technology	0.872	4
Comparative Biochemical Physiology B- Biochemistry	Biochemistry & Molecular Biology	0.685	2
	Total:	122.831	43

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports.*
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1994 *Journal Citation Report* (1995).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Food Science and Human Nutrition, University of Florida. Data is for the year 1992, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1995. *1994 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E2. Journal set data for the Department of Foods and Nutrition, University of Georgia, 1992.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biocehmistry & Molecular Biology	15.115	7
American Journal of Physiology	Physiology	3.276	1
American Journal of Clinical Nutrition	Nutrition & Dietetics	2.864	1
Journal of Nutrition	Nutrition & Dietetics	1.977	3
Journal of Applied Physiology	Physiology	1.852	1
Brain Research Bulletin	Neurosciences	1.811	1
International Journal of Obesity	Nutrition & Dietetics	1.568	1
Pharmacology Biochemistry & Behavior	Pharmacology & Pharmacy	1.450	1
Critical Reviews in Food Science & Nutrition	Food Science & Technology	1.377	1
Physiology & Behavior	Physiology	1.110	2
Journal of Nutritional Biochemistry	Nutrition & Dietetics	1.015	1
Biochemical Archives	Biochemistry & Molecular Biology	0.714	1
	Total:	34.129	21

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1994 *Journal Citation Report* (1995).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Foods and Nutrition, University of Georgia. Data is for the year 1992, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1995. *1994 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E3. Journal set data for the Department of Nutrition, University of Tennessee-Knoxville, 1992.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	15.115	3
American Journal of Physiology	Physiology	3.276	1
American Journal of Clinical Nutrition	Nutrition & Dietetics	2.864	1
Diabetes Care	Endocrinology & Metabolism	2.755	1
Journal of Nutrition	Nutrition & Dietetics	1.977	1
American Journal of Hypertension	Cardiovascular System	1.907	1
Lipids	Nutrition & Dietetics	1.530	1
Journal of the American Dietetic Association	Nutrition & Dietetics	1.090	5
Journal of Food Science	Food Science & Technology	0.872	1
Biochemical Archives	Biochemistry & Molecular Biology	0.714	1
Journal of the Canadian Dietetic Association	Nutrition & Dietetics	0.220	1
	Total:	32.32	17

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1994 *Journal Citation Report* (1995).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Nutrition, University of Tennessee- Knoxville. Data is for the year 1992, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):

Institute for Scientific Information. 1995. *1994 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E4. Journal set data for the Department of Human Nutrition, Foods, and Exercise, Virginia Polytechnic Institute and State University, 1992.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	15.115	1
JAMA-Journal of the American Medical Association	Medicine, General & Internal	6.863	1
Journal of Agricultural & Food Chemistry	Food Science & Technology	1.342	1
Journal of Animal Science	Agriculture, Dairy & Animal Science	1.335	1
Journal of the American Dietetic Association	Nutrition & Dietetics	1.090	2
Journal of Nutritional Education	Nutrition & Dietetics	0.309	1
Journal of Food Quality	Food Science & Technology	0.219	1
Ecology of Food & Nutrition	Nutrition & Dietetics	0.211	1
	Total:	26.484	9

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1994 *Journal Citation Report* (1995).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Human Nutrition, Foods, and Exercise, Virginia Polytechnic Institute and State University. Data is for the year 1992, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1995. *1994 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

1993 Journal Set Data

Table E5. Journal set data for the Department of Food Science and Human Nutrition, University of Florida, 1993.

Journal Title	Field Name	ISI JIF	P
Abstracts of Papers of the American Chemical Society	Chemistry	31.000	1
FASEB Journal	Biochemistry & Molecular Biology	13.404	7
Proceedings of the National Academy of Sciences of the USA	Multidisciplinary Studies	10.520	1
American Journal of Physiology	Physiology	3.244	1
Journal of Nutrition	Nutrition & Dietetics	1.925	6
Proceedings of the Society for Experimental Biology & Medicine	Medicine, Research and Experimental	1.654	1
Nutritional Reviews	Nutrition & Dietetics	1.457	1
Journal of Agricultural & Food Chemistry	Food Science & Technology	1.434	1
Journal of the American Oil Chemists Society	Food Science & Technology	1.228	3
Journal of the American Dietetic Association	Nutrition & Dietetics	1.202	2
Journal of Food Science	Food Science & Technology	0.998	5
Current Microbiology	Microbiology	0.962	2
Food Technology	Food Science & Technology	0.857	1
Journal of Pharmacy & Pharmacology	Pharmacology & Pharmacy	0.848	1
Journal of the Science of Food & Agriculture	Food Science & Technology	0.842	1
Letters in Applied Microbiology	Biotechnology & Applied Microbiology	0.764	1
ACS Symposium Series	Chemistry	0.655	2
Biological Trace Element Research	Biochemistry & Molecular Biology	0.471	1
	Total:	73.465	38

Table E5. (continued)

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1995 *Journal Citation Report* (1996).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Food Science and Human Nutrition, University of Florida. Data is for 1993, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1996. *1995 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E6. Journal set data for the Department of Foods and Nutrition, University of Georgia, 1993.

Journal Title	Field Name	ISI JIF	P
Abstracts of Papers of the American Chemical Society	Chemistry	31.000	1
FASAB Journal	Biochemistry & Molecular Biology	13.404	17
Endocrinology	Endocrinology & Metabolism	4.736	1
Biotechniques	Biomethods	2.305	1
Journal of Nutrition	Nutrition & Dietetics	1.925	3
Society of Experimental Biology and Medicine	Medicine, Research & Experimental	1.654	1
Journal of Nutritional Biochemistry	Nutrition & Dietetics	1.188	2
Physiology & Behavior	Physiology	1.171	1
Progress in Food & Nutritional Science	Nutrition & Dietetics	1.000	1
Journal of Pharmacological & Toxicological Methods	Pharmacology & Pharmacy	0.758	1
Hormone & Metabolic Research	Endocrinology & Metabolism	0.674	1
Nutrition	Nutrition & Dietetics	0.656	1
Biology of the Neonate	Pediatrics	0.634	1
Nutritional Research	Nutrition & Dietetics	0.559	2
Comparative Biochemical Physiology A- Physiology	Physiology	0.531	1
Biological Trace Element Research	Biochemistry & Molecular Biology	0.471	1
Biochemical Archives	Biochemistry & Molecular Biology	0.434	1
	Total:	63.100	37

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1995 *Journal Citation Report* (1996).

Table E6. (continued)

P is the total number of papers in a given journal that is authored by at least one member of the Department of Foods and Nutrition, University of Georgia. Data is for 1993, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):

Institute for Scientific Information. 1996. *1995 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E7. Journal set data for the Department of Nutrition, University of Tennessee-Knoxville, 1993.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	13.404	6
Hypertension	Cardiovascular Systems	4.981	2
Archives of Internal Medicine	Medicine, General & Internal	4.166	1
Pediatrics	Pediatrics	2.710	1
Journal of Nutrition	Nutrition & Dietetics	1.925	2
American Journal of Hypertension	Cardiovascular Systems	1.880	1
Experimental Gerontology	Geriatrics & Gerontology	1.124	1
Journal of the American College of Nutrition	Nutrition & Dietetics	0.925	1
Nutrition Research	Nutrition & Dietetics	0.559	1
Biochemical Archives	Biochemistry & Molecular Biology	0.434	1
Journal of Food Quality	Food Science & Technology	0.244	1
	Total:	32.352	18

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1995 *Journal Citation Report* (1996).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Nutrition, University of Tennessee- Knoxville. Data is for 1993, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1996. *1995 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E8. Journal set data for the Department of Human Nutrition, Foods, and Exercise, Virginia Polytechnic Institute and State University, 1993.

Journal Title	Field Name	ISI JIF	P
Journal of Chromatography	Chemistry	2.296	1
Journal of Nutrition	Nutrition & Dietetics	1.925	1
Journal of Cereal Science	Food Science & Technology	1.373	1
Journal of the American Dietetic Association	Nutrition & Dietetics	1.202	1
International Journal of Sports Medicine	Sports Sciences	0.810	1
Journal of the Society of Dairy Technology	Food Science & Technology	0.250	1
Plant Foods for Human Nutrition	Food Science & Technology	0.117	1
	Total:	7.973	7

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1995 *Journal Citation Report* (1996).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Human Nutrition, Foods, and Exercise, Virginia Polytechnic Institute and State University. Data is for 1993, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1996. *1995 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

1994 Journal Set Data

Table E9. Journal set data for the Department of Food Science and Human Nutrition, University of Florida, 1994.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	13.771	14
JAMA- Journal of the American Medical Association	Medicine, General & Internal	9.277	1
Annual Review of Nutrition	Nutrition & Dietetics	5.867	1
Biochemistry Journal	Biochemistry & Molecular Biology	3.687	2
Journal of Acquired Immune Deficiency Syndromes & Human Retrovirology	Immunology	3.511	1
American Journal of Clinical Nutrition	Nutrition & Dietetics	3.245	1
Applied & Environmental Microbiology	Biotechnology & Applied Microbiology	3.129	1
Vaccine	Immunology	2.323	1
Journal of Nutrition	Nutrition & Dietetics	1.986	2
Metabolism- Clinical & Experimental	Endocrinology & Metabolism	1.788	1
FEMS Microbiology Letters	Microbiology	1.735	1
Journal of Agricultural & Food Chemistry	Food Science & Technology	1.732	2
Journal of Food Science	Food Science & Technology	1.225	1
Journal of Nutritional Biochemistry	Nutrition & Dietetics	1.172	2
Journal of the American Dietetic Association	Nutrition & Dietetics	1.158	1
Current Microbiology	Microbiology	1.092	1
American Journal of Enology & Viticulture	Food Science & Technology	0.908	1
ACS Symposium Series	Chemistry	0.657	1
Nutritional Research	Nutrition & Dietetics	0.638	1

Table E9. (continued)

Journal Title	Field Name	ISI JIF	P
Biological Trace Element Research	Biochemistry & Molecular Biology	0.627	1
Food Research International	Food Science & Technology	0.613	1
Medical Hypotheses	Medicine, Research & Experimental	0.561	1
Journal of Food Quality	Food Science & Technology	0.351	1
	Total:	61.053	40

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1996 *Journal Citation Report* (1997).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Food Science and Human Nutrition, University of Florida. Data is for 1994, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1997. *1996 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E10. Journal set data for the Department of Foods and Nutrition, University of Georgia, 1994.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	13.771	13
Journal of Clinical Investigation	Medicine, Research & Experimental	9.486	1
Journal for the American Society of Nephrology	Urology & Nephrology	6.846	1
Journal of Cellular Biochemistry	Cell Biology	3.471	2
American Journal of Physiology	Physiology	3.323	2
Journal of Nutrition	Nutrition & Dietetics	1.986	2
Proceedings of the Society for Experimental Biology & Medicine	Medicine, Research & Experimental	1.827	1
Physiology & Behavior	Physiology	1.242	1
Journal of Nutritional Biochemistry	Nutrition & Dietetics	1.172	1
Food Technology	Food Science & Technology	1.100	1
International Journal for Vitamin & Nutrition Research	Nutrition & Dietetics	0.764	1
Amino Acids	Biochemistry & Molecular Biology	0.744	1
Biochemical Archives	Biochemistry & Molecular Biology	0.373	2
	Total:	46.105	29

Note(s):

The journals are listed in order of their respective journal impact factors, highest to lowest.

Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.

ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1996 *Journal Citation Report* (1997).

P is the total number of papers in a given journal that is authored by at least one member of the Department of Foods and Nutrition, University of Georgia. Data is for 1994, and is from the Web of Science (2000), accessed 8 October 2000.

Table E10. (continued)

Source(s):
Institute for Scientific Information. 1997. *1996 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E11. Journal set data for the Department of Nutrition, University of Tennessee-Knoxville, 1994.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	13.771	10
Journal of Lipid Research	Biochemistry & Molecular Biology	3.620	1
American Journal of Physiology	Physiology	3.323	1
Biochemical & Biophysical Research Communications	Biochemistry & Molecular Biology	2.872	1
Journal of Nutrition	Nutrition & Dietetics	1.986	2
Journal of the American College of Nutrition	Nutrition & Dietetics	1.226	2
Comparative Biochemistry & Physiology A- Physiology	Biochemistry & Molecular Biology	0.618	1
	Total:	27.416	18

Note(s):

The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1996 *Journal Citation Report* (1997).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Nutrition, University of Tennessee- Knoxville. Data is for 1994, and is from the Web of Science (2000), accessed 8 October 2000.

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Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E12. Journal set data for the Department of Human Nutrition, Foods, and Exercise, Virginia Polytechnic Institute and State University, 1994.

Journal Title	Field Name	ISI JIF	P
American Journal of Clinical Nutrition	Nutrition & Dietetics	3.245	1
Journal of Nutritional Biochemistry	Nutrition & Dietetics	1.172	1
Environmental Health Perspectives	Environmental Sciences	1.688	1
Journal of Dairy Science	Food Science & Technology	1.139	1
Nutritional Research	Nutrition & Dietetics	0.638	1
Journal of Nutritional Education	Nutrition & Dietetics	0.575	1
Journal of the Society of Dairy Technology	Food Science & Technology	0.535	1
Plant Food & Human Nutrition	Food Science & Technology	0.175	1
	Total:	9.167	8

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
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Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

1995 Journal Set Data

Table E13. Journal set data for the Department of Food Science and Human Nutrition, University of Florida, 1995.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	14.629	10
Journal of Biological Chemistry	Biochemistry & Molecular Biology	6.963	1
Investigative Ophthalmology & Visual Science	Ophthalmology	5.250	1
American Journal of Clinical Nutrition	Nutrition & Dietetics	3.980	2
Applied Environmental Microbiology	Biotechnology & Applied Microbiology	3.336	2
Critical Reviews in Microbiology	Microbiology	2.435	1
Microbiology-UK	Microbiology	2.307	1
Journal of Nutrition	Nutrition & Dietetics	2.141	4
Medicine & Science in Sport & Exercise	Sport Sciences	1.851	1
Journal of Agricultural & Food Chemistry	Food Science & Technology	1.502	3
Journal of Animal Science	Agriculture, Dairy & Animal Science	1.435	2
Nutrition Review	Nutrition & Dietetics	1.302	1
Journal of Food Protection	Food Science & Technology	1.288	1
American Journal of Enology & Viticulture	Food Science & Technology	1.259	1
Journal of Food Science	Food Science & Technology	1.249	6
Journal of Child Neurology	Pediatrics	0.918	1
American Journal of Human Biology	Biology, Miscellaneous	0.728	1
Food Control	Food Science & Technology	0.688	1

Table E13. (continued)

Journal Title	Field Name	ISI JIF	P
Journal of Food Processing Engineering	Food Science & Technology	0.571	1
Cereal Foods World	Food Science & Technology	0.425	1
	Total:	54.257	42

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1997 *Journal Citation Report* (1998).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Food Science and Human Nutrition, University of Florida. Data is for 1995, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1998. *1997 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E14. Journal set data for the Department of Foods and Nutrition, University of Georgia, 1995.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	14.629	24
Journal of Nutrition	Nutrition & Dietetics	2.141	2
Proceedings of the Society for Experimental Biology & Medicine	Medicine, Research & Experimental	2.062	2
Medicine & Science in Sport & Exercise	Sport Sciences	1.851	2
Regulatory Peptides	Physiology	1.841	2
Journal of the American Dietetic Association	Nutrition & Dietetics	1.435	1
Journal of Animal Science	Agriculture, Dairy & Animal Science	1.435	2
Biochemical Archives	Biochemistry & Molecular Biology	0.288	1
	Total:	25.682	36

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1997 *Journal Citation Report* (1998).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Foods and Nutrition, University of Georgia. Data is for 1995, and is from the Web of Science (2000), accessed 8 October 2000.

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Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E15. Journal set data for the Department of Nutrition, University of Tennessee-Knoxville, 1995.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	14.629	13
Proceedings of the National Academy of Science of the USA	Multidisciplinary Studies	9.040	1
American Journal of Clinical Nutrition	Nutrition & Dietetics	3.980	1
Biochemical Journal	Biochemistry & Molecular Biology	3.579	1
Journal of Nutrition	Nutrition & Dietetics	2.141	5
Lipids	Nutrition & Dietetics	1.947	1
Alcohol	Pharmacology & Pharmacy	1.264	1
Journal of Nutrition Education	Nutrition & Dietetics	1.042	1
Nutrition Metabolism & Cardiovascular Disease	Nutrition & Dietetics	0.672	1
	Total:	38.294	25

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1997 *Journal Citation Report* (1998).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Nutrition, University of Tennessee- Knoxville. Data is for 1995, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1998. *1997 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E16. Journal set data for the Department of Human Nutrition, Foods, and Exercise, Virginia Polytechnic Institute and State University, 1995.

Journal Title	Field Name	ISI JIF	P
American Journal of Clinical Nutrition	Nutrition & Dietetics	3.980	1
Journal of Gerontology Series A- Biological Sciences & Medical Sciences	Geriatrics & Gerontology	1.695	1
Muscle & Nerve	Neurosciences	1.690	1
Journal of the American Dietetic Association	Nutrition & Dietetics	1.435	2
Poultry Science	Agriculture, Dairy & Animal Science	1.183	1
International Journal of Sport Nutrition	Nutrition & Dietetics	1.141	1
Journal of Food Biochemistry	Nutrition & Dietetics	0.764	1
Ecology of Food & Nutrition	Nutrition & Dietetics	0.455	1
Journal of Food Quality	Food Science & Technology	0.260	1
	Total:	12.603	10

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1997 *Journal Citation Report* (1998).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Human Nutrition, Foods, and Exercise, Virginia Polytechnic Institute and State University. Data is for 1995, and is from the Web of Science (2000), accessed 8 October 2000.

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1996 Journal Set Data

Table E17. Journal set data for the Department of Food Science and Human Nutrition, University of Florida, 1996.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	13.861	9
Proceedings of the National Academy of Science of the USA	Multidisciplinary Studies	9.821	1
Journal of Leukocyte Biology	Immunology	4.262	1
Molecular Medicine Today	Biochemistry & Molecular Biology	3.458	1
Clinical Chemistry	Medical Laboratory Technology	3.423	1
American Journal of Clinical Nutrition	Nutrition & Dietetics	3.417	2
Environmental & Molecular Mutagenesis	Environmental Sciences	2.259	1
Journal of Nutrition	Nutrition & Dietetics	2.127	3
Trends in Food Science & Technology	Food Science & Technology	1.898	1
Journal of Toxicology & Environmental Health	Toxicology	1.689	1
Journal of Nutritional Biochemistry	Nutrition & Dietetics	1.335	1
Toxicology Letters	Toxicology	1.303	1
Journal of Food Science	Food Science & Technology	1.207	7
Journal of Trace Elements in Medicine & Biology	Biochemistry & Molecular Biology	0.844	1
American Journal of Enology & Viticulture	Food Science & Technology	0.797	2
Food Research International	Food Science & Technology	0.477	1
Food Control	Food Science & Technology	0.418	3
	Total:	52.596	37

Table E17. (continued)

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.

Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1998 *Journal Citation Report* (1999).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Food Science and Human Nutrition, University of Florida. Data is for 1996, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1999. *1998 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E18. Journal set data for the Department of Foods and Nutrition, University of Georgia, 1996.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	13.861	21
American Journal of Clinical Nutrition	Nutrition & Dietetics	3.417	2
Obesity Research	Nutrition & Dietetics	2.265	1
Journal of Nutrition	Nutrition & Dietetics	2.127	1
Journal of Applied Physiology	Sport Sciences	2.122	2
Journal of Animal Science	Agriculture, Dairy & Animal Science	1.560	1
Sports Medicine	Sport Sciences	1.397	1
Biology of the Neonate	Pediatrics	0.784	1
Experimental Aging Research	Geriatrics & Gerontology	0.477	2
Growth Development & Aging	Geriatrics & Gerontology	0.364	1
	Total:	28.374	33

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
ISI Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1998 *Journal Citation Report* (1999).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Foods and Nutrition, University of Georgia. Data is for 1996, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1999. *1998 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E19. Journal set data for the Department of Nutrition, University of Tennessee-Knoxville, 1996.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	13.861	6
American Journal of Clinical Nutrition	Nutrition & Dietetics	3.417	1
Hormone & Metabolic Research	Endocrinology & Metabolism	2.242	1
Journal of Nutrition	Nutrition & Dietetics	2.127	4
Journal of the American Dietetic Association	Nutrition & Dietetics	1.709	2
Journal of Nutritional Biochemistry	Nutrition & Dietetics	1.335	2
Journal of Nutritional Education	Nutrition & Dietetics	0.782	1
Postgraduate Medical Journal	Medicine, General & Internal	0.478	1
	Total:	25.951	18

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1998 *Journal Citation Report* (1999).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Nutrition, University of Tennessee- Knoxville. Data is for 1996, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1999. *1998 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

Web of Science. 2000. [On-line database]. Philadelphia: Institute for Scientific Information.

Table E20. Journal set data for the Department of Human Nutrition, Foods, and Exercise, Virginia Polytechnic Institute and State University, 1996.

Journal Title	Field Name	ISI JIF	P
FASEB Journal	Biochemistry & Molecular Biology	13.861	4
Medicine & Science in Sport & Exercise	Sport Sciences	2.026	1
Journal of Agricultural & Food Chemistry	Food Science & Technology	1.434	1
Journal of Nutritional Biochemistry	Nutrition & Dietetics	1.335	1
Journal of Nutritional Education	Nutrition & Dietetics	0.782	2
Nutritional Research	Nutrition & Dietetics	0.670	1
Journal of Food Quality	Food Science & Technology	0.273	1
	Total:	20.381	11

Note(s):
The journals are listed in order of their respective journal impact factors, highest to lowest.
Field Name is the same as the Subject Category used by the Institute for Scientific Information in their *Journal Citation Reports*.
ISI JIF is the journal impact factor for the journal as found in the Institute for Scientific Information's 1998 *Journal Citation Report* (1999).
P is the total number of papers in a given journal that is authored by at least one member of the Department of Human Nutrition, Foods, and Exercise, Virginia Polytechnic Institute and State University. Data is for 1996, and is from the Web of Science (2000), accessed 8 October 2000.

Source(s):
Institute for Scientific Information. 1999. *1998 JCR: Journal Citation Reports, Science Edition, A Bibliometric Analysis of Science Journals in the ISI Database*. Philadelphia, Institute for Scientific Information Press.

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VITA

Eric Ackermann was born in Birmingham, Alabama, in 1953, a propitious year according to all the omens. He graduated from Shades Valley High School (now defunct and bulldozed into a shopping mall) in 1972. After wandering around a bit, he eventually graduated in 1978 with a B.A. in History from the University of Alabama in Birmingham. Soon thereafter, Ackermann completed his M.A. in History from the same august institution in 1985. After several post-graduate adventures, including a stint as a field archaeologist in Tidewater Virginia, he went to work in 1992 in the Special Collections Department of the University Libraries at Virginia Polytechnic Institute and State University in Blacksburg, Virginia. As of the turn of the new millennium, Ackermann is still employed in the same Special Collections unit, now part of the University Libraries' Digital Library and Archives, while he awaits the completion of a M.S. in Information Sciences from the University of Tennessee- Knoxville, of which this thesis, which you hold in your hands, is part of the process.

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