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Research Productivity and Its Relationship to Library Collections

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See table of contents

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Article abstract

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Methods – Demographic data (e.g., faculty size, student size, research and development expenditures), library budget data (e.g., collection expenditures), collection use data (e.g., full-text article requests and database searches), and publication output for 81 doctoral granting universities in the United States were collected to explore potential relationships between research productivity, collection use, library budgets, collection size, and research expenditures using partial correlations. A hierarchical multiple regression was also used to ascertain the significance of certain predictors of research productivity (publications).

Results – A correlation existed between the number of publications (research productivity) and library expenditures (total library expenditures, total library material expenditures, and ongoing library resource expenditures), collection size (volumes, titles, and ebooks), use of collection (full-text article requests and total number of references in the articles), and research and development expenditures. Another key finding from the hierarchical multiple regression analysis showed that full-text article requests were the best predictor of research productivity, which uniquely explained 10.2% of the variation in publication.

Conclusion – The primary findings were that full-text article requests, followed by library material expenditures and research expenditures, were found to be the best predictor of research productivity as measured by articles published.

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Evidence Based Library and Information Practice

Research Article

Research Productivity and Its Relationship to Library Collections

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Abstract

Objective – The purpose of this study was to explore in the current academic library environment, the relationship between library collections data (collections' size, expenditures, and usage) and faculty productivity (scholarly output). The researchers also examined the degree to which new and existing library metrics predict faculty productivity.

Methods – Demographic data (e.g., faculty size, student size, research and development expenditures), library budget data (e.g., collection expenditures), collection use data (e.g., full-text article requests and database searches), and publication output for 81 doctoral granting universities in the United States were collected to explore potential relationships between research productivity, collection use, library budgets, collection size, and research expenditures using partial correlations. A hierarchical multiple regression was also used to ascertain the significance of certain predictors of research productivity (publications).

Results – A correlation existed between the number of publications (research productivity) and library expenditures (total library expenditures, total library material expenditures, and ongoing library resource expenditures), collection size (volumes, titles, and ebooks), use of collection (full-text article requests and total number of references in the articles), and research and development expenditures. Another key finding from the hierarchical multiple regression analysis showed that full-text article requests were the best predictor of research productivity, which uniquely explained 10.2% of the variation in publication.

Conclusion – The primary findings were that full-text article requests, followed by library material expenditures and research expenditures, were found to be the best predictor of research productivity as measured by articles published.

Introduction

In this study, the authors examined the relationship between academic library collections and research output at research intensive doctoral granting academic institutions. With shrinking library budgets and increasing costs for the online resources licensed or purchased by libraries, it is becoming more challenging to provide access to the information resources needed by researchers at academic institutions. Librarians are increasingly spending more time trying to determine how best to spend their limited budgets as they consider what new resources to purchase, what resources to maintain, and what resources to cancel. Academic libraries face challenges demonstrating the need for appropriate funding to continue to meet the information needs of researchers.

Academic libraries have evolved greatly since the migration to electronics resources (e.g., online journals, databases). Many libraries have increased the number of journal titles available to users through the licensing of "big deal" journal packages (packages are selected for needed journal titles but also typically include journal titles that a library would not necessarily choose). Journal collections have moved from a print to an online format and Abstracting and Indexing (A&I) tools for finding journal literature, once found only in print, have also moved online and increased in numbers. As a result, the way in

which researchers seek and obtain information from the library has changed dramatically.

With resources online, new sources of usage data are also available. For example, libraries can obtain data on how many full-text article downloads occur and how many database searches are run, a direct reflection of patron activities. In databases such as Scopus and Web of Science, data can be more readily obtained, compared to a print-based environment, on how many articles were published by an institution, how many references were included in those articles, and how many times those articles were cited. How libraries are asked to report collections and collections usage has also changed. Between 2011 and 2012, the Association of Research Libraries (ARL) ceased asking for data on certain metrics (monographs purchases, total current serials, expenditures for monographs, expenditures for serials), and began asking for data on such metrics as number of electronic books (ebooks), ongoing resource purchases, collection support, number of successful full-text article requests (journals), and number of regular searches (databases) for their ARL Annual Library Statistics. One question that arises is whether any of the new metrics available can illustrate a relationship between faculty productivity and the use or availability of library resources.

The purpose of this study was to explore what new and existing library metrics demonstrate a relationship with faculty productivity. This study explored the relationship between research productivity, as defined by the number of journal articles published by an institution, and (a) the size of library collection budgets, (b) the size of the collection (e.g., number of titles held, number of volumes held), (c) use of the collection (number of successful full-text article requests, number of database searches, references included in publications), and (d) other library and institutional expenditures.

Literature Review

Several researchers have quantitatively examined the relationship between research productivity and various metrics reflecting resources available to an institution, including library collections. Rushton and Meltzer (1981) studied 169 leading universities from the United States, the UK, and Canada, exploring the relationship between total publications and total faculty size, total student size, revenue, number of volumes in the library, and number of current library periodical subscriptions. They found that when universities were high on one measure, they were high on others as well. Specific to the American universities, there was a positive correlation between the number of volumes in the library and total publications and the number of current journal subscriptions and total publications. Revenue was found to be the principal factor that could predict the result of the other variables being examined, concluding that "the quality and wealth of a university are clearly related" (Rushton & Meltzer, 1981, p. 301). Dunbar and Lewis (1998) also explored quantitative factors influencing and contributing to research performance at doctoral institutions in the United States, using data from the 1993 National Research Council study. They explored 30 doctoral programs in the biological sciences, physical sciences and mathematics, social and behavioral sciences, and engineering from top Carnegie classification research universities. They found programs with more faculty were more productive, although when some programs got beyond a certain size, productivity declined. In addition, more full professors and more financial research support within a department also resulted in increased research productivity. With respect to the library, except for engineering and social sciences, departmental research productivity was found to have a significant positive relationship with library expenditures. In a more recent study, Rawls (2015) used ARL

Annual Library Statistics prior to the 2011/2012 change of variables. Rawls utilized ARL library expenditure variables and other data including total number of faculty publications, faculty size, research expenditures, and grant awards from a five-year period (2005–2009) to explore the relationship between faculty research productivity and library investment. Rawls found that research productivity was positively correlated with library investment. More specifically, electronic library resource expenditures correlated positively with an increase in productivity.

Surveys of academic researchers have also been conducted to examine researchers' use of the library and their information seeking behavior, and to assess the value of the library's collection as it relates to their research and other academic activities. Results of a survey of randomly selected faculty at four large state universities in Texas found only 2.6% reported that the library resources were not important in their research efforts and over 68% indicated library resources were of "considerable" or "very high" importance to their research (Cluff & Murrah, 1987). The findings also suggested that the larger the university, the more likely faculty would report dependence on the library for research purposes. Faculty members from seven universities (five U.S. and two Australian) were surveyed in 2004/2005 about their scholarly article reading habits (Tenopir, King, Spencer, & Wu, 2009). Faculty were asked to recall how many scholarly articles they had read in the past 30 days and the source of the articles they read. Faculty members in more research-oriented positions reported reading more for research purposes (62%) compared to the amount reported by teaching-oriented faculty (49%). Also, the more a faculty member published, the greater they reported their reading was for research purposes. Faculty members in research-oriented positions also reported that 58% of their reading materials were provided by the library, in contrast to faculty in teaching-oriented positions, who reported that 37.8% of their reading materials were provided by the library. A more recent survey of provosts assessed their perceived value of the academic library (Murray & Ireland, 2018). Respondents from universities falling under the Carnegie Classification as "Research Very High" institutions perceived the academic library as very involved (84.21%), somewhat involved (10.53%), or marginally involved (5.26%) in faculty research productivity.

Longitudinal survey data collected over a 30-year period has also provided insight toward researcher behavior over time and their use of the library. Tenopir, King, Edwards, and Wu (2009) concluded that faculty are reading more articles than they had in the past and that faculty were relying more on the library to provide access to articles rather than the personal subscriptions they had relied upon in the past. The availability of online articles resulted in faculty using more methods to identify the articles to read, including browsing the table of contents of online journals and searching for articles using Internet search engines, full-text databases, and online A&I databases, compared to how they searched for articles in the print environment.

The value of using literature in grant proposals, grant reports, and articles has also been studied, in part to examine the impact of increased access to journals available in the electronic collections of academic libraries. A 2009 online survey, sent to faculty at seven different institutions in seven different countries, examined faculty citing behavior (Tenopir et al., 2011). On average, 90% of the respondents indicated that citations were "important", "very important" or "essential" as part of the grant writing process. Approximately 69.6% of respondents reported citing 10 or more references in grant proposals, and 82.2% of respondents reported citing at least one reference in final grant reports. Seventy-five percent reported accessing more than half of the articles through their library's electronic collection, and over 50% reported accessing 75% of the articles from the library's electronic collection. Using a Return on Investment (ROI) model, Kaufman (2008) explored the connection between use and

investment in the library and funded grant proposals. Grant applicants at University of Illinois at Urbana-Champaign were surveyed regarding the role of the library in their research and grant processes. Ninety-five percent of respondents indicated that references were important for obtaining grants, and approximately 75% of respondents noted that 75% of the references used in grant proposals were provided through the library. The resulting ROI calculation found that for every dollar invested in the library, there was a return on investment of $4.38 in grant funding (Kaufman, 2008).

Using various methodologies, the studies noted above illustrated that academic library collections, such as journal articles, books, and databases, are important sources of information for use in research, teaching, and grant proposals. However, while surveys assessing information seeking behavior, library collections use, and the value of the library provide valuable insight and allow for flexibility in terms of the questions asked, they rely on memory and perception to provide the data from which the findings are drawn. While researchers in older studies have shown a relationship between research productivity and collection size (Rushton & Meltzer, 1981) or collection expenditures (Dundar & Lewis, 1998; Rawls, 2015), these studies were based on data gathered prior to or during the transition of the library from a print based to an online environment. Academic library collections have changed, user information seeking behavior has changed, and the measures for tracking library usage have also changed and evolved. Newer literature exploring quantitative data in relation to research productivity is limited. Exploring older metrics in the present library environment and exploring newer library metrics, such as collections usage data, in relation to research productivity can contribute to validating the impact academic libraries have on scholarly output. This study will explore faculty productivity and its relationship with library resource usage, library budgets, and collection size. Because past researchers have noted the relationship with faculty productivity and overall institutional support (Rushton & Meltzer, 1981), research support (Dunbar & Lewis, 1998), and library expenditures (Dunbar and Lewis, 1998; Rawls, 2015), we also explore overall research expenditures with respect to faculty productivity and library expenditures.

Aims

This study aimed to examine the relationship between library collections, budgets, and use and research productivity among academic research institutions in the United States that were both members of the ARL and designated as doctoral universities according to the Carnegie Classification of Institutions of Higher Education.

Methods

To identify the list of institutions to include in the study, the list of ARL institutions was downloaded from the ARL website (Association of Research Libraries, 2016) and the list of universities designated as Very High Research Activity or High Research Activity Doctoral Institutions was downloaded from the Carnegie Classification of Institutions of Higher Education website using the basic classification feature to select the Doctoral Universities (Carnegie Classifications, 2016). This data was entered into a single spreadsheet, where a total of 104 academic research institutions were identified for inclusion in the study.

Data regarding library collection size, budget, and use, research productivity (journal publications), and institutional demographic data were also obtained from various resources and entered into the spreadsheet. Because ARL surveys its ARL member libraries on an annual basis related to multiple data points including staffing collections, expenditures, services, and usage, the ARL Annual Library Statistics was an ideal resource for library related data. Scopus, an online indexing and abstracting database produced by Elsevier, was selected to provide the number of

publications for each institution included in the study. Scopus has been reported to be the most comprehensive article-level index of scholarly articles (Laakso & Bjork, 2012). In order to have a metric for the overall expenditures of an institution, the Research and Development Expenditures from the Higher Education Research Development (HERD) survey was selected, as this is the primary source of information on research and development expenditures at U.S. universities (National Science Foundation, 2017). Further details on how the data were collected is provided below.

Data Collection

ARL Annual Library Statistics Data

Data related to library collections size, use, expenditures, and additional institutional demographic information reported by each institution to ARL Statistics (https://www.arlstatistics.org) was obtained for 2015, 2016, and 2017. Because data and resources might fluctuate somewhat from year to year, instead of examining a single year of data, the last three available years of data were collected. The three years of data were then averaged for each variable to obtain the final data used in the analyses. The variables collected included:

- Ongoing library resources expenditures – total amount spent on subscriptions and annual license fees (online and print serials, online indexes and abstract resources, et al.)
- Total materials expenditures – includes one-time purchases (non-subscription, one-time purchases such as books, software, backfiles, et al.), ongoing library resources expenditures, and other collections support
- Total library expenditures – the total expenditure of all library funds (includes total library materials, total salaries and wages, and other operating expenditures but excludes fringe benefits)
- Ebooks – total number of ebooks available in the collection
- Volumes held – total number of print only items and ebooks
- Titles held – total number of print and electronic serials, monographs, manuscripts, dissertations and theses, archives, microforms, and computer files held in the collection (excludes duplicates)
- Number of successful full-text article requests for journal articles (defined by the COUNTER Code of Practice – www.projectcounter.org)
- Number of regular searches – number of database searches as defined by the COUNTER Code of Practice – www.projectcounter.org)
- Total full-time students (undergraduates and graduates) and total faculty (full-time members of the instruction/research staff)
- Size of students and faculty were included as control variables that represents the institutional size, which may have an impact on research productivity and use of the resources.

Research Productivity Data

Research productivity in this study is referring to the number of journal publications produced by an institution. In August of 2018, we searched the *Scopus* database using the affiliation field and entering the name of each institution included in the study. Abbreviations from a sample of institutions were tested to ensure they would link to the full names of the institutions. If multiple variations of the same institution were displayed in the results of the institutional names, all relevant versions were selected to provide the total number of publications. The search results were limited by "Document type" to articles or review, to retrieve the number of journal article publications published in 2016, 2017, and 2018 at each institution.

References Data

As another measure of potential use of library collections, the total number of references used in the publications studied were also obtained. For each list of institutional publications presented in Scopus, the number of total references included in these publications were obtained by clicking all the publications in a list and selecting "View References." The Scopus system limits reference lists to a maximum of 2000. When institutions had more than 2000 publications, results were grouped using some of the limiting features of the system to obtain numbers for the full set. The total number of references included in the institutional publications was also entered into the spreadsheet. Because the number of references was not displayed per article but per set of articles, it is possible an article was cited multiple times, but would only be displayed once in the list of references. Thus, this data may underreport the number of references included in the studied articles when references to articles were cited by multiple articles within a set of publications.

As with other data included in the study, the average number of publications and the average number of total references were obtained by averaging the three years of data. Because of the time delay between writing a manuscript and it being published, it is likely that much of the literature searching and use of the library is done in the year previous to an article being published. Therefore, ARL data from 2015 to 2017 was collected while publication data was obtained from 2016 to 2018 to better approximate and coincide with potential library usage. For example, while it is not a perfect assumption, given the time to write and publish an article, if an article was published in 2018, there is logic in assuming that in many cases the literature review and use of library collections occurred in 2017, or potentially earlier.

Since the total number of references included in all publications at an institution is impacted by the number of articles written, the average number of references per article was obtained by dividing the total number of references included in the publications (all three years) by the total number of publications (all three years).

Research Expenditures

Research and Development Expenditures for each institution for 2015-2017 were obtained from the HERD, where universities report research expenditure and sources of revenue (National Science Foundation, 2017). The data were entered into the spreadsheet and the average over the three years was calculated.

It was not always possible to match up institutional data from the four data sources. For example, some universities have multiple locations and it was not always clear if data sets covered all locations or a specific location. In other situations, it appeared that medical colleges' libraries often had separate budgets, and data might not have included data from the full institution. In other cases, full data was not available for all the years. In situations where the limits of the data were not clear or if data were missing (except for collections use data), the institution was dropped from the study. As a result, 81 institutions remained in the study. Table 1 summarizes the average numbers of all the variables used in the analysis to demonstrate the overall data patterns of a total of 81 ARL member libraries.

Data Analysis and Research Questions

All data were analyzed using SPSS 26. Multiple statistical tests were employed to examine direct and indirect impacts of the library on faculty productivity. The analyses included partial correlations and hierarchical multiple regression. Partial correlation is a measure of strength and direction of the linear relationship between two variables, while controlling for the effect of one or more variables (covariates). Partial correlation allows finding a unique relationship between two variables while eliminating the influence of a third

Table 1
Descriptive Statistics for All Variables (Institution Size and Expenditures, Library Budgets, Collection Size, Collection Use, and Research Productivity)

	N	**Minimum**	**Maximum**	***M***	***SD***
Institution Demographics					
Total full-time students	81	6,253	69,939	25,285	11,674
Total faculty	81	659	4,481	1,792	821
Institutional Expenditures					
HERD	81	38,244	71,840,290	1,381,179	7,933,921
Library Budgets					
Total library expenditures	81	10,349,703	116,533,712	31,751,291	17,713,781
Total library materials expenditures	81	4,606,644	47,791,377	14,339,988	7,292,618
Ongoing resource expenditures	80	3,865,090	20,754,521	10,230,944	3,494,542
Size of Library Collections					
Volumes held	81	1,941,116	20,837,233	5,849,571	3,433,706
Titles held	81	970,064	14,863,477	4,653,645	2,583,329
Ebooks	81	134,801	3,291,347	1,205,576	570,905
Use of the Collection					
Full-text article requests	75	192,686	12,752,344	4,100,529	2,779,468
Regular searches	73	636,732	7,8174,661	9,303,921	12,823,470
Total number of references in the publications	81	20,430	861,817	195,173	131,808
Number of references per article	81	40	51	46	2
Research Productivity					
Total publications	81	458	19,171	4,306	2,976

variable, which may drive the relationship. Hierarchical multiple regression, a form of multiple regression in which independent variables are entered into the regression "in the order specified by the researcher based on the theoretical grounds" (Pallant, 2012, p.149), is used to predict the value of one dependent variable after controlling for another, in this case, for faculty size. As shown in the literature, there are several factors that influence faculty productivity. As part of the institutional factors, faculty size (e.g., Dunbar & Lewis, 1998) and overall wealth (e.g., Rushton & Melzer, 1981) were found to be linked to research productivity. Among library factors, library expenditure is well known to correlate with publications (Dunbar & Lewis, 1998; Rawls, 2015). However, library expenditures is a broad category and contains expenses beyond just materials (operating budgets, salaries). To compare our findings to past studies, we also compared library expenditures data to productivity. In addition, we explored narrower categories of library expenditures including the overall materials budgets and ongoing library

Table 2
Statistical Tests

Statistical Test	**Variables**	**Research Question**
Partial Correlations		
Collection use and research productivity	• Successful full-text article requests, number of regular database searches, number of references included in publications, average number of references per publication (IVs) • Total number of articles published (DV) • Total number of full-time students and faculty, Research and development expenditures (HERD), Total materials expenditures (Covariates)	Holding number of full-time students, faculty, total materials expenditures, and research and development expenditures constant, what is the relationship between use of the collection and total number of articles published in an institution?
Library budgets and research productivity	• Total materials expenditures; total library expenditures; ongoing resource expenditures (IVs) • Total number of articles published (DV) • Total number of full-time students and faculty, Research and development expenditures (Covariates)	Holding number of full-time students, faculty and research and development expenditures constant, what is the relationship between library budgets and total number of articles published in an institution?
Collection size and research productivity	• Volumes held, titles held; ebooks (IVs) • Total number of articles published (DV) • Total number of full-time students and faculty, Research and development expenditures (Covariates)	Holding number of full-time students, faculty, and research and development expenditures constant, what is the relationship between library collection size and total number of articles published in an institution?
Research expenditures and research productivity	• Research and Development expenditures (IV) • Total number of articles published (DV) • Total number of full-time students and faculty, Total library expenditures, Total materials expenditures, Ongoing resource expenditure (Covariates)	Holding number of full-time students, faculty, total library expenditures, total materials expenditures, and ongoing resource expenditures constant, what is the relationship between Research and Development expenditures and total number of articles published in an institution?
Library budgets and research expenditures	• Total library expenditures, Total materials expenditures, Ongoing resource expenditure (IVs) • Research and Development	Holding number of full-time students and faculty, what is the relationship between Research and Development expenditures

	expenditures (HERD) (DV) • Total number of full-time students and faculty (Covariates)	and Library expenditures?
Hierarchical Multiple Regression		
	• Total number of faculty, Research and development expenditures, Library material expenditure and Full-text article requests (IVs) • Total number of publications from 2016 to 2018 (DV)	Controlling for the possible effect of total number of faculty, is the set of variables (research and development expenditures, library materials expenditures and full-text article requests) still able to predict a significant amount of the variance in total number of publications?

resource expenditures. Moreover, our current study expanded on the previous literature by examining whether factors related to library resource use (full-text article requests, database searches) contribute to faculty productivity.

Table 2 outlines which tests were used to address the research questions. Before running the statistical analyses, tests of assumptions were run to confirm it was appropriate to run the proposed analysis including the possibility of multicollinearity using cut-off points for tolerance value of less than .10 or VIF value of above 10 guided by Pallant (2010). There is no violation of the multicollinearity assumption.

Results

Partial Correlations Among Collection Use, Budgets, Collections, Research Expenditures, and Research Productivity

Results from partial correlations are displayed in Table 3. As the number of faculty and students, amount of research and development expenditures, and library materials expenditures were likely to influence the number of publications and use of the collection, their contribution to the relationship was eliminated through partial correlation. The first partial correlation explored collection use and research productivity. It revealed a moderate positive relationship between successful full-text article requests and the number of articles published at an institution, r (69) = .504, p < .001, suggesting higher use of the library (successful full-text article requests) is associated with research productivity. Not surprisingly, there was a strong positive correlation between the total number of references (average over 3 years) included in the publications and the total number of publications per institution, controlling for the number of full-time students and faculty, total library materials expenditures, and research and development expenditures, r (75) = .994, p < .001. One would expect as the number of total publications increased, so would the number of references included in those publications. However, when the average number of references per article was compared to the total number of publications, there was a weak negative correlation, r (75) = -.279, p = .014. This suggests the more references used, the fewer publications or, the more articles published, fewer references will be included. There was not a significant correlation found between the number of publications and the number of regular database searches, r (67) = -.200, p = .100.

The second set of partial correlation analyses explored library expenditures and research productivity. These analyses demonstrated a

Table 3
Partial Correlations Among Collection Use, Library Budgets, Collection Size, Research Productivity, and Research Expenditures[a]

	df	***r***	***p***
Collection Use and Research Productivity			
Article requests	69	.504	< .001*
Database searches	67	-.200	.100
References included in publication	75	.994	< .001*
Average number of references per publication	75	-.279	.014 *
Library Budgets and Research Productivity			
Ongoing resources expenditures	75	.551	< .001*
Materials expenditures	76	.661	< .001*
Library expenditures	76	.748	< .001*
Collection Size and Research Productivity			
Volumes held	76	.708	< .001*
Titles held	76	.646	< .001*
Ebooks	76	.282	.012*
Research Expenditures and Research Productivity			
Research and development expenditures	73	.323	.005*
Library Budgets and Research Expenditures			
Ongoing resource expenditures	76	.294	.009*
Material expenditures	77	.135	.236
Library expenditures	77	.126	.269

[a] Strength of correlations as indicated by Dancey and Reidy (2011) for absolute value of r – $|.10| < r < |.30|$ weak, $|.40| < r < |.60|$ moderate, $|.70| < r < |.90|$ strong
* Indicates significant p value.

strong positive relationship between articles published at an institution and total library materials expenditures (r (76) =.661, p < .001) and total library expenditures (r (76) =.748, p < .001), but only a moderate positive correlation between articles published at an institution and ongoing resource expenditures (r (75) =.551, p < .001). The higher the expenditures allocated for a library, the higher the numbers of publications were produced at an institution. This demonstrates a significant relationship between library expenditures and research productivity.

The partial correlations exploring collection size and research productivity suggested that articles published at an institution correlated positively with the size of library collections (volumes held, r (76) = .708, p < .001; titles held, r (76) = .646, p < .001; and ebooks, r (76) = .282, p = .012). This means the greater the size of a library's collection (volumes, titles and ebooks), the greater the number of publications produced at the institution. However, the strength of correlations for ebooks were weak r < .30, as Dancey and Reidy (2011) previously found.

The partial correlation revealed a positive moderate relationship between research development expenditures and the number of articles published at an institution, controlling for the number of full time students and faculty, total library expenditures, total library materials expenditures, and ongoing resource expenditures,

r (73) = .323, p = .005, suggesting the higher the research and development expenditures obtained by an institution, the higher the number of publications produced at the institution.

The last partial correlation suggested that the amount of research and development expenditures correlated positively with ongoing resource expenditures (r (76) = .294, p = .009); however, the strength of the correlation is weak r < .30. This means the greater the amount of ongoing resource expenditures, the greater the amount of research and development expenditures. There was not a significant correlation found between other library expenditures and the amount of research and development expenditures (total materials expenditures, r (77) = .135, p = .236; total library expenditures, r (77) = .126, p = .269).

Predicting Research Productivity (Publications)

Next, a four-stage hierarchical multiple regression was conducted to examine the degree to which research and development expenditures and the library related collection measures (library materials expenditures and full-text article requests) affected research productivity, after controlling for the influence of the institutional size (total number of faculty). The sample size of 81 was considered adequate given four independent variables subjected to the analysis: a ratio of 15 cases for every independent variable (Tabachnick & Fidell, 2001). Total number of faculty was entered at stage one of the regression to control for faculty size. The research and development expenditures variable was included at stage two; the library materials expenditures variable was entered at stage three, and full-text article requests was entered at stage four. Institutional funding (research and development expenditures), library related variables (i.e., library materials expenditures and full-text article requests) were entered in this order because research and development expenditures represents the institutional funding size, library materials expenditures represents library collections, and library usage (full-text article requests) is followed by it. Library collection size was not included in this analysis because collection size is highly correlated with library materials expenditures. The reason for choosing full-text article requests, rather than the number of regular database searches at stage four, is that this variable has a higher correlation with publications in the partial correlation described above. We did not use total library expenditures as the variable here because it contains expenditures beyond the collection, such as salaries and operational expenses. We wanted to explore the unique contribution of the collections expenditures, as reflected through the use of materials expenditures.

Table 4 indicates the significance of each of the four ANOVA models. While all four models were significant at p < .001, the F value was largest for Model 4 with four predictors (total number of faculty, research and development expenditures, library materials expenditures, and full-text article requests), meaning that Model 4 as a whole is the most significant (F (4, 70) = 45.932, p <.001) as a predictive model.

The hierarchical multiple regression showed that in Model 1, the total number of faculty contributed significantly to the regression model, F (1,73) = 23.063, p < .001 and accounted for 24% of the variation in publications (Table 4). In Model 2, research and development expenditures explained an additional 9.8% of the variation in publications, after controlling for total number of faculty; this change in R^2 was significant, F change (1,72) = 10.676, p = .002. After introducing library materials expenditures in Model 3, the total variance explained by the model as a whole (which includes faculty, research and development expenditures and library materials expenditures) was 62.2%, F (3,71) =38.911, p < .001. The library materials expenditures explained an additional 28.4% of the variance in publications, after controlling for total number of faculty and research and development expenditures. The change in R^2 was highly significant, F change (1,71) = 53.239, p < .001. This result clearly showed

Table 4
ANOVA Results of the Four Model-Hierarchical Regression Analysis[a]

		Sum of Squares	**df**	**Mean square**	***F***
Model 1[b]	Regression	164658876.662	1	164658876.662	23.063*
	Residual	521175432.352	73	7139389.484	
	Total	685834309.014	74		
Model 2[c]	Regression	231958134.313	2	115979067.157	18.398*
	Residual	453876174.701	72	6303835.76	
	Total	685834309.014	74		
Model 3[d]	Regression	426452545.391	3	142150848.464	38.911*
	Residual	259381763.622	71	3653264.276	
	Total	685834309.014	74		
Model 4[e]	Regression	496623237.92	4	124155809.48	45.932*
	Residual	189211071.094	70	2703015.301	
	Total	685834309.014	74		

[a] Dependent variable: total number of publications
[b] Predictors: total number of faculty
[c] Predictors: total number of faculty, research and development expenditures
[d] Predictors: total number of faculty, research and development expenditures, library materials expenditures
[e] Predictors: total number of faculty, research and development expenditures, library materials expenditures, full-text article requests
* Indicates p is significant at < .001.

Table 5
Summary of Hierarchical Regression Analysis for Variables Predicting Publications[a]

	β	***t***	R^2	ΔR^2	***F***	ΔF
Model 1			.240	.240	23.063***	23.063***
Total number of faculty	.490	4.802***				
Model 2			.338	.098	18.398***	10.676**
Total number of faculty	.506	5.269***				
HERD	.314	3.267**				
Model 3			.622	.284	38.911***	53.239***
Total number of faculty	.173	2.377*				
HERD	.227	3.514**				
Library materials expenditures	.595	7.296***				
Model 4			.724	.102	45.932***	25.960**
Total number of faculty	.052	.636				
HERD	.150	2.284*				
Library materials expenditures	.341	3.965***				
Full-text article requests	.509	5.095***				

[a] Dependent variable: Total number of publications.
* p < .05. ** p < .01. *** p < .001.

that library materials expenditures contributed significantly to the total number of publications. Finally, including full-text article requests in the fourth and final model explained an additional 10.2% of the variation in publications, after controlling for total number of faculty, research and development expenditures, and library materials expenditures. This change in R^2 was also significant, F change (1,70) = 25.960, p = .001, indicating that full-text article requests has a significant effect on the publications. When all four independent variables were included in stage four of the regression model, the total number of faculty was not a significant predictor of publications. As shown in Table 5, the best predictor of publications was full-text downloads (β =.509), which uniquely explained 10.2% of the variation in publications. In order of the next important predictors of publications they were library materials expenditures (β =.341) and research and development expenditures (β =.150). Together the four independent variables accounted for 72.4% of the variance in publications.

Discussion

The purpose of this study was to obtain information concerning the relationship between the use of library collections and research productivity in the electronic era. The findings illustrated the strength of this relationship and document the contributions that today's academic library has on an institution's research success. Because previous literature exploring quantitative library metrics with research productivity is limited and older, this study also bridges a gap.

Like previous work (Rushton & Melzer, 1981), this study found a correlation between research productivity and library expenditures, collections held, and research and development expenditures. As Rushton and Melzer concluded, the overall wealth of an institution likely contributes to faculty productivity because a strong infrastructure of support is likely to be in place. More research is needed to better understand and to uncover underlying factors. Similar to Rawls' (2015) exploration of the ARL data from 2005 to 2009, this study of 2015 to 2018 data also found productivity was positively correlated with library expenditures. We also found that total materials expenditures and ongoing library resource expenditures were also correlated, but not as strongly as total library expenditures. Distinct from studies of the past, this study examined usage data and found a more direct link between use of the collection (full-text article requests) and research productivity. The greater the research productivity (journal article publications), the greater the use of the library's collection, as demonstrated through full-text article requests.

Based on the findings from the partial correlations and literature review, we further examined if a set of variables (research and development expenditures, library materials expenditures, and full-text article requests) were still able to predict a significant amount of the variance in total number of publications after controlling for the possible effect of total number of faculty. The primary findings from the hierarchical multiple regression analysis was that full-text article requests were found to be the strongest predictor of research productivity as measured by articles published, followed by the library material expenditures and research expenditures. Even when controlling for the total number of the faculty, research expenditures, and library materials expenditures, full-text article requests uniquely explained 10.2% of the variation in publications. These findings provide strong evidence that funding libraries supports faculty research success. The findings demonstrated not just that an investment in library collections correlated with productivity, but that the use of the library collections positively contributed to faculty productivity. Given the cyclical nature of research, faculty productivity likely leads to further faculty success, through additional research development and expenditures. Libraries can use this information to communicate the library's impact on faculty productivity with various stakeholders. Libraries should also explore their faculty's research

agendas and the use of the journal collection through full-text article requests, to assist with future collection development decisions so they are in line with the needs of the faculty. Examining both existing metrics (e.g., collection size or collection expenditures) and new metrics (e.g., the use of the collection) in the current study expands on the existing literature and confirms that the use of library collections has a great impact on research productivity.

One of the unexpected findings of this study is that the number of average references used per publication decreased the more productive an institution was. One speculation for this is that the more productive faculty are, the less likely they may be to search broadly for articles. It could also be that as experts in their field, they are able to be more selective in the publications that they choose to cite to address their findings. Alternatively, it might be the case that as productivity increases, the articles produced are more narrowly focused or cutting edge, and fewer relevant resources are available for citing. Further exploration at the author level is needed to understand this finding.

Limitations

There were some limitations to the data collected. In this study, we largely explored research productivity as it related to journal articles, and library usage as it related to journal article usage (database searches, full-text article requests, and number of references in journal articles). Therefore, disciplines that do not produce journal articles or are not reliant upon them for research are excluded from this study. Although Scopus is the most comprehensive journal literature database, it does not index all journals, nor books or book chapters. Thus, the publication and reference data obtained from Scopus was limited to journal publications indexed in Scopus. The above-mentioned factors tend to bias the data toward those disciplines (e.g., STEM, social sciences) whose research is reported primarily through the journal literature. In addition, it was not possible to limit the examination of the data collected in this study to specific disciplines. For example, ARL Annual Library Statistics are reported in aggregate for each academic institution, although a broad category of health sciences is available. With respect to disciplines and publications, only the institutional affiliation is indexed using standardized terminology within the Scopus database, thus making it difficult to retrieve comprehensive publication data from a college or department. This means the findings of this study will apply broadly to institutions but will not provide insight into correlations or relationships within specific disciplines.

The "number of full-text article requests" and the "number of regular searches" were obtained from vendors that provide "COUNTER" statistics. COUNTER statistics were developed to provide consistent and credible data regarding the usage of databases and journals. However, not all vendors provide this data, so the numbers provided to ARL from each institution were likely not complete. This study was also reliant upon the accuracy of the reported survey data collected and used in the study (ARL Annual Library Statistics, HERD); while institutions attempt to report the most accurate information, there is always the potential for error or incomplete data reporting.

Conclusion

As found in past studies, research productivity correlated positively with library expenditures. We also found that the use of the collection had a relationship with research productivity. Even more important, full-text article downloads uniquely explained approximately 10% of variation in research productivity, over and above other factors including research and development expenditures and library expenditures. Full-text article downloads were a better predictor of research productivity than research and development expenditures or library expenditures. This finding suggests that the use of collections has more impact on the articles published than the total collections dollars libraries spend. Collections developed to fit with

the current research agendas of faculty may impact their productivity. This finding may support library decisions surrounding expenditures and future selections of resources related to research support. This may also be important information for academic libraries at other Carnegie levels that are building support for their research programs.

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