

Relationships between Association of Research Libraries (ARL) Statistics and Bibliometric Indicators: A Principal Components Analysis

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This study analyzed 2005–2006 Web of Science bibliometric data from institutions belonging to the Association of Research Libraries (ARL) and corresponding ARL statistics to find any associations between indicators from the two data sets. Principal components analysis on 36 variables from 103 universities revealed obvious associations between size-dependent variables, such as institution size, gross totals of library measures, and gross totals of articles and citations. However, size-independent library measures did not associate positively or negatively with any bibliometric indicator. More quantitative research must be done to authentically assess academic libraries' influence on research outcomes.



Statistical relationships between collected library measures and bibliometric indicators offer a valuable perspective in viewing the research library's role in the broader context of their institution's research. Macro analyses measure the overall strength in which a specific public services, collection development, or fiscal metric is linked with established indicators of research productivity and impact across institutions. Useful to librarians at major research institutions, these data analyses may inform their decision-making processes in determining the focus of library services, collections, and staffing in order to affect institutional research outcomes. Using principal component analysis, this study's objective was to discover if the most rec-

ognized library measures, Association of Research Libraries (ARL) statistics, demonstrate statistical relationships with Web of Science (WOS) bibliometric indicators, well-regarded measures of an institution's research productivity and impact.

Using homegrown assessment statistics, several libraries have quantitatively illustrated the effect of library collections and services on users at the micro level, such as assessments of information literacy efforts on student learning and confidence. However, a paucity of quantitative analyses on the institutional effects of libraries' services and collections exists on a macro level. Closest in scope to this study, John M. Budd studied the relationships between publication statistics at ARL and Association of College and Research Libraries (ACRL) member institutions and ARL

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statistics. Using rank-order correlations, Budd concluded that rank of total library materials budget, total volumes, and total PhDs awarded correlated positively with rank of total publications—an indicator of raw productivity. To a lesser degree, Budd correlated per capita ranks with total publications at ARL institutions.¹ To gauge the adequacy of resource allocations to academic libraries, Dickie and Allen created a library funding model using ARL data and institutional statistics.² Employing ARL metrics, Mezick moderately correlated library expenditures, collection size, and total number of serials to undergraduate student persistence.³

Background

Though controversial, bibliometric indicators have become increasingly important in academia. Employed by universities as evaluative tools, bibliometric measures may characterize aspects of research productivity and influence. Institutionally, university administrators use bibliometric indicators to assess their research groups, departments, and schools as well as their own university's comparative standing domestically and internationally. These appraisals often assist in determining intra-university financial allocations⁴ and benchmarks⁵ in addition to identifying the extent of extramural collaboration,⁶ institutional strengths,⁷ and new and promising research fields.⁸ To individual university faculty, the use of bibliometric indicators—such as gross totals of publications and citations, *h*-indices, and journal impact factors in tenure, promotion, and reappointment decisions—can affect the direction of their career.⁹

Advocating for the interest of its 123 institutional members, ARL is one of the most influential organizations in the library world. As a part of its mission, ARL annually compiles statistics that describe collections, services, human resources, and finances at the top research libraries in the United States and Canada. As a requirement of membership, ARL libraries "...must contribute the data necessary

to establish the membership indices and to compile the annual ARL Statistics."¹⁰ From these data, an ARL index score is calculated, and subsequently a rank is assigned for member libraries. The professional literature contains studies that discussed the meaning,¹¹ temporal characteristics,¹² internal library relationships,¹³ and limitations¹⁴ of ARL statistics, but very few explored connections with broader institutional measures.

Methods

The population for this study is academic institutions that have ARL libraries on their campuses (n=113). To retrieve bibliometric data, the author searched WOS using inclusive search strategies to retrieve institution-specific articles. Employing the "Analyze Results" feature in WOS, the author refined the results to include articles published in 2005 and 2006. The author refined by institution and searched for the institutions and name variants. The author exercised due diligence in capturing all possible name variants of a university (for instance, Univ N Carolina, UNC, Univ North Carolina) within WOS. Bibliographic information from satellite campuses or other universities comprising a larger university system were not included.

From the WOS searches, the author retrieved four measures for each ARL academic institution:

- Total articles published, 2005–2006
- Total citations to articles published in 2005–2006

- Institutional *h*-index, 2005–2006
- Total articles not cited, 2005–2006

At the time of data gathering, the latest published ARL statistics were from 2005–2006. The 2005–2006 ARL Statistics¹⁵ provided the following measures for most ARL libraries:

- Total number of faculty
- Total number of full-time students
- Total number of library presentations
- Total number of reference transactions
- Total number of circulation transactions

- Total number of interlibrary loan transactions
- Total number of professional librarians
- Total number of library staff
- Total amount of library expenditures
- Total amount of library expenditures on library materials
- Total amount of library expenditures on monographs
- Total amount of library expenditures on serials
- Total amount of library expenditures on electronic resources
- Total number of volumes
- Total number of serials

Ten libraries failed to disclose certain pieces of information to ARL; thus, the author could not use data from those universities during the principal components analysis.

These libraries are: University of California, Berkeley; Dartmouth University; Georgia Institute of Technology; Harvard University; University of Michigan; Ohio State University; Oklahoma State University; University of Pennsylvania; Rice University; and University of Wisconsin.

All of the aforementioned measures were size-dependent indicators—measures entirely based on the sum totals (size). Though they provide a picture of gross productivity and expenditures, size-dependent indicators do not measure institutional research impact, individual faculty productivity, individual library productivity, or expenditures on a standardized scale. To address this problem and provide more robust data sets, the author synthesized 18 size-independent indicators from the size-dependent data. These included:

- Citations per article
- Impact index
- Percentage of uncited articles
- Articles per faculty member
- Citations per faculty member
- Library presentations per capita (faculty and students)
- Reference transactions per capita

- Circulation transactions per capita
- Interlibrary loan transactions per capita
- Professional librarians per capita
- Library staff per capita
- Library expenditures per capita
- Percentage of total library expenditures spent on materials
- Percentage of material expenditures spent on monographs
- Percentage of material expenditures spent on serials
- Percentage of material expenditures spent on electronic resources
- Volumes per capita
- Serials per capita

Commonly used in the social sciences, principal component analysis (a multivariate statistical technique) reduces the known variables to common hidden variables known as factors, which may reveal fundamental relationships between variables. To uncover the significant factors, principal component analysis uses eigenvalues, a value that explains the variance of the known variables linked with each factor. Rotational methods, such as Varimax, simplify the data interpretation by diversifying the variable loadings, thus showing which variables cluster together more clearly. Employing SPSS v.15 for statistical analysis, the author conducted a principal component analysis to examine which variables cluster together.¹⁶

Results of the Principal Components Analysis

Variance

For the 103 universities eligible for analysis, principal components analysis of the 37 variables sought to reveal significant relationships. Initially, the author ran a principal components analysis that extracted all factors with eigenvalues over one, and subsequently rotated orthogonally using the Varimax technique. Eight factors with eigenvalues over one were extracted initially; however, review of the scree plot and the total explained variance led the author to recalculate the principal components analysis, limiting to five fac-

tors. The five extracted factors explained 75.6 percent of the total variance.

Clustering of Variables

Table 1 shows how the studied variables grouped together. The variables are sorted by the significance of their relationship to the factor. The first factor characterizes the size of an institution and its library as most of the size-dependent variables clustered together. Only two of the nineteen variables related to the first factor—percentage of the materials budget spent on monographs and percentage of the materials budget spent on serials—were size-independent. Only one variable—percentage of the materials budget spent on serials—showed a negative and significant relationship. The second factor illustrates the significant relationship between most of the size-independent library measures. The only anomaly, total number of students, demonstrated a negative and significant relationship with these per-capita measures due to its overwhelming influence in calculating the per-capita denominator for these measures. The third factor grouped both size-dependent and size-independent bibliometric data together. The fourth factor was the most difficult to decipher. The factor describes a positive and significant relationship between reference service and library presentations, but it also indicates a negative and significant relationship between the aforementioned measures and two size-independent expenditure measures, percentage of total library expenditures spent on materials and percentage of material expenditures spent on electronic resources. The fifth factor expresses the link between the two interlibrary loan measures in the matrix.

Table 2 illustrates statistically the clustering of factor loadings of essential factors and the strength of their associations. Considering the size of the population ($n=103$), the threshold value for significant factor loadings was close to 0.512, according to Stevens.¹⁷ All factor loadings under 0.512 were excluded in the table.

Discussion of the Results

Principal components analysis confirmed some obvious assumptions regarding the size of an institution and its libraries. Described by the first component, gross productivity in terms of total articles and citations exhibited a significant relationship with all gross library expenditure measures, gross library and university staffing measures, and most gross library services measures. In the same vein, larger universities and libraries showed significant associations with larger total numbers of uncited articles.

Inextricably linked, the percentage of a library's material budget spent on monographs and the percentage of a library's material budget spent on serials clustered around the size-dependent measures, too. The data suggested that smaller universities and libraries tended to spend a larger percentage of their materials budgets on serials. Consequently, gross productivity in terms of total articles and citations showed significant statistical links with libraries that spent a larger percentage of their materials budgets on monographs. The author postulated that smaller libraries may have instituted more severe cuts in monographic acquisitions to keep pace with serials inflation.

For size-independent bibliometric measures, no associations with any library measures revealed themselves. Volume counts, library services transactions, and budgets exhibited no measurable link to bibliometric measures that afford equitable institutional comparisons, such as citations per article, impact index, and articles per faculty member. Therefore, the author concluded that ARL measures do not demonstrate any association with the general impact and influence of an individual article or faculty member.

Hardest to define, the fourth factor may indicate that libraries that perform more reference and instruction services dedicate less of their budget toward materials purchases, especially electronic resources. Because of the strong negative association, the fourth factor also suggests that libraries that al-

| <p align="center">TABLE 1 Variable Clustering from the Principal Components Analysis in Order of Significance</p> | | | | |
|--|--|--|--|---|
| Factor 1: Size of an institution and its library | Factor 2: Per capita library data | Factor 3: Bibliometric data | Factor 4: The relationship between library public services and library expenditures | Factor 5: Interlibrary loan data |
| Total amount of library expenditures on materials (SD) | Total library expenditures per capita (SI) | Citations per faculty member (SI) | Reference transactions per capita (SI) | Total number of interlibrary loan transactions (SD) |
| Total amount of library expenditures (SD) | Library staff per capita (SI) | h-index (SD) | Total number of reference transactions (SD) | Interlibrary loan transactions per capita (SI) |
| Total number of library staff (SD) | Volumes per capita (SI) | Citations per article (SI) | Total number of library presentations (SD) | |
| Total amount of library expenditures on monographs (SD) | Librarians per capita (SI) | Total number of citations (SD) | Percentage of material expenditures spent on electronic resources (SI) | |
| Total number of volumes (SD) | Serials per capita (SI) | Articles per faculty member (SI) | Percentage of total library expenditures spent on materials (SI) | |
| Total amount of library expenditures on serials (SD) | Total number of students (SD) (Negative association) | Impact index (SI) | | |
| Total number of librarians (SD) | Library presentations per capita (SI) | Total number of articles (SD) | | |
| Total number of serials (SD) | Interlibrary loan transactions per capita (SI) | Not cited article percentage (SI) (Negative association) | | |
| Total number of faculty (SD) | | Total number of articles with no citations (SD) | | |

TABLE 1
Variable Clustering from the Principal Components Analysis in Order of Significance

| Factor 1: Size of an institution and its library | Factor 2: Per capita library data | Factor 3: Bibliometric data | Factor 4: The relationship between library public services and library expenditures | Factor 5: Interlibrary loan data |
|---|--|------------------------------------|--|---|
| Total number of circulation transactions (SD) | | | | |
| Total number of students (SD) | | | | |
| Total number of articles with no citations (SD) | | | | |
| Total amount of library expenditures on electronic resources (SD) | | | | |
| Percentage of the materials budget spent on serials (SI) (Negative association) | | | | |
| Total number of articles (SD) | | | | |
| Percentage of the materials budget spent on monographs (SI) | | | | |
| Total number of reference transactions (SD) | | | | |
| Total number of library presentations (SD) | | | | |
| Total number of citations (SD) | | | | |
| SD = Size Dependent Variable SI = Size Independent Variable | | | | |

| TABLE 2 | | | | | |
|--|------------------------|----------|----------|----------|----------|
| Rotated Component Matrix from Principal Components Analysis, Varimax Rotation | | | | | |
| | Factor loadings | | | | |
| | 1 | 2 | 3 | 4 | 5 |
| Total amount of library expenditures on materials | 0.867 | | | | |
| Total amount of library expenditures | 0.854 | | | | |
| Total number of library staff | 0.851 | | | | |
| Total amount of library expenditures on monographs | 0.827 | | | | |
| Total number of volumes | 0.805 | | | | |
| Total amount of library expenditures on serials | 0.735 | | | | |
| Total number of librarians | 0.713 | | | | |
| Total number of serials | 0.678 | | | | |
| Total number of faculty | 0.672 | | | | |
| Total number of circulation transactions | 0.653 | | | | |
| Total amount of library expenditures on electronic resources | 0.615 | | | | |
| Percentage of the materials budget spent on serials | -0.613 | | | | |
| Percentage of the materials budget spent on monographs | 0.591 | | | | |
| Total library expenditures per capita | | 0.923 | | | |
| Library staff per capita | | 0.914 | | | |
| Volumes per capita | | 0.892 | | | |
| Librarians per capita | | 0.884 | | | |
| Serials per capita | | 0.805 | | | |
| Total number of students | 0.643 | -0.670 | | | |
| Library presentations per capita | | 0.657 | | | |
| Citations per faculty member | | | 0.844 | | |
| h-index | | | 0.842 | | |
| Citations per article | | | 0.825 | | |
| Total number of citations | 0.513 | | 0.793 | | |
| Articles per faculty member | | | 0.772 | | |
| Impact index | | | 0.738 | | |
| Total number of articles | 0.603 | | 0.707 | | |
| Not cited article percentage | | | -0.704 | | |
| Total number of articles with no citations | 0.628 | | 0.641 | | |
| Circulation transactions per capita | | | | | |
| Percentage of total library expenditures spent on materials | | | | -0.681 | |

TABLE 2
Rotated Component Matrix from Principal Components Analysis, Varimax Rotation

| | Factor loadings | | | | |
|--|-----------------|-------|---|--------|-------|
| | 1 | 2 | 3 | 4 | 5 |
| Reference transactions per capita | | | | 0.641 | |
| Total number of reference transactions | 0.556 | | | 0.584 | |
| Percentage of material expenditures spent on electronic resources | | | | -0.549 | |
| Total number of library presentations | 0.516 | | | 0.534 | |
| Total number of interlibrary loan transactions | | | | | 0.840 |
| Interlibrary loan transactions per capita | | 0.595 | | | 0.682 |
| Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Factor Loading Threshold Value: 0.512 | | | | | |

locate more of their budgets to collections and electronic resources field fewer reference questions and perform fewer library presentations. This may point to an inherent tension between public services and collection development at ARL libraries. Furthermore, the inclusion of the percentage of material expenditures spent on electronic resources variable in this clustering raises related questions. Does the administration of electronic resources require so much more library staff and time that public services are scaled back to accommodate it? Do more expensive electronic resources also require more library resources that subsequently affect the provision of reference and instruction services?

Limitations

Traditional ARL measures, such as volume counts and total expenditures, have severe limitations qualitatively, as they only measure size and temporal growth. Assessing the effectiveness and quality of library services through traditional ARL statistics is not possible. Moreover, as libraries proffer more online services, the significance of evaluating electronic collections and services (also known as e-metrics) has increased. ARL measures used in this study did not include the raw numbers of database usage statistics,

e-journal access statistics, e-book access statistics, and online tutorial statistics or any qualitative assessment of electronic collections and services. ARL is involved with several statistical initiatives to fill the void that address qualitative measures and electronic collections and services, such as LibQUAL+TM,¹⁸ E-Metrics,¹⁹ and MINES for LibrariesTM Project,²⁰ but they were not analyzed in this study.

Other limitations include inherent problems with the self-reporting methodology employed by ARL. Libraries may define the same measure differently, thus reporting inconsistent numbers. Data omissions from some major universities required those libraries to be removed from the analysis. Part-time faculty members were not considered in the faculty counts.

With ISI data, several limitations also emerge. First, citations errors exist within the Web of Science database. Moed stated that 7 percent of all cited references were erroneous.²¹ The author attempted to capture all the institutional name variants while searching but acknowledges that records with unfamiliar institutional names and acronyms may have been missed. Another limitation with ISI data is selectivity. Proceedings, patents, technical reports, and many international journals are not indexed by the database. The au-

thor did not apply fractional attribution methodologies in cases where multiple authors worked at different universities; all authors received equal treatment. Furthermore, self-citations were included, which may alter the data set. However, bibliometric analyses concluded that the effect of self-citations is inconsequential when performing macro level analyses.²²

Conclusions

This macro analysis demonstrated that traditional ARL measures of library services, library expenditures, and library collections are not reliable predictors of research influence or impact at the individual researcher and article levels. To be clear, this does not mean librarians and their work do not affect the research quality and productivity of the users they serve. Great numbers of case studies in the library and information science literature reflect that the opposite is true. In fact, micro level studies may be preferable in articulating the library's influence on individual researchers.

As expected, the size of an institution demonstrates positive associations with library metrics and with bibliometric totals. These raw data show that a larger library budget and more librarians are linked to more institutional citations, but these crude statistics are not the foundation for proving a library's impact. It merely points out that larger universities are characterized by larger faculties, which produce

more scholarship as a whole, and larger libraries, which spend more money and offer more services as a whole. The aforementioned analysis of size-independent measures diminishes meaningful associations between library service and collection metrics with bibliometric indicators.

On an internal library level, this study discovered an oppositional relationship between some public services measures and collection development budget allocations. At an individual library level, this tension may or may not be readily apparent. Nonetheless, library administrators may want to keep this interrelatedness in mind to strike a healthy balance that works for their institutions.

Assessing outcomes of library services and collections in relation to a university's mission and objectives in a meaningful way proves difficult. Often, these missions and objectives are not clearly defined (or even quantifiable) and can change from university administration to university administration. For universities whose missions include scholarly research, bibliometric indicators may offer standards from which to measure institutional outcomes. Further research using different data sets and a variety of statistical tests and measures—including canonical correlation and power law equations—must be performed to genuinely quantify libraries' influence on their parent universities at the macro level.

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