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Scientific and Technical Serials Holdings Optimization in an Inefficient Market: A LSU Serials Redesign Project Exercise

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In this paper, we analyze the structure of the library market for scientific and technical (ST) serials. The analysis takes the form of an exercise aimed at a theoretical reconstruction of the ST serials holdings of LSU Libraries after almost a decade of massive cancellations and a policy of adding no new subscriptions. This exercise was done in conjunction with the Louisiana State University (LSU) Serials Redesign Project (SRP), and it utilized an experimental computer program called the Serials Evaluator. Much of the paper is devoted to a discussion of the set definitions, measures, and algorithms necessary in the design of a computer program to appraise ST serials.

LSU faculty ratings were utilized as the main measure of ST value, and we investigated the nature as well as the strengths and weaknesses of faculty ratings. Chemistry played the role of the test discipline, and other ST fields were investigated to determine whether the processes affecting chemistry are also active in them. We develop the hypothesis that human knowledge functions on the same probability structure as biological nature and society. We show that this probability structure results in the highly skewed, stable distributions that characterize the social stratification system of science and technology as well as of the serials system based upon it.

Science and technology are seen in this paper as dominated by stable elites, who tend to center around traditionally prestigious institutions and publish their work in U.S. association journals. Consequently, U.S. association serials have higher ST value, and they play a dominant role not only in internal library use but also in interlibrary loan. Due to their higher ST value, U.S. association journals can be sold to libraries in greater numbers at cheaper prices than the journals of commercial publishers, and this causes the ST serials market to bifurcate, with ST value tending to concentrate on the U.S. association serials and costs on the commercial ones.

As a result of the highly skewed, stable nature of the ST serials system, the

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ST serials holdings of LSU Libraries were found to have suffered little damage, despite almost a decade of massive cancellations and no new subscriptions in the face of an exponentially growing serials population. To bring the serials holdings at LSU Libraries up to optimal level in 33 ST disciplines, it was estimated that only 118 new subscriptions costing $81,882 were needed, and of these much of the perceived value derived from 53 titles that cost $39,948. Moreover, it was still possible to cancel subscriptions to another 342 titles that cost $222,409 without materially affecting the perceived value of LSU Libraries' serials holdings in the 33 disciplines. We see no solution to the present crisis of the ST serials system in its present form, through technology, cooperative collection development, or consortia, and we state that librarians will have to change the nature of this system by utilizing the new technology's capability of delivering information rapidly to move from subscriptions to a free market in ST information through document delivery.

In this paper, we describe an exploration of the structure of the library market for scientific and technical (ST) serials that was done in conjunction with the Louisiana State University (LSU) Serials Redesign Project (SRP). It is a continuation of Bensman (1996). The purpose of the exploration was to analyze the options open to academic libraries for resolving the serials crisis currently occurring. The exploration was done as a mock exercise in reconstructing the ST journal holdings of LSU Libraries after almost a decade of massive cancellations and a policy of adding no new subscriptions. An experimental computer program called the Serials Evaluator was designed and utilized in the reconstruction of these holdings.

This paper is divided into five main sections. The first section is historical, locating the roots of the current crisis in the nature of ST growth and price inflation and showing that these factors compelled academic libraries to begin the transition from ownership to access in their handling of ST serials. The section describes how the crisis forced LSU Libraries into massive serials cancellations and increased reliance on interlibrary loan borrowings, finally culminating in the birth of the SRP—a conscious attempt to integrate the concepts of ownership and access.

The next section is theoretical. The nature of set definitions and probability distributions in library and information science together with their statistical ramifications are analyzed. The system of probability distributions that biologists have developed to model patterns in nature is set forth, and we show how the key distribution of this system—the negative binomial distribution (NBD)—has penetrated the information and social sciences because it models the stochastic processes underlying the highly skewed distributions typically found in these disciplines. Particular attention is given here to the controversy over the applicability of the NBD to external monographic circulation.

Using chemistry as an example, we then illustrate with the aid of the National Research Council (NRC) database how the highly stratified social system of science and technology resulting from these stochastic processes is dominated by stable elite groups. We next demonstrate with chemistry data that the ST journal system is a reflection of this social structure, proving by citation analysis that the superiority of U.S. association journals derives from the elite group publishing in them. We conclude the theoretical section by describing how the ST journal system functions in much the same way as the social stratification system of science and technology, concentrating on the stability at the top of the citation distribution and the zero citation class.

Following the theoretical section are two practical sections in which we demonstrate the implementation of theory in an analysis of the LSU Libraries serials holdings in science and technology. The vehicle for this is a discussion of the set definitions and measures necessary for the design and operation of an experimental computer program called the Serials

Evaluator. We begin by showing how the Library of Congress (LC) classification schedules were utilized to construct statistically valid subject sets. We then describe the way in which LSU faculty ratings of journals were quantified into an ST value measure called faculty score and our method for validating this score with citation-based measures as well as both external and internal library use.

Data from the University of Illinois at Urbana–Champaign (UIUC) Chemistry Library are employed to measure the effect of the operating algorithms of the Serials Evaluator in terms of cost-per-use. We then show that virtually all ST fields manifest the same phenomenon previously found in chemistry, i.e., a bifurcated pattern with ST value concentrating in the journals of the U.S. associations and costs in the titles of commercial publishers. We conclude by demonstrating how this fact was utilized to design a leveraged restructuring of LSU Libraries' ST serials holdings.

The last section is an economic one, and it delineates the contradiction between social and economic logic that leads to the paradox of an inefficient market in which libraries have to pay more money for the less important ST information. Analyzing the options available to librarians, we conclude that librarians will be compelled to continue the transition from ownership to access by moving from subscriptions to the free market of document delivery.

Such is the overall structure of the paper. However, a caveat must be issued before it is read. We present what can be called "a stick figure view" of the ST elite. This elite is much more complex than the depiction given here, where we analyze only the academic social stratification system of U.S. science and technology. Even here the picture may be oversimplified. The ST elite is not located entirely at the academic institutions repeatedly mentioned in this paper. These institutions are utilized as exemplars of the ST elite, which spreads out over other institutions in the manner typical of bibliometric distributions. Then there is the question of the role of research establishments in government and industry. Moreover, the presentation of the elite in this paper may be distorted from the international perspective. There is ample anecdotal evidence that the superiority of U.S. association journals may not be so much a function of the superiority of U.S. science and technology as of a globalization of world science and technology through the U.S. associations.

As a result of doing the research for this paper, we have formed the opinion that library and information science might be poised to rise from a social to a natural science. This is because library and information science appears to have a coherent probability structure, strong relationships, and stable phenomena, resulting in a high degree of predictability.

However, before library and information science can make this transition, two major problems have to be solved. The first is the crucial problem of set definition. The persistent failure to define proper sets obscured for years the strong correlation of citations with library use. Now this same problem appears to be complicating the uncovering of the true probability structure of human knowledge. Sets in library and information science are inherently ambiguous due to the way disciplines overlap and share the same literature. For example, during the course of the research, there were constant problems with biochemistry journals. The logic of the chemistry journal set used in this paper and its predecessor was defined by a survey of the Department of Chemistry without the participation of the Department of Biochemistry. This resulted in the biochemistry journals being more highly cited than warranted by their importance to the faculty of the Department of Chemistry alone—a characteristic particularly of the *Journal of Biochemistry*, which had a citation rate much higher than that of the most highly faculty-rated title, the *Journal of the American Chemical Society*. Consequently, sometimes the biochemistry journals fell out of the statistical models as outliers, and sometimes they remained in the models, distorting the parameters. This problem was crudely handled by

running the models both with and without the outliers, but a far better solution would probably have been the application of fuzzy set theory.

The other major problem that has to be solved is the construction of better measures of ST value. These better measures must exhibit two primary characteristics. First, they have to reflect accurately the way the human mind perceives such value. From this perspective, major deficiencies were discovered in the impact factor citation measure published by the Institute for Scientific Information (ISI), even though ISI citations performed much better as predictors of library use than LSU faculty ratings, which not only suffered major perceptual failures but were politically difficult and expensive to obtain. Unlike total citations, ISI impact factor failed to correlate well with either faculty ratings or library use due to its controlling for size. The only way impact factor could be used statistically was to construct from it crude ordinal variables for nonparametric models.

The second necessary attribute of value measures is that they must accurately capture the stochastic processes underlying the production, utilization, and evaluation of information. On this attribute the traditional way of measuring the peer opinion of the scholarly quality of U.S. research-doctorate program faculty suffered a total failure. When tested, the peer ratings of the scholarly quality of chemistry research-doctorate program faculty resulted in a probability distribution that not only gave a false picture of the structure of these ratings but also of the stochastic processes by which this structure arose.

The Crisis and the Birth of the Serials Redesign Project

The Crisis and the Transition from Ownership to Access

Scientific Growth and Price Inflation

The current serials crisis engulfing academic libraries is rooted in the very nature of scientific growth. Price (1986, 4–29) brilliantly described this nature a generation ago. According to Price, the normal mode of scientific growth is exponential, and in this respect it agrees with the common natural law of growth governing the number of human beings in a country, the number of fruit flies growing in a bottle, or the number of miles of railroad built in the early Industrial Revolution. However, the law of scientific growth is marked by two remarkable features. First, the exponential law of scientific growth holds true with high accuracy for long time periods extending for centuries. Second, scientific growth is surprisingly rapid, outstripping that of the size of the population and nonscientific institutions.

It is in the latter feature that the roots of the current serials crisis should be sought. In Price's view, all exponential growth curves must ultimately hit an upper limit and flatten into logistic curves, and such a flattening process is marked by violent fluctuations of the curve and prolonged periods of crisis. With telling prescience, Price (p. 28) predicted for science just such a period of crisis marked by "rapidly increasing concern over those problems of manpower, literature, and expenditure that demand solution by reorganization."

As part of his analysis of scientific growth, Price (1986, 5–8; 1975, 164–73) dealt with the problem of scientific journals. He stated that the exponential increase in the number of scientific periodicals has proceeded with an extraordinary regularity seldom seen in any human-made or natural statistic ever since the earliest surviving such journal, *Philosophical Transactions of the Royal Society of London,* was first published in 1665. Price estimated that starting from 1750, when there were 10 scientific periodicals, the number of such periodicals has increased by a power of 10 every half century, which has lead to a doubling every 15 years. Taking a longer view, he calculated that this corresponded to a factor of 1,000 in a century and a half and of 1,000,000 since the mid-seventeenth century. Price compared the growth of scientific journals to that of a colony of rabbits breeding among themselves and reproducing ever so often.

Price might have overestimated the growth in the number of scientific jour-

nals, because he did not exclude discontinued serials (Line and Roberts 1976, 128). Nevertheless, his estimates take on a frightening reality as soon as one considers the constantly expanding coverage of the standard reference source on serials, *Ulrich's International Periodicals Directory*. Whereas the 20th edition of *Ulrich's* for 1981 (vii) together with its companion volume *Irregular Serials & Annuals* (6th ed. 1980–81) listed some 96,000 titles, the 34th edition of *Ulrich's* for 1996 (vol. 1, vii) contained information on nearly 165,000 titles including irregulars and annuals–a gain of 71.9%. As a base of comparison, it should be noted that the first edition of this publication (Ulrich 1932, ix) covered 6,000 titles.

By itself, the exponential growth in the number of scientific serials would have been a difficult enough problem for academic libraries to handle. However, the problem has been immensely compounded by an extraordinary inflation in serials prices. An idea of the extent of this inflation and the role of scientific serials in it can be gained from analyzing the data published annually in the U.S. Periodical Price Index (USPPI) (Carpenter and Alexander 1996). Excluding Russian translation journals, the average price of a U.S. periodical rose 154.8% from $65.00 in 1986 to $165.61 in 1996. This rate of inflation exceeded both the general inflation rate as measured by the U.S. Consumer Price Index (CPI) and that in the cost of higher education as measured by Higher Education Price Index (HEPI).

Thus, from 1986 to 1995 the USPPI rose 129.9%, while the CPI increased 39.0%; whereas from 1986 to 1994 the USPPI gained 108.3%, the HEPI went up 41.2%. The most expensive subject category in the 1996 USPPI is Chemistry and Physics. Its inflation rate by far outstripped that of the overall USPPI, and the average price of chemistry and physics periodicals rose 228.4% from $264.05 in 1986 to $867.00 in 1996. The rapid increase in chemistry and physics serials prices greatly affected the overall structure of U.S. periodical prices, and this was evident in an exploding Gap Factor, which was calculated by dividing the average price of the highest priced subject category by the average price of the lowest priced subject category after discarding Russian translations and children's periodicals as constant outliers. In both 1987 and 1996 Chemistry and Physics was the highest cost subject category, but the Gap Factor surged from 11.49 in 1987 to 22.02 in 1996. The ultimate result of this process is evident from the fact that, with again the exclusion of Russian translations and children's periodicals, while chemistry and physics serials comprised only 4.7% the titles of the periodical sample used to construct the 1996 USPPI, these serials accounted for 23.9% of the total cost of this sample.

Impact on Association of Research Libraries

Under the twin pressures of exponential growth and rampant price inflation, academic libraries have begun to undergo fundamental changes. This emerges from the statistics published by the Association of Research Libraries (ARL) for 1994–95 (pp. 7–16) on its 119 members, which constitute the largest research libraries in North America. Of these 119 ARL members, 108 are university libraries. The ARL statistics reveal that inflationary pressures forced research libraries to cut down on the number of their paid serials subscriptions through cancellations even in the face of the exponentially growing number of serials. Thus, while the median serial unit price paid by ARL libraries rose 137.9% from $88.81 in 1986 to $211.29 in 1995, during the same period the median number of ARL paid subscriptions dropped 7.8% from 16,198 to 14,942.

This drop, however, did not relieve the budgetary pressures on ARL libraries, and their median serials expenditure increased 106.5% from $1,517,724 in 1986 to $3,133,885 in 1995. To maintain their serials collections even at reduced levels, it appears from the ARL statistics that research libraries were compelled to utilize monograph funds. This is shown by the fact that while the median monograph unit price paid by ARL libraries increased 58.0% from $28.65 in 1986 to $45.27 in

1995—less than half the median serials price increase—the median number of monographs purchased by ARL libraries fell 22.6% from 33,210 in 1986 to 25,719 in 1995 (nearly triple the drop in serials subscriptions). Moreover, the median amount spent by ARL libraries for monographs increased 21.9% from $1,120,645 in 1986 to $1,365,575 in 1995—approximately one-fifth the percentage increase in median ARL serials expenditures during the same period. The sharp reduction in the purchasing power of academic libraries took place in conjunction with a continued growth in their patron base, with the median number of teaching faculty served by ARL libraries rising 17.4% and the median number of students increasing 8.4% during the period 1986–95.

All these factors combined to force a change of emphasis among academic libraries from ownership to access as the cost of access became more affordable compared to the cost of ownership—a trend assisted by improvements in electronic communications and the establishment of networks, consortia, etc. This continuous shift from ownership to access was marked by the annual average increase of 9.3% in the median number of interlibrary borrowings by ARL members during the period 1986–95, which grew 104.3% from 7,049 in 1986 to 14,403 in 1995.

Impact on the Libraries of LSU

The serials crisis hit the libraries at LSU harder than other members of the ARL. These libraries are organized into three administratively separate units: (1) LSU Libraries, encompassing the main Middleton Library, Hill Memorial Library for special collections, and a number of branch libraries; (2) the Law Library; and (3) the Veterinary Medicine Library. Louisiana has always ranked near the bottom on all economic and social indices, and from around the mid-1980s onward the state's fiscal problems were compounded by the decline of petroleum as a source of revenue. LSU was wracked by a series of budgetary emergencies that severely affected its libraries.

The impact of these emergencies is evident in the *ARL Statistics* for fiscal years 1985–86 and 1994–95, which reports on all three LSU library administrative units. Of crucial importance was the freezing of the materials budgets for these libraries. In fiscal year 1985–86 these materials budgets were $3,385,282, and in fiscal year 1994–95 they were $3,094,789—a decline of 8.6%. Not surprisingly, there began wave after wave of serials cancellations. Internal LSU Libraries documents show that 2,207 titles were canceled from 1986 to 1994 and that the serials canceled in the period 1987–94 cost $618,883.54. These cancellations were accompanied by a policy of no new subscriptions. For its part, in 1993 LSU Law Library canceled approximately 2,000 of its 4,000 current serials. The consequences of these actions are manifested in the *ARL Statistics*. Whereas in 1985–86 the libraries of LSU are listed as having 17,970 current serials, the ARL data for 1994–95 show these libraries as subscribing to only 11,853 serials—a reduction of 34.0% or 4.4 times more than median reduction in the number of such serials for all ARL libraries in the same period.

However, even these drastic reductions in the number of subscriptions did not provide budgetary relief, and current serials expenditures of the libraries on the LSU campus rose 29.8% from $1,897,212 in 1985–86 to $2,462,368 in 1994–95. The increase was 3.6 times less than the median increase in current serials expenditures for all ARL libraries, but it was not enough to save monograph purchases, given the conditions of frozen materials budgets. While median monograph expenditures of all ARL libraries rose 21.9%, such expenditures at the libraries of LSU dropped 50.3% from $1,244,466 in 1985–86 to $617,998 in 1994–95. Due to inflation, the drop in the number of monographs acquired was even greater, falling 62.9% from 29,811 in 1985–86 to 11,048 in 1994–95.

As a result of such pressures, the libraries on the LSU campus rapidly transferred from ownership of materials to access to them. Interlibrary borrowing increased 138.3% from 4,802 in 1985–86 to 11,441 in 1994–95. However, the rapid escalation in interlibrary borrowing

might not have been due only to reductions in serials and monographic acquisitions; it might also have been affected by a major improvement in the academic level of the libraries' patron base. While from the fall of 1986 to the fall of 1994 the number of faculty remained virtually constant, the number of full-time-equivalent graduate students rose 27.5% from 3,177 to 4,052, even though the overall number of full-time-equivalent students was sharply decreased 22.2% from 26,180 to 20,379 by the raising of entrance requirements.

It was under such crisis conditions that LSU Libraries decided to launch its Serials Redesign Project (SRP).

Birth of the Serials Redesign Project

Provision of Access

The Serials Redesign Project (SRP) can be described as an endeavor to integrate the two concepts of access and ownership. The first step in this integration related to access and was taken in 1993, when LSU Libraries introduced the UnCover document delivery system. UnCover was developed starting in 1988 by the Colorado Alliance of Research Libraries through its CARL Systems, Inc., which in 1993 formed The UnCover Company in joint partnership with B.H. Blackwell, the British subscription agency. The UnCover database contains approximately 17,000 journals primarily in the English language. Of these journals, an estimated 51% are in science, medicine, and technology; 40% in the social sciences; and 9% in the arts and humanities.

Among other services, UnCover provides subscribers with free online access and searching; delivery of full-text articles by fax within 24 hours for $8.50 plus copyright fee and applicable fax surcharge; and a current awareness alerting service covering the table of contents of up to 50 titles. For libraries, UnCover has a special service called the Customized Gateway designed to assist in serials collection development. Its features include support for unmediated—i.e., without the mediation of the library—article ordering, holdings match, and patron validation.

LSU Libraries took advantage of this service to provide faculty, research staff, and graduate students with direct access to serials that had been either canceled or never on subscription. Serials available at LSU were blocked from the system. LSU Libraries covered the expense of obtaining these articles except for those costing more than $26.50 or those from researchers making heavy demands on the system.

There are definitely problems with UnCover, including unclear fax copies of articles; difficulty in using the system; lack of foreign titles in the database; and publishers forbidding the transmission of articles from their journals. However, these problems appear to be more than offset by the cost effectiveness of the system. In a study covering a six-month period of UnCover use, Hamaker (1996), Assistant Dean for Collection Development at LSU Libraries, found that LSU Libraries spent $12,278, including $5,740 in copyright fees, to obtain 1,006 articles from 480 journals whose subscriptions would have cost $207,000. It was facts such as these that caused Hamaker to call for the integration of the concept of remote access into local collection development policies.

Adjustment of Ownership

With respect to ownership, by the early 1990s there was a growing realization within LSU Libraries that major changes had to be made in the method of dealing with the serials crisis. The old method had consisted primarily in distributing lists of serials holdings to the faculty in order to identify titles for cancellation. This method was perceived to have two basic faults. First, it was a negative exercise in the emotional sense, causing major discontent among the faculty. Second, the distribution of prepared lists of serials had led faculty to make poorly considered decisions and to identify readily as important titles that were not necessarily high in priority. Thus, in the 1992 cancellation project, the faculty reviewed over a million dollars in serials but identified less than $60,000 worth of titles that could be canceled (Hamaker 1994, 37). Combined with the perceived faults of the old

method, a restructuring of serials holdings of LSU Libraries became regarded as necessary both to bring them into conformance with the current needs of the university, because no new subscriptions had been instituted since 1986, and to take advantage of the opportunities offered by the UnCover document delivery system.

The Faculty Survey

The above considerations gave birth to the concept of surveying the faculty not by having them mark prepared lists of serials for cancellation purposes alone, but by having them list on blank questionnaires in priority order the journals they considered important for research and teaching. This survey was to be conducted after faculty were instructed in the use of UnCover and after they were informed that the cancellations would provide resources for new subscriptions. The faculty was to designate on the questionnaires whether the journals had to be on the LSU campus or whether remote access to them via document delivery would be sufficient.

The concept was tested in 1993 with pilot projects with the Department of Chemistry and the Department of Geography & Anthropology. The results were promising. Whereas in the 1989 serials review project the chemistry faculty had ranked 410 titles as important to research and teaching, in the 1993 project it did so only for 287 titles. Moreover, in 1993, 35 titles on subscription in the Chemistry Library were omitted from the high priority list, in comparison with 1989 when 20 of these same titles were ranked as "essential." The outcome of the pilot project with Geography & Anthropology was similar. In 1989, faculty in this department ranked 1,808 titles as important to teaching and research, but in 1993 gave such status only to 535. In 1994, the LSU Faculty Senate Library Committee approved the concept, and the SRP was born. The project was intended to be carried out in three stages: (1) science and technology, (2) social sciences, and (3) humanities.

Phase one of the SRP began in the autumn of 1994 and lasted through 1995. To initiate the survey, library subject liaisons met with the faculty of the LSU academic units involved in science and technology. At these meetings, the liaisons explained the budgetary situation of LSU Libraries and the need to restructure the serials collection. The liaisons also gave a demonstration of the capabilities of UnCover.

Following the presentation, survey forms along with a cover letter were distributed to the faculty. Faculty were asked to list in descending rank order of priority up to a maximum of 45 titles important to them for teaching and research. In listing these titles, the faculty were instructed to disregard whether LSU Libraries had them on subscription or not. Each title also had to be designated as either DD (Document Delivery) or S (Subscription). In the first case, access to it could be satisfied by a service such as UnCover; in the second, it had to be on subscription at LSU Libraries.

The faculty were instructed that the ones marked for subscription should be "titles used on a daily or weekly basis or that are published in a format that requires direct access (i.e. illustrations that do not photocopy well)." Henceforth in this paper the titles so selected by the faculty will be called the "desired universe" of serials. Upon the return of the survey forms, the titles on them were bibliographically identified, classed with Library of Congress (LC) call numbers, and given their prices as of 1995. Table 1 lists the LSU academic units surveyed in the first phase of the SRP together with their faculty response rates.

Overall the response rate was 392 faculty members of 728, or 53.8%. However, if the branch research stations of the College of Agriculture are excluded as isolated for the most part from the LSU campus, the response rate becomes 384 of 662 or 58.0%. For a comparison, the faculty response rate in the 1993 survey of U.S. research-doctorate programs carried out by the National Research Council (NRC) was 51.0% (Goldberger, Maher, and Flattau 1995, 134). An additional indicator of the validity of the SRP survey was that a Spearman correlation coefficient of 0.56 was found between the

percentages of faculty response and the 1993 NRC peer ratings of the scholarly quality of the faculty for the academic units where such comparisons could be made. This is evidence that the faculty tending to respond to the SRP survey were those more actively engaged in research recognized at the national level.

We will examine the validity of faculty ratings of serials and the options such ratings opened in serials collection development for LSU Libraries by the first phase of the SRP. Henceforth in this paper, this first phase will be referred to as just the SRP.

The Serial Evaluator and the Structure of the Scientific and Technical (ST) Journal System

Origin of the Serials Evaluator

As the SRP was being launched, a special project was undertaken within LSU Libraries to analyze the structure of the library market for ST serials. Faculty survey data obtained in the 1993 pilot project with the Department of Chemistry was used to determine whether cancellations could be made without seriously damaging the ST serials holdings at LSU Libraries. The results of the study have been published (Bensman 1996), and the main conclusion was that scientific value as measured by faculty ratings and total citations played no role in the pricing of scientific serials. Not only is this the case, the study also revealed that the library market for ST serials appeared to be severely bifurcated, with scientific value concentrating on the titles of the U.S. associations and costs concentrating on the serials of the commercial—largely foreign—publishers.

Because of this fact, major cancellations could be implemented without seriously affecting the ST value of the LSU Libraries' serials holdings. Moreover, during the course of the study, it became obvious that a computer program could be developed to take advantage of this situation. This software, ultimately called the Serials Evaluator, was created with the assistance of a programmer in the university's Administrative Information Systems. However, before one can understand how the Evaluator works, one must have an understanding of three principles that affect the structure of the ST journal system: (1) set definition, (2) skewed distributions, and (3) the social bases of ST value.

Set Definition and Its Statistical Consequences

Need for Set Definition

Any database in library and information science contains a witches' brew of variables. This is a result of the complex actions of social groups differing in size, subject interest, level of understanding and agreement, time framework, as well as purpose and intention. Due to these reasons, before library and information science data are analyzed, they should be broken down into well-defined sets. Otherwise, complex interactions among the variables will negate statistical relationships and lead to mistaken conclusions.

The usual way of sorting library and information science data into sets is to define the sets by subject matter. This is particularly important in serials analysis, where prices, citation rates, etc., differ vastly from subject group to subject group. For example, if one decides to cancel subscriptions by price alone, one runs the risk of canceling good science journals while leaving bad social science and humanities journals outside the range of analysis. However, set definition in library and information science is complicated by the interaction of processes that are best described by two eponymic bibliometric laws.

Bibliometric Laws That Affect Set Definition in Library and Information Science

The first of these is "Bradford's law of scattering" formulated by Bradford while he served as chief librarian from 1925 to 1938 at the National Science Library in South Kensington, England. In the formulation of his law, Bradford (1953, 148–59) started from the principle that "every scientific subject is related, more or less remotely, to every other scientific subject" and that therefore "the articles of

TABLE 1

ACADEMIC UNITS SURVEYED DURING THE FIRST PHASE OF THE SERIALS REDESIGN PROJECT AND FACULTY RESPONSE RATES

Academic Units	No. of Faculty Responding	Total Faculty in Unit	Response Rate (%)
College of Agriculture			
Agricultural Economics & Agribusiness	13	13	100.0
Agronomy	15	20	75.0
Animal Science	8	16	50.0
Dairy Science	4	8	50.0
Entomology	13	18	72.2
Experimental Statistics	5	12	41.7
Food Science	3	6	50.0
Forestry, Wildlife, & Fisheries	29	33	87.9
Horticulture	0	8	0.0
Human Ecology	18	26	69.2
Plant Pathology & Crop Physiology	14	17	82.4
Poultry Science	4	5	80.0
Vocational Education	5	10	50.0
Branch Research Stations[1]	8	66	12.1
College of Arts & Sciences			
Geography & Anthropology	27	27	100.0
Mathematics	22	44	50.0
College of Basic Sciences			
Biochemistry	8	10	80.0
Chemistry	23	40	57.5
Computer Science	4	15	26.7
Geology & Geophysics	10	20	50.0
Microbiology	5	13	38.5
Physics & Astronomy	25	39	64.1
Plant Biology	6	12	50.0
Zoology & Physiology	12	22	54.5

(Continued on next page)

an interest to a specialist must occur not only in the periodicals specialising on his subject, but also, from time to time, in other periodicals." He applied this principle in an analysis of two specific subjects, applied geophysics and lubrication, and the results of this study led him to state his famous law on the scattering of articles on a given subject among scientific journals in the following manner (p. 154):

TABLE 1 (cont.)

ACADEMIC UNITS SURVEYED DURING THE FIRST PHASE OF THE SERIALS REDESIGN PROJECT AND FACULTY RESPONSE RATES

Academic Units	No. of Faculty Responding	Total Faculty in Unit	Response Rate (%)
College of Education			
Kinesiology	6	12	50.0
College of Engineering			
Biological & Agricultural Engineering	11	12	91.7
Chemical Engineering	7	16	43.8
Civil & Environmental Engineering	6	30	20.0
Electrical & Computer Engineering	13	27	48.1
Industrial & Manufacturing Systems Engineering	8	14	57.1
Mechanical Engineering	11	22	50.0
Petroleum Engineering	3	7	42.9
Office of Research & Economic Development			
Advanced Microstructures & Devices[2]	2	6	33.3
Coastal, Energy, & Environmental Resources[3]	44	82	53.7
TOTALS	392	728	53.8

[1] LSU has 18 branch agricultural research stations spread out across the state of Louisiana. Five of these branch stations have respectively research specialties in the following areas: citrus, pecans, rice, sugar, and sweet potatos.

[2] The Center for Advanced Microstructures & Devices is a purely research institute centered around a high-energy particle accelerator. It specializes in the following areas: (1) fabrication of extremely small electronic and mechanical devices, using X-ray lithography; (2) spectroscopic investigations of atoms, molecules, solids, and surfaces; and analytical applications for determining the structure and elemental composition of materials.

[3] The Center for Coastal, Energy, & Enviromental Resources consists of a melange of departments, centers, and institutes. Among these are the following: Basin Research Institute, Center for Energy Studies, Coastal Ecology Institute, Coastal Fisheries Institute, Coastal Studies Institute, Department of Oceanography & Coastal Sciences, Institute for Environmental Studies, Mining & Mineral Resources Research Institute, Nuclear Science Center, and Wetland Biogeochemistry Institute. However, only 3 of these units—the Department of Oceanography & Coastal Sciences, Institute for Environmental Studies, and Nuclear Science Center—have curricula attached to them and give courses for credit.

> . . . if scientific journals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject and several groups or zones containing the same number of articles as the nucleus, when the numbers of periodicals in the nucleus and succeeding zones will be as $1:n:n^2$. . . .

Bensman (1982, 286–87) further analyzed Bradford's data to reveal (1) that in the applied geophysics set, 9.2% of journals accounted for 51.7% of the articles on that subject with the other 48.3% of these articles spread out over journals of other disciplines, and (2) that in the lubrication set, the same 9.2% of the journals accounted for 40.8% of the articles on this subject with the remaining 59.2% spread out over the journals of other disciplines.

The second bibliometric law that

complicates set definition in library and information science is "Garfield's law of concentration." This law was formulated by Garfield, founder of the Institute of Scientific Information (ISI), which publishes the *Science Citation Index* (*SCI*), *Social Sciences Citation Index* (*SSCI*), and *Arts & Humanities Citation Index* (*A&HCI*). Along with its citation indexes, ISI produces two annual publications, the *SCI Journal Citation Reports* (*SCI JCR*) and the *SSCI Journal Citation Reports* (*SSCI JCR*), which give various citation measures for the serials covered by their respective indexes. A series of exploratory studies was conducted at ISI with a prototype of the *SCI JCR* containing citation data from one quarter of 1969, and these studies revealed that a multidisciplinary mix of 152 journals accounted for 50% of the citations processed for the *SCI* in 1969.

This finding caused Garfield to formulate his law of concentration, which he derived from Bradford's law of scattering by transposing the latter law from the level of a single discipline to that of science as a whole. Garfield devised a physical analogy to Bradford's law, one based upon a comet. In this analogy, the nucleus of the comet represents the core journals of a discipline's literature with the debris and gas molecules of the tail representing the additional journals that sometimes publish material relevant to the discipline. With this analogy in mind, Garfield described his law of concentration and its practical implications in the following manner (1979, 160):

> [The bibliographic law of concentration] goes an important step beyond the Bradford law by stating that the tail of the literature of any one discipline consists, in large part, of the cores of the literature of all other disciplines, and that all the disciplines combined produce a multidisciplinary literature core for all of science that consists of no more than 1,000 journals. In fact, this multidisciplinary core might be as small as 500 journals. Though larger collections certainly can be justified in many cases, the single function of providing reasonably cost-effective coverage of the literature most used by research scientists requires no more than 500 to 1,000 journals.

The findings of the study with the 1969 *SCI JCR* data were replicated with an analysis of 1974 *SCI JCR* data (Garfield 1979, 21–23, 158–61).

Reflection of the Bibliometric Laws in Library Use

Both Bradford's and Garfield's laws are operative in the arrangement and use of library materials. Librarians have long known about the inadequacies of classification schemes. For example, Kelley (1937, 66–99) listed no less than 13 factors limiting the usefulness of any classification scheme for books. Among these factors, the most interesting were the following: the changing order of knowledge, which makes impossible the static perfection of any classification system; the inadequacy of any single linear representation of subject matter for expressing the variety of its relationships; the nature of systematic classification, which separates parts from the whole, and that sometimes results in forced and useless subdivisions; the tendency of students or specialists to organize subject matter around their own special and immediate interests; the content make-up of books, which interferes with the satisfactory application to books of any system of classification; and the general impracticality of reclassifying old books on any wide scale as new expansions and reconstructions of the classification system appear. Checking three simple concepts—beaver, buffalo, and cormorant—against the Library of Congress (LC) and Dewey Decimal classification schemes, Kelley found that only from 2.2% to 5.9% of the total material in a library on those subjects were found under their specific class number.

In a pioneer study, Fussler (1949) checked the citations made by chemists and physicists against the LC classification system. To obtain the citations for his study, he constructed subject cores of journals for the two disciplines by using the two key journals in each discipline—*Journal of the American Chemical Society* and *Physical Review*—and then

selected the other journals for the cores from among those most cited by these key journals and located in the same LC class group—QD (Chemistry) and QC (Physics). For 1939, Fussler found that only 30.5% of titles cited by chemists were in QD, although 71.2% of the citations went to these journals, and that only 20.2% of the journals cited by physicists were classed in QC, although 63.1% of the citations were to these journals.

The rest of the titles and citations were spread out over other LC classes. Thus, 12.2% of the titles cited by chemists in 1939 were in QC, but these citations comprised only 6.5% of the chemists' total citations, whereas 10.4% of the titles cited by physicists in that year were in QD, although these citations were only 3.1% of the physicists' citations.

Fussler's findings with respect to chemistry were replicated by Hurd (1992), who compared the articles published by the chemistry faculty of the University of Illinois at Chicago against the broad subject categories of the 27th edition of *Ulrich's International Periodicals Directory*. Hurd found that only 59.3% of these articles were published in journals classed by Ulrich's in chemistry and that only 47.4% of the references made in these articles were to journals classed in that same category.

An interesting approach to the relationship of the LC class groups to university departments was taken by McGrath, Simon, and Bullard (1979) at the University of Southwestern Louisiana (USL). They started out by utilizing the LC schedules to classify courses given at USL in 43 academic departments that granted bachelor's degrees, using a method developed by McGrath and Durand (1969). Of these 43 departments, 19 offered graduate degrees. With both books and students classified in the same manner, McGrath, Simon, and Bullard then used circulation data for academic years 1974–75 and 1975–76 to test whether and by how much student majors in the 43 subject areas were "ethnocentric"—i.e., used books in their own subject areas—and whether and by how much books in the 43 subject areas were "supportive"—i.e., used by students majoring in other subject areas.

Concerning the former characteristic, undergraduate music majors were the most ethnocentric, borrowing books from their own subject area 71.7% of the time, while undergraduate vocational education majors were the least ethnocentric, checking out no books in their subject area. The undergraduate ethnocentricity median was represented by French majors at 17.9%. Graduate students exhibited higher ethnocentricity, where again music majors were highest at 87.4%, while management majors were the lowest at 2.2%. The graduate ethnocentricity median was the 45.7% of computer science majors.

In terms of supportiveness of other programs at the undergraduate level, vocational education books were the highest, with 100.0% of them being checked out by nonmajors, and nursing books were the lowest, with only 24.7% being charged out to nonmajors. Applied arts books were at the undergraduate median of 81.6%. Supportiveness was lower at the graduate level. Management was highest at 98.5%, while computer science was lowest at 13.1%. The graduate supportiveness median was 55.2%, as seen in biology. These subject use patterns were fairly stable over the two-year period.

The techniques and concepts of McGrath, Simon, and Bullard (1979) were utilized by Metz (1983) in his study of external monographic circulation at Virginia Polytechnic Institute and State University (VPI). Metz obtained the main data for his study from a computer program run against the library database on May 24–25, 1982. The result was a snapshot of the books in circulation at that particular point in time. He also related academic departments to LC class groups, and he tested monographic use by the VPI faculty for ethnocentricity and supportiveness. Concerning ethnocentricity, the range ran from a high of 68.4% for the mathematics faculty to a low of 7.8% for the geography faculty. The median ethnocentricity of 14 subject groups was 38.9%, between the sociology faculty at 37.1% and the foreign language faculty at

40.7%. On a broad basis, the checkout rates were the following: for the humanities faculty—78.8% in the humanities, 12.0% in the social sciences, and 9.1% in science and technology; for the social sciences faculty—24.4% in the humanities, 64.1% in the social sciences, and 11.5% in science and technology; and for the science and technology faculty—8.9% in the humanities, 6.7% in the social sciences, and 84.3% in science and technology (Metz 1983, 66–69). As for faculty supportiveness, psychology materials were most supportive with a 96% supportiveness ranking, and classics materials were the least supportive with a 2% supportiveness ranking. The median supportiveness was 51%, as seen in library science. Of great import was Metz' finding (1983, 81) that knowledge of an undergraduate's major was significantly less predictive of the library materials the undergraduate would borrow than knowing the departmental affiliation of a faculty or graduate student.

Metz and Litchfield (1988) conducted another study of VPI library use in which they gathered monthly circulation data for each month from January through May 1987, and compared these data with the 1982 data. They found that the subject distribution of circulation patterns was remarkably stable over time for an institution not undergoing dramatic curricular change or extensive changes in the direction of library acquisitions.

Statistical Consequences of Set Definition in Library and Information Science

Set definition by subject in library and information science entails two major statistical consequences. The first of these consequences relates to the concept of a statistical set and the interaction between subject fields as described by Bradford's and Garfield's laws. In his classic statistics textbook, Hays (1994, 973–74) places the concept of a set at the basis of all modern mathematics and probability, giving the following definition of a set: **"Any well-defined collection of objects is a set"** (bold in original). He then goes on to point out that the qualification "well-*defined" means that "it must be possible, at least in principle, to specify the set so that one can decide whether any given object does or does not belong"* (italics in original). To make things more complicated, Hays goes on to point out that the word "object" denotes not only an object in the usual sense but also a "phenomenon," "happening," or "logical possibility." For example, the fact that there are no females in the set of U.S. presidents might not mean that there are none in the set but simply that one has not yet "happened."

Due to the interaction of Bradford's and Garfield's laws, it is extremely difficult, if not impossible, to follow Hays' rules for set definition. The principle behind these laws is that subjects intermix, and the problem of subject intermixing is compounded, when one uses a library classification system to define subject sets, by the flaws inherent in such a system as described by Kelley (1937). Due to these factors, defining sets by subject in library and information science brings one face to face with the statistical problem of "outliers."

As defined by Barnett and Lewis (1984, 4), an outlier in a set of data is *"an observation (or subset of observations) which appears to be inconsistent with the remainder of that set of data"* (italics in original). As such, the appearance of outliers depends upon the logic underlying the definition of the set. In their literature review of outliers, Beckman and Cook (1983) describe outliers as a "subjective, post-data concept," and they divide them into two types: (1) "discordant observations"—any observations that appear discordant or discrepant to the investigator, and (2) "contaminants"—any observations that are not a realization from the target population. Given the operation of Bradford's and Garfield's laws, contaminants or observations foreign to the population under investigation are a common problem in library and information science, and it is often impossible to exclude them on a logical basis. When contaminants appear at the extreme end of a distribution, they can cause major difficulties in attempts to represent the

population by grossly distorting the parameter estimates in some model of the population. Often the only alternative open to an investigator in library and information science is to do the test with and without the contaminants to determine their effects.

The other major statistical consequence brought forward by subject set definition in library and information science relates to the differing levels of consensus in the various fields of human knowledge. This problem was most succinctly defined by Kuhn (1970) in his famous book, *The Structure of Scientific Revolutions*. In this book Kuhn advanced two closely interrelated concepts: scientific community and paradigm. Scientific community was described by him as follows (1970, 177):

> A scientific community consists . . . of the practitioners of a scientific specialty. To an extent unparalleled in most other fields, they have undergone similar educations and professional initiations; in the process they have absorbed the same technical literature and drawn many of the same lessons from it. Usually the boundaries of that standard literature mark the limits of a scientific subject matter, and each community ordinarily has a subject matter of its own.

Kuhn defined his concept of a paradigm in the following way (1970, 175):

> . . . the term 'paradigm' is used in two different senses. On the one hand, it stands for the entire constellation of beliefs, values, techniques, and so on shared by members of a given community. On the other, it denotes one sort of element in that constellation, the concrete puzzle-solutions [which], employed as models or examples, can replace explicit rules as a basis for the solution of the remaining puzzles of normal science.

Kuhn distinguished between disciplines having a paradigm and those in a preparadigmatic phase. A preparadigmatic school has no generally accepted theory and is split into several competing schools. For example, he considered it an open question whether the social sciences had yet acquired any paradigms at all and noted, "History suggests that the road to a firm research consensus is extraordinarily arduous" (1970, 15).

The two statistical consequences of subject set definition—contaminants and differing levels of consensus—have important implications for the analysis of the skewed distributions that dominate library and information science. Attention will now be turned to this analysis.

Skewed Distributions

Absence of the Normal Distribution in Library and Information Science

It is with great trepidation that mere practitioners of statistics undertake a discussion of probability distributions. This is a world where statisticians conduct dogfights in the mathematical stratosphere, and a ground observer in the trenches has extreme difficulty in deriving conclusions about the course of the combat from the formulaic contrails in the skies overhead. Yet it is a necessary exercise. Standard parametric statistical operations such as correlation and regression assume the so-called normal distribution, which is virtually absent in library and information science. In this respect, library and information science is like many areas of human knowledge, particularly in the biological and social sciences. The relatively infrequent occurrence of the normal distribution was noted by Geary (1947, 240–41), who attributed the use of it in statistics largely to its mathematical characteristics as well as its applicability predominantly in astronomy and games of chance—areas suitable for the mathematical model. However, as a result of its rarity, Geary advised that the following warning be printed in bold type in all statistics textbooks to make amends to future generations of students: ***"Normality is a myth; there never was, and never will be, a normal distribution."***

Given this clash between statistical theory and much of reality, one must have some concept of the probability distribution underlying the data, so that it can be transformed mathematically into at least an approximation of the normal distribution in order to obtain correct results

from standard statistical operations. As if this is not complicated enough, many sets of data in library and information science are what is known technically as "truncated on the left." This means that a group of observations—the so-called "zero class"—should have been included in them but were not counted because they either did not happen or were excluded by the system of measurement. The zero class can be the source of enormous difficulties.

Bibliometric Laws, Stochastic Processes, and the Biological Model: The Negative Binomial Distribution

Library and information science has been marked by a number of empirical, eponymous laws describing the skewed distributions inherent within it. Not only are there "Bradford's law of scattering" and "Garfield's law of concentration" described above, but there are also "Lotka's law of scientific productivity"—later modified by Price (1986, 38–44, 222–23)—on the distribution of authorship over scientists; "Zipf's law of word frequency" on the occurrence of words in a text; and "Trueswell's 80/20 rule" on library circulation. A major trend in library and information science literature has been to treat these laws as particular manifestations of more general statistical distributions and develop stochastic models to represent them (Oluić-Vuković 1997).

In a series of papers worthy of being termed an intellectual tour de force, Bookstein (1990a; 1990b; 1995; 1997) compares these "informetric" laws to similar laws in the biological and social sciences, such as those of John Christopher Willis on the distribution of species and Vilfredo Pareto on the distribution of income. According to Bookstein, all these laws are similar in that they describe the distribution of the yield in a population of discrete entities over a time-like variable. He defines "yield" as a quantity such as income or journal citations that is possible to cumulate. In his view, the underlying similarity of these laws has been obscured by their differing subject content as well as their different ways of describing the distribution of yields. Bookstein then subjected Bradford's law, the Leimkuhler variant of Bradford's law, Lotka's law, Zipf's law, and Pareto's law to rigorous mathematical analysis, and came to the conclusion that all these distributions were "variants of a single distribution." Bookstein further found this distribution to be extremely robust and resilient to ambiguity in that it was not sensitive to time period or to the way the data are counted or conceptualized. Bookstein finished by locating this single informetric distribution in the family of compound Poisson distributions.

A workable candidate for the single informetric distribution posited by Bookstein appears to be the negative binomial distribution (NBD). Although Bookstein did not endorse the distribution, he did indicate that the NBD has been successfully applied to many problems in the information sciences (Bookstein 1997, 8). An interesting feature of the NBD its malleability, i.e., its capability of being shaped into other probability distributions by the adjustment of its parameters. In the biological sciences, the NBD is usually presented in conjunction with the binomial and Poisson distributions (Elliot 1977, 14–66; Williams 1964, 15–16; Bliss 1953, 176–77). Here it serves to model concentration in contrast to the binomial (which models uniformity) and the Poisson (which models randomness). The generating function of the binomial is $(p+q)^k$, where p and q are chances of two alternative happenings in k number of repetitions. Its defining characteristic is that the variance is less than the mean. The NBD is the mathematical counterpart of the binomial, and therefore the probability series of the NBD is given by the expansion of $(q-p)^{-k}$.

The defining characteristic of the NBD is that the variance is greater than the mean, and it has two parameters, the arithmetic mean and the exponent k. However, unlike in the binomial, k does not measure number of repetitions but degree of concentration. As k approaches infinity, the NBD converges to the Poisson, whose defining characteristic is that the variance equals the mean. On the

other side, as k approaches 0, the NBD converges into the logarithmic series, which models superconcentration. The geometric distribution is a particular case of the NBD with k=1 (Cooper and Weekes 1983, 137; Haight 1978, 158). However, perhaps the most useful feature of the NBD is that it can be converted into the normal distribution for standard parametric statistical operations by a series of logarithmic transformations whose form depends upon the size of the exponent k and whether the data contains zero counts (Elliot 1977, 30–36). In the study utilizing survey data gathered by the 1993 pilot project with the LSU Department of Chemistry, it was found that all the quantitative variables—faculty ratings, total citations, impact factor, source items, journal age, library holdings, and price—satisfied the basic NBD criterion of overdispersion, i.e., the variances significantly exceeded the means (Bensman 1996, 154–56).

The NBD satisfies one of the major conditions posited by Bookstein (1990a, 369) for his single informetric distribution given its robustness, i.e., that it be the consequence of a wide variety of underlying models. In a review of the chance mechanisms causing the NBD, Boswell and Patil (1970) described no less than 12 stochastic models that lead to the full NBD plus two more leading to its zero-truncated form. This multitude of causal processes is probably behind its apparent ubiquity. However, of all these models, two have proven to be the most influential: the compound gamma-Poisson model and the Polya-Eggenberger model derived from the Polya urn scheme.

The first can perhaps be simply presented in the following way. A Poisson distribution arises from counts of random occurrences happening over time or space at a given rate in a population, and a compound Poisson distribution arises when there is a mixed population of different elements, each having different rates of occurrence distributed according to some function. If the function is the gamma function, the model is called gamma-Poisson. In contrast, the Polya-Eggenberger model is derived by drawing balls of two different colors from an urn. As the balls are drawn, they are not only replaced, but new balls of the same color are added. In this way, numerous drawings of balls of one color greatly increases the probability of that color being drawn.

The conceptual interest of the negative binomial distribution for library and information science lies in the conundrum posed by Feller (1943) about *apparent contagion* and *true contagion* with respect to these two models. As Feller pointed out, the Poisson distribution describes mutually independent occurrences that have no influence on each other. Due to this feature, the compound Poisson distribution arises as a result of the inhomogeneity of the population. With the Polya-Eggenberger urn model, the occurrence of an event increases the likelihood of its happening again. Describing the first model as *apparent contagion* and the second as *true contagion*, Feller pointed out that because both models lead to the same result, it is impossible to know which process is taking place if the data conforms to the NBD.

Penetration of the NBD into the Information and Social Sciences

It is in the Polya-Eggenberger form that the NBD passed into library and information science as well as other social sciences as the model of "social contagion," "cumulative advantage," or the "success-breeds-success" phenomenon (Rapoport and Horvath 1961; Coleman 1961, 288–380; Price 1976; Tague 1981). This process was given its most elegant formulation by Merton (1968) in his concept of the Matthew Effect, whereby rewards were allocated among scientists according to the biblical dictum of St. Matthew (13:12): "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath."

Price (1976) described the Polya urn NBD as modeling the "double-edged" Matthew Effect, because in it success is rewarded by increased chance of further success and failure is punished by

increased chance of further failure. He contrasted it to the beta function, which he found to model the "single-edged" Matthew Effect with an urn scheme where success increases the chance of success, but failure has no subsequent effect in changing the probabilities.

In a series of articles devoted to the foundations of information science, Brookes (1980a; 1980b; 1980c; 1981) utilized a discography of phonograph recordings devoted wholly to the works of one composer and issued in the period 1972–76 to demonstrate frequency-rank statistics in contrast to frequency-distribution statistics. To illustrate the former, he applied the mathematics of Bradford's law to segregate composers into groups ranked in descending order of number of recordings on which their works appeared and then measured the Matthew Effect of the degree to which composers with the most recordings "robbed" those composers with the least. Brookes then exemplified frequency-distribution statistics by fitting the NBD to the discographic data, and stated that although the NBD explained the underlying probability mechanism of the recording industry, its application entailed the loss of important empirical information.

Incongruously, Brooks based the NBD on the gamma-Poisson version, which models qualitative inhomogeneity, after demonstrating cumulative advantage. Brookes then proceeded to argue that information quantities should be measured logarithmically to place them in proper perspective. As noted above, the NBD is converted into the normal distribution for parametric statistical operations by logarithmic transformations.

Regardless, given Feller's conundrum, if one finds the negative binomial, one still does not know, for example: whether the LSU chemistry faculty ranked one journal higher than another due to its inherent quality, or due to collegial influences; whether some of the journals selected by the LSU chemistry faculty were cited more than others due to their inherent quality, or because they had been cited heavily before; or whether some of these same journals were priced higher due to inherent propensity of publishers to price differently, or due to the ability of some publishers to raise prices continually, thus reducing the ability of other publishers to do likewise.

The negative binomial distribution models all these possibilities, and all these possibilities are not only conceptually plausible but can be conceived of as interacting with each other. Thus, with the NBD, statistics and conception merge in a particularly elegant fashion.

An interesting facet of the NBD is that it appears to link the production, dissemination, and use of human knowledge with other life processes. The NBD is widely used in the biological sciences, where it has been found to be the most useful mathematical model for contagious distributions (Elliott 1977, 23, 51). From this viewpoint it is also interesting to note that Williams (1964, 295) described the logarithmic series, into which the NBD converges as k approaches zero, as the biological equivalent of "nothing succeeds like success."

The work of Cohen (1971, 1980, 1981) in primatology forms a bridge from the biological to the social and information sciences. He formulated his basic premise with the classic understatement that "Who sleeps with whom interests primates of several species" (Cohen 1971, 3). Using a zero-truncated gamma-Poisson version, Cohen found the NBD to be the equilibrium frequency distribution of size predicted by stochastic models for the dynamics of freely forming primate social groups. According to Cohen, not only is the NBD descriptive of the way monkeys distribute themselves into troops in the tree tops for sleeping and breeding purposes as well as of how children gather into play groups in nursery school, but it also describes the way scientists distributed themselves over the laboratories at Rockefeller University, the National Cancer Institute, and the British National Institute for Medical Research. Cohen found publication rate to be linearly related to the size of the laboratories at a rate of about 1.1 publications for each additional scientist.

Cohen's findings bring into perspective those of Rapoport and Horvath (1961), Coleman (1964, 326–32), and Ehrenberg (1959). In their study Rapoport and Horvath discovered that the distribution of popularity among junior high school students fitted the NBD. This finding was replicated with data from seven 26-member cottages of girls by Coleman, who called the NBD the "contagious Poisson." Because of Feller's conundrum, neither Rapoport and Horvath nor Coleman could definitively state whether the skewed distribution of popularity was due to the inherent qualities of those chosen as popular or to some process of social contagion whereby the students and the girls influenced each other's decisions. For his part, Ehrenberg introduced the compound NBD into marketing as the model for consumer buying, with purchases following the Poisson distribution in time and the purchasing rates of different consumers being proportional to the chi-square or gamma distributions.

However, these are relatively simple situations. When Kochen, Crickman, and Blaivas (1982) and Blaivas et al. (1982) attempted to apply the NBD to the ratings by scholars of other scholars in seven academic disciplines, they ran into severe problems of set definition and levels of consensus within the disciplines. Despite these difficulties, they found that a law of cumulative advantage provided the best theoretical approximation of peer ratings but was fully effective only in well-defined disciplines with high levels of consensus. Their work shows the need for proper set definition to control for contaminants as well the effect of Kuhnian paradigms.

Pioneering work in the application of the NBD in library and information science has been done at the University of Western Ontario. Here, at the School of Library & Information Science, Tague and Farradane (1978) found that the NBD modeled the processes of document retrieval, and Tague (1981) utilized single- and multiple-urn models to demonstrate that the NBD arises as a result of the success-breeds-success phenomenon. However, the most interesting work on the NBD was done by Ravichandra Rao, who obtained his doctorate at Western Ontario. In a further development of Lotka's work, Ravichandra Rao (1980) demonstrated that the NBD describes the pattern of the productivity of scientists under the success-breeds-success condition in a wide variety of social circumstances.

At approximately the same time, the sociologist Allison (1980, 170–73) also found the NBD to describe scientific productivity. However, Allison was aware of Feller's conundrum through the work of Coleman (1964), pointing out that the NBD could have arisen as a result of either the qualitative inhomogeneity of the scientists or a cumulative advantage process. Huber (1998) found that the gamma-Poisson NBD model of inhomogeneity fit the distribution of patents across a population of inventors, but he rejected cumulative advantage, because there was no evidence of increasing productivity with experience—grounds one of his referees found questionable.

In an extremely interesting paper, Ravichandra Rao (1990) confronted the problem of proper set definition in fitting the NBD to informetric data. He analyzed the distribution of 4,130 articles over 744 journals in economics. When he attempted to fit the negative binomial to the data on a global basis without any set definitions, he found that the NBD did not describe the distribution. Hypothesizing that he was dealing not with one but several NBD populations, he then conducted two experiments. First, he defined the journals that provided the most articles as contaminants originating from a different NBD set and eliminated them by truncating the distribution on the right. Chi-square tests showed that the NBD fit this truncated distribution very well. Second, he classified the journals under 15 subject rubrics such as "Methods," "History of Economic Thought," "Organization of Production," etc., thereby controlling for contaminants by defining the data into more homogeneous sets. When this had been done, the NBD fit 12 of the 15 subject groups, demonstrating the importance of proper set definition.

The Controversy over the NBD and Monographic Circulation

Ravichandra Rao (1982; 1988) dedicated his doctoral dissertation at Western Ontario to testing probability distributions against data from the automated circulation systems of six large Canadian academic libraries. These data sets covered circulation periods lasting from 1 academic year for the University of Guelph up to 11 academic years for the University of Saskatchewan. Ravichandra Rao tested no less than 17 probability distributions against 203 document frequency distributions and 200 user frequency distributions for different types of user populations. In both cases he found the NBD to be the best probability distribution for both theoretical and practical reasons. The full NBD fit 92 (45.3%) of the 203 document distributions tested at the 0.01 level, and the truncated NBD fit 102 (51.0%) of the 200 user distributions tested at the 0.01 level. In line with the work of Tague and his own work on scientific productivity, Ravichandra Rao located the causal process of the NBD in the success-breeds-success phenomenon.

Most interestingly, Ravichandra Rao found that in the majority of cases the NBD did not fit the document distributions from undergraduate populations. Undergraduates may be considered a preparadigmatic population in the Kuhnian sense. Therefore, this finding of Ravichandra Rao corroborates the conclusion of Kochen, Crickman, and Blaivas (1982) that a certain level of knowledge and consensus is necessary for the NBD to form. It also corroborates Metz (1983, 81) that knowledge of an undergraduate's major was significantly less predictive of the library materials the undergraduate would borrow than knowing the departmental affiliation of a faculty or graduate student borrower.

However, the application of the negative binomial to library circulation data is chiefly associated with the name of Burrell at the Department of Mathematics Statistical Laboratory of the University of Manchester. Burrell developed his model in a series of papers over the years (Burrell 1980, 1982; Burrell and Cane 1982; Burrell 1985, 1986, 1987, 1988). His motivation was the appearance in Great Britain in 1976 of the Atkinson Report, in which the principle was set forth that the assessment of future university library building requirements should be based on the concept of the "self-renewing" library, i.e., a library that is limited in size in which after a certain point material should be removed in proportion to the rate of acquisition. Burrell's aim was the development of a simple stochastic model that librarians could use to decide whether to purchase multiple copies or relegate stock, and he concentrated on monographic circulation at various university libraries in the Britain and the United States.

Burrell decided upon the gamma-Poisson NBD, finding that it approximated Trueswell's 80/20 rule in certain cases (Burrell and Cane 1982, 460) . Although he was aware of Feller's conundrum through the work of his collaborator Cane (Burrell and Cane 1982, 450), he deliberately chose to emphasize the processes of inhomogeneity in contrast to Ravichandra Rao, who based his work on the principle of contagion. As Burrell's model emerged in the mid-1980s, it consisted of three basic tenets. First, the borrowing of individual monographs is a Poisson process with a rate that varies from item to item. Second, the different borrowing rates of the individual monographs is described by a desirability distribution, which is the gamma function. And third, the aging of the desirability occurs exponentially at the same rate for all monographs, which results in fairly stable distributions over time, with a permanent and growing zero class, because certain monographs have zero desirability to begin with (Burrell 1985, 1986, 1987). It is interesting to note that in his analysis of monographs Burrell mathematically modeled on the basis of one side of Feller's conundrum, inhomogeneity, what Bensman (1985b, 24–26) deduced at about the same time in his study of journals as a logical consequence of the operation of the double-edged Matthew Effect, itself a reflection of the other side of Feller's conundrum, contagion, i.e.,

stable distributions of library usage over time with a large zero class.

Burrell developed his model largely on global library circulation data, without subject set definitions. However, in an interesting application of the NBD to public library circulation, Brownsey and Burrell (1986) constructed a model consisting of a mixture of three NBDs to account for the three gross subject classes of British public libraries—adult fiction, adult nonfiction, and junior. The result was a much improved fit to the data. This result was confirmed by Kinnucan and Wolfram (1990), and it corroborates the conclusion of Kochen, Crickman, and Blaivas (1982) as well as of Ravichandra Rao (1990) on the need for proper set definitions when dealing with information concerning human knowledge. After this, Burrell (1988, 303) wrote, " . . . when we speak of a collection we do not necessarily mean the entire holdings of the library but rather some well-defined set of items within the library, e.g., all books acquisitioned in a particular year in a particular subject class."

The development by Burrell of his model was accompanied by a number of major controversies. The first of these involved his concept of a permanent zero class. For Burrell (1982, 2–3) the zero class as it appeared in circulation statistics was a highly complex phenomenon because it contained not only items that had zero desirability but also those that could not appear in these statistics because they were lost, stolen, placed on reserve, etc. Therefore, in his opinion, the zero class could not be treated as an item of hard data as the other circulation frequencies. To deal with it, he initially used a technique called "with added zeros," which basically involves first estimating the parameters of the distribution truncated by the omission of the zero class and then estimating the size of the zero class by assigning an artificial probability to it (Johnson and Kotz 1969, 205–7).

When Burrell presented his model calculated in this fashion to a session of the Royal Statistical Society, it drew fire from Chatfield, a professor of marketing and collaborator of Ehrenberg, who had introduced the NBD into marketing. Chatfield criticized the concept of zero desirability, noting that it had been found impossible to distinguish between "never-buyers" and buyers with a low mean rate of purchase who just had not purchased during the time period under review (Burrell and Cane 1982, 467). He recommended calculating the parameters on the full distribution with an estimated zero class.

Chatfield's criticism was repeated in a study of public library circulation by Bagust (1983), who described Burrell's concepts of desirability and zero class as "gratuitous assumptions" (p. 25). Accusing Burrell of "data-fitting," Bagust declared that (p. 25) " . . . if a book is exposed to the client population no one can be certain that one day it will not be borrowed, i.e., it has a non-zero-probability of circulation." He then proceeded to fit the NBD to the full distribution of a public library, declaring (p. 32) that "the absence of a 'zero class' in the Negative Binomial model ensures that every acquisition kept on open access shelving will eventually circulate (if not eaten by bookworms first!)." Burrell (1984) responded with a harsh attack on both Bagust's reasoning and mathematics. Burrell (1985) then proceeded to develop his aging concept, the logic of which inevitably leads to a certain proportion of the collection never circulating (p. 103).

A second controversy arising from the development by Burrell of his model related to the other end of the distribution. It, too, began during the discussion of the model at the Royal Statistical Society with an observation by Chatfield that the NBD tended to overestimate the number of monographs at the high-circulation end of the distribution. Chatfield found this overestimation natural, because there is an upper limit to the number of times a book can go out in a year (Burrell and Cane 1982, 467). However, the matter took a serious turn when the tendency of the NBD to overestimate the number of high-circulation monographs caused Gelman and Sichel (1987) to question the validity of applying the Poisson process to

library monographic circulation. An understanding of the nature of the controversy can be found in the following passage (Coleman 1964, 291):

> The appropriateness of the Poisson process for social phenomena lies not in its empirical fit to social data. It lies instead in the assumptions on which the distribution is based. In the first place, it deals with *numbers* of events. Therefore, continuous-variable measurements, which are extremely rare in social science, are unnecessary. Second, the Poisson process occurs continuously over time, rather than at discrete "trials" like the binomial distribution. Thus, for naturally occurring events, in contrast to controlled experiments, something akin to the Poisson process is often appropriate.

Based on this difference, Gelman and Sichel (1987) believed that external monographic circulation more closely resembled the binomial process of discrete trials for two reasons: the books could not be continuously borrowed, because they were out for extended periods; and there was a finite bound to the number of circulations in a given time period. Therefore, in place of the gamma-Poisson NBD, they proposed for external monographic circulation the beta-binomial distribution (BBD), which is a compound binomial distribution with the beta function as the mixing function. Testing both the BBD and the NBD against the external monographic circulation of two university libraries, Gelman and Sichel found that the BBD provided a much better fit to the high-circulation end of the distribution.

Haight (1978, 158) describes the BBD as the discrete time analog of the gamma-Poisson NBD in that it models qualitative inhomogeneity for short time periods so that only a success or failure can be recorded. Interestingly enough, the mixing beta function is the very function that Price (1976) demonstrated as modeling the single-edged Matthew Effect. Moreover, the NBD arises as a limit of the BBD (Boswell and Patil 1970, 8–9). In library terms, as Gelman and Sichel (1987) describe it, the binomial process turns into a Poisson process as the loan period shortens and the time the item is available for further use lengthens. Therefore, they suggested that binomial mixture models be applied to low-frequency use such as book lending and that Poisson mixture models be applied to high-frequency use such as journal or in-library use.

The controversies surrounding Burrell's development of his NBD model with aging on the basis of external monographic circulation came to a head with a study done by Tague and Ajiferuke (1987) at the Western Ontario School of Library and Information Science. They utilized University of Saskatchewan monographic circulation data for the academic years 1967–68 through 1977–78, which were organized into Collection I and Collection II. Collection I consisted of all those monographs that had circulated in the initial year 1967–68, and it traced their circulation history through the subsequent 10 academic years. It contained a zero class. Collection II contained monographic circulation data for the 11 academic years from 1967–68 through 1977–78. It was different from the first in that it provided information not on one set of monographs over time but on the 11 differing sets of the monographs that had circulated in each of the 11 academic years. Collection II did not have a zero class.

Tague and Ajiferuke applied the NBD to both of these collections. With respect to Collection I, they used two different ways to estimate the parameters of the NBD. The first way was to estimate the parameters by the method of moments in combination with another method that incorporated Burrell's aging factor (a proportion crudely obtained by dividing the circulation mean of the initial year into the circulation mean of the following year). This way comprised a technique for testing the predictiveness of Burrell's model. The second way was to use the method of moments to estimate both parameters for each year of circulation. As for Collection II, Tague and Ajiferuke employed a technique for estimating the parameters of the zero-truncated NBD, whose own inventor (Brass 1958, 59) described as suitable for exploratory work or to provide first-stage values for iterative

maximum likelihood solutions. Tague and Ajiferuke then employed chi-square goodness-of-fit tests on the various circulation distributions, and in all cases the NBD was rejected as the appropriate model.

At this point it is necessary to pause to describe the general features of Collection I of the Saskatchewan circulation data and the results of Tague and Ajiferuke's tests upon it in order to bring into focus precisely what is at stake in these controversies. Collection I contained circulation data on 68,590 monographs, and in the first year, 1968–69, the zero class comprised 51,992 or 75.8% of the monographs in the set. Over the years, the zero class rapidly expanded until in the last year, 1977–78, it contained 63,251 or 92.2%. For the complete ten-year period, the mean of the zero class was 86.2% of the monographs in the set. Such a phenomenon is not unusual in library use. For example, in his seminal article on library use, Trueswell (1969) showed that 50% to 60% of library holdings satisfied 99% of circulation requirements.

During the 1970s Kent et al. found that 39.9% of the monographs acquired in 1969 by the Hillman Library at the University of Pittsburgh never circulated in the period from 1969 to 1975 and that in 6 branch science and technical libraries the zero class for journals ranged from a low of 63.1% in the Physics Library to a high of 93.2% in the Engineering Library. These zero classes can consume a considerable amount of resources, and the researchers found that the subscription costs of the zero class ranged from 47.9% of the Physics Library's serials budget to 86.5% of the Computer Science Library's serials budget (Kent et al. 1978, 61–62, 104–10; Kent et al. 1979, 9–104, 209–68; Flynn 1979). However, the Pittsburgh figures for serials might be overstated due to poor methodology. Whereas at Pittsburgh the Chemistry Library's serials zero class was estimated at 85.5% of the serials collection and its cost at 64.8% of the serials budget, a more careful study with a better sample by Chrzastowski (1991) at the University of Illinois at Urbana–Champaign (UIUC) Chemistry Library found the size of the zero class to be only 9% and its cost to be merely 3%.

In comparison to the zero class, the high-circulation class of the Saskatchewan data—defined here as 5 uses per year or more—was extremely small and shrank rapidly. In 1968–69, the top monograph circulated in the range of 17 to 19 times, but by 1977–78 the highest number of circulations for any monograph had fallen to 6. The size of the high-circulation class shrank parellel to the fall of the upper limit. In 1968–69 the high-circulation class contained 2,011(2.9%) of the monographs in Collection I, and by 1977–78 it had diminished to 39 (0.06%). Over the ten-year period the mean of the high-circulation class was 1.0% of the monographic set.

Tague and Ajiferuke's test of Burrell's NBD model with aging found that it underpredicted the zero class 8 of the 10 years and overpredicted it 2 of the 10 years. The absolute error rate for the zero class ranged from 141 (0.22%) of the predicted frequency to 5,671 (10.4%) of the predicted frequency, averaging out to 3.1% for the 10 years. However, viewed from the perspective of the entire set of 68,590 monographs, the picture drastically changes. The highest absolute error of 5,671 was then 8.3%, and the average absolute error rate was 1,747 monographs (2.6%). Burrell's model was much less accurate with respect to the high-circulation class, and this is not surprising, given the much smaller size of this class. His model consistently underpredicted the high-circulation class 10 of the 10 years, and its error rate ranged from 10.1% to 228.6%, tending to grow larger as the high-circulation class became smaller. The average error rate in predicting the high-circulation class was 92.7%. However, once again, viewing the error rate from the perspective of the entire set of 68,590 monographs radically alters the picture. The highest underprediction was 605 (merely 0.9%), and the average underprediction of 177.4 (only 0.3%) of the total set.

The standard NBD without aging performed much better in Tague and Ajiferuke's tests, and this is understand-

able, because the parameters were estimated for each year without the element of predictiveness in Burrell's model. With respect to the zero class, the standard NBD's expected frequencies were consistently below the observed frequencies in all of the years. These differences ranged from 62 (0.1%) to 1,258 (2.3%), resulting in an average underestimation of 0.8%. Needless to say, the perspective from the entire set of 68,590 monographs leads to a much different assessment. From this viewpoint, the largest underprediction of 1,258 was only 1.8%, and the average underprediction error of 458.4 equaled only 0.7% of the entire set.

The performance of the standard NBD on the high-circulation class resembled that of Burrell's model, being much more erratic here, but its error rate was much smaller. Out of the 10 years, the expected frequencies were under the observed frequencies for 6 years, over for 3, and exactly correct for 1. The absolute error rate of the standard NBD on the high-circulation class ranged from 0.0% to 16.9%, averaging out to 8.8%. This error rate drops considerably when the entire set of 68,590 monographs is taken into account. In these terms, the highest absolute error of 268 equaled 0.4% of the set, whereas the average absolute error of 65.5 amounted to only 0.1% of the set. If the authors of this paper could bet the ponies or play the stock market with such odds, they would not be writing this paper! Moreover, without going into the highly technical question of the choice of estimators, it should be pointed out that Tague and Ajiferuke were running their tests on a global database without any division into well-defined subject sets, a procedure that Brownsey and Burrell (1986) as well as Ravichandra Rao (1990) have shown would have very possibly led to far better fits to the NBD.

The studies of Gelman and Sichel as well as of Tague and Ajiferuke provoked an outburst of exasperation from Burrell. Pointing to the general predictive success of his model in the tests by Tague and Ajiferuke, he concentrated his fire on them and wrote (1990, 166):

> Any theoretical model can only be regarded as an approximation to reality, to the extent that any differences between the model and the reality will inevitably be revealed by, e.g., a X^2 [chi-square] goodness-of-fit test given a sufficiently large sample, and our sample sizes here are very large. On the other hand, it is not really our aim to seek out an "optimal" model but rather one that catches the essential features of the data and provides useful information for management purposes.

Burrell concluded with the declaration (p. 167):

> For all its deficiencies and theoretical drawbacks, the gamma-Poisson model can give the library manager useful guidance in decision making. It may not be the correct model or even the best, but in general terms it works!

Nevertheless, he went on to incorporate loan periods in his library book circulation model (Burrell and Fenton 1994).

The last word in this controversy will be given to several library school students in Belgium, which has become a center of informetrics due to the efforts of Egghe and Rousseau. As part of "bibliometric field work" for a course taught by Rousseau at the University of Antwerp, Leemans et al. (1992), collected book circulation data from several Flemish public libraries and fitted the NBD to it. They also sent one data set to Sichel to be fitted to the BBD. Although the BBD better fit the data, the students decided in favor of the NBD, pointing out that two attitudes are possible in the study of circulation data. The first is that of a statistician trying to fit the data as precisely as possible. In that case the NBD will often not be good enough, and more complicated models with more and more parameters will be necessary. The second attitude is to admit that there is more variation than simple statistics can explain and admit some discrepancies at the high end of the distribution. In this case simple statistics such as the NBD yield excellent trend curves, which are all the practicing librarian really needs. At the conclusion of their paper the students recommended that

the NBD be taught in introductory library management courses.

It appears from the above literature survey that the NBD is a workable general probability distribution for library and information science. Therefore, if one finds a highly and positively skewed distribution in such work, one may operate under the assumption that one is dealing with the NBD or—if not precisely the NBD—a probability distribution closely related to it and modeling the same, often interacting processes of qualitative inhomogeneity and cumulative advantage. External monographic circulation might well be a special case, and even here the NBD works reasonably well. Gelman and Sichel themselves recommend mixed Poisson distributions for journal and in-library use. Therefore, for most purposes, practitioners can limit themselves to the simple index of dispersion test (Elliott 1977, 40–44), and, if the variance is found to be significantly greater than the means—and it almost invariably is, indicating a contagious distribution—one only has to carry out the proper logarithmic transformations and proceed to other questions.

Much of the work described above was done by statisticians trying to solve the problem mathematically without either proper set definitions or without reference to the sociological factors in human knowledge. Library use is strongly affected by these sociological factors, which comprise not only the Kuhnian concept of the "paradigm" but also the social bases of ST value. The case for the NBD is strengthened by the fact that the social bases of ST value are measured by such variables as peer ratings and citation rates, which are not subject to the periodicity limits of external library monographic circulation. It is to the problem of the social bases of ST value that attention is now directed.

The Social Bases of Scientific and Technical (ST) Value

Social Stratification and Library Use

In two papers Bensman (1982; 1985b) analyzed the social bases of bibliometric laws and library use particularly as they related to scholarly journals. During this analysis he demonstrated that the concentration of use on a relatively small proportion of a library's serials holdings was a function of a series of sociobibliometric laws based on the principle of cumulative advantage or, more specifically, the double-edged Matthew Effect. Bensman argued that these laws were operative not only in library use but also in the social stratification of scholarship, and he developed the hypothesis that the concentration of journal use in academic libraries was partially a reflection of the process of formation of scholarly elites. Bensman found peer ratings and citations to be virtually equivalent measures of scientific value, and he theorized that a logical result of the double-edged Matthew Effect should be distributions stable over time with large zero or random classes. In his opinion, citations represented a measure of the formation of scholarly elites, the highly stratified and relatively stable social system of scholarship, as well as of those journals that research scholars regard as important.

A unique opportunity to investigate this hypothesis further occurred when, through the mediation of the university's Dean of Graduate School and subsequent Provost, LSU Libraries became a test site for the database developed by the National Research Council (NRC) during its 1993 survey of U.S. research- doctorate programs (Goldberger, Maher, and Flattau 1995). Because a major study of the structure of the library market for scientific journals in chemistry had just been completed, with data collected in the SRP pilot project at the LSU Department of Chemistry, it was decided to utilize the NRC database to investigate the interrelationship of the scientific social stratification system with the scientific journal system in this field. The NRC database is a massive one, containing not only the 1993 peer ratings of academic departments but also data developed by the Institute for Scientific Information (ISI) on the publication and citation rates of departments in the sciences, engineering, and the social sciences. An extremely

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