Faculty Publication Patterns over 25 Years at a Large Public University: Correlations with Literature Use

Sandra L. De Groote, Jung Mi Scoulas, Paula R. Dempsey, and Felicia Barrett

As libraries succeed in making journal literature seamlessly available through internet searches, faculty may be less aware of the library's role in their intellectual output. This research project explores how publication patterns of faculty at a public research university changed over time in relation to collection size, literature use, productivity, co-authorship, grant funding, and faculty demographics. Correlations among data points demonstrate how the availability and use of the literature is associated with faculty productivity. Use of the literature varies by discipline, co-authorship, and grant funding.

Introduction

The University Library at the University of Illinois Chicago (UIC), like all academic libraries, develops collections to enable teaching, learning, and research. Because we are accountable to our users and want to ensure that our investment in resources is utilized, we sought evidence that the resources provided by the library for research purposes demonstrate use and have an impact in terms of productivity and impact. As noted in the Association of Research Libraries (ARL) Research Library Impact Framework, it is important to explore how the library may influence the lifecycle of research and scholarship by exploring how it enables, fosters, and promotes relevant and unique research, increases productivity, and enables research collaborations.[1] Academic libraries are often challenged to demonstrate the need for greater funding for resources, particularly when universities are facing budget challenges. The challenges are compounded because library impact on faculty research productivity and impact often cannot be directly measured. Online databases and journals dominate the information landscape of most disciplines, and yet there are no recent in-depth studies exploring the impact or use

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of these online journals in faculty publications. This research seeks to demonstrate how the availability and use of literature influences faculty productivity.

Literature Review

The early 2000s saw a major shift in the journal collections of academic libraries. Libraries gained access to greater numbers of journals through "Big Deal" journal licenses.[2] In addition to the increase in journals available to researchers, the method of accessing journals was transforming. No longer did users have to enter the physical library to access journals, but instead they could do so remotely online in their home or office. The availability of online journals in turn reduced the use of the print collections. In one study examining the use of references in health sciences faculty journal articles, the use of journals only available in print decreased in several disciplines (dentistry and nursing), while the use of journals available in an online format increased.[3] Eventually, libraries began to reduce the print journal collections in favor of online journal collections.[4]

In addition to the online journals, the number of indexing and abstracting tools available remotely was also increasing. As databases and journals moved online, the number of references included in journal articles increased.[5] Through interviews with faculty, a study by Martin Brennan, et al. reported that online journals and databases have allowed faculty easier access to the literature and a greater number of articles.[6]

Relationships between the behaviors of researchers and library use have also been reported. Carol Tenopir, et al., asked faculty to recall how many scholarly articles they had read in the past 30 days and the sources of the articles they read. Faculty members in research-oriented positions reported reading articles more for research purposes (62%) compared to teaching-oriented faculty (49%).[7] Faculty members engaged in research also reported a greater amount of their reading materials (58%) were from the library compared to teaching-oriented faculty (38%). In a survey of health sciences faculty, 91 percent reported their primary reason for searching for articles was for research purposes, followed by keeping current (63.8%), preparing instruction (57.7%), and caring for patients (37.2%).[8] In a later study by Tenopir, et al., most articles read were from online journals, which were primarily accessed through library or departmental descriptions.[9] A 2019 study found researchers read about 20 articles a month, primarily related to research purposes.[10]

Libraries have also attempted to demonstrate the impact of the library on research. In 1981, J. Phillipe Rushton and Sari Meltzer found a positive correlation between the number of current journal subscriptions (among other variables) and total publications, and concluded that revenue was the primary factor that could predict the result of other examined variables, including productivity.[11] More than 30 years later, Michael Rawls used ARL library expenditure data and other metrics including faculty publications and research expenditures to conclude that research productivity was positively correlated with electronic library resource expenditures.[12] A more recent study compared ARL expenditures data, grant expenditures, and faculty articles in journal publications.[13] The authors found a correlation between the number of research publications produced at an institution and library expenditures, collection size, and the use of collections including full-text article requests and total number of references included in articles. This study also found a weak but negative correlation between the number of publications at an institution and the number of references included in the publications, suggesting the more articles published, the fewer references that were included in publications.

As the above literature demonstrates, multiple changes have impacted researchers and the academic library. Changes include increased journal holdings, move to online journals and online databases, increased numbers of databases, access to free databases, remote access to information once only accessible within the library, and computer technology. While the number of journals available to researchers through the libraries increased over the years, so did the ease at which articles could be accessed remotely online. The causal logic connecting availability of resources and their use in research and scholarship also leaves room for additional variables that are not accounted for, which may result in a hidden effect on those relationships. It is likely that several of these changes influenced use of the literature and faculty productivity. While it may not be possible to identify or control for all these potential variables, previous studies have shown that several additional variables are known to influence faculty productivity, including grant funding and co-authorship.

Many grant recipients disseminate research findings and knowledge gained through publications.[14] Most of the studies found in the literature found a positive relationship between grant funding and faculty productivity of scholarly articles. Ashkan Ebadi and Andrea Schiffauerova "confirmed the significant positive impact of funding on the productivity of the researchers."[15] Several other studies also found a positive relationship.[16] Not all evidence suggests that grant funding increases the amount of productivity. Brian Jacob and Lars Lefgren found that receipt of a standard NIH grant has "at most a relatively small effect on the number of publications and citations of the marginal applicants."[17] Studies have also observed that co-authorship is also associated with greater productivity.[18]

Ascertaining the contribution of library collections to intellectual life on campus is crucial for assuring continued funding. Yet no recent study has examined in depth the connection between the availability of online journals and online databases and its influence on literature use (measured by references in publications) and faculty productivity (measured by published articles), and no study has taken a long-term perspective since the dawn of online journals through to the present. This study fills the gap with a 25-year data set from a research university addressing the following research questions:

- In what ways do faculty publication patterns change as library collections change over time?
- To what degree do faculty publication patterns differ by discipline?
- To what degree do faculty publication patterns differ by rank?
- Are there correlations among faculty's literature use and their productivity?
- In what ways do patterns of faculty productivity vary over time?
- In what ways does faculty's use of literature in publications vary over time?
- What other variables (e.g., faculty's demographics, co-authorship, and grant funding) influence faculty productivity?

Methods and Data

Setting

This exploratory study examined factors affecting publication patterns of faculty at a public research university over 25 years. The University of Illinois Chicago is a large urban Research 1 institution with regional health sciences campuses in Peoria, Rockford, and Urbana. The University Library consists of a multi-disciplinary library and a health sciences library in Chicago, and several regional health sciences libraries. During the time period of this study (1995–2019), a smaller science library located on the main campus closed. Between 1995 and 1999 (prior to

the library's licensing of online journals), the UIC Library had approximately 15,948 active print journal subscriptions (all locations). In the late 1990s, the library began to license online journals, starting with a package of 15 biomedical journals in 1998.[19] In 1999, there were 204 online journals and by 2000, the library had more than 3,000 online journals. By 2008, close to 25,000 online journals were available remotely through the UIC library through big deals and as part of licensed databases offering full-text. This means at least 9,000 journals not previously in the collection had become available for UIC students and faculty through online journals. In addition to this, to increase space for users in the library and because the separate science library had been closed, the back files of many journal subscriptions were also licensed or purchased, facilitating online access to older material that had previously only been available in print through the UIC library.

At the time that access to online journals was increasing at UIC, the number of databases was also increasing, which made identifying articles to read and include in publications easier to find, compared to relying on print indexes and abstracts or electronic database that could only be accessed at the physical library.[20] In some cases, the databases also contained the full-text of journal articles, making discovery and access even easier. Databases such as MEDLINE became publicly available through Internet Grateful Med in 1996 and PubMed in 1998, and new multi-disciplinary databases also emerged such as the freely available Google Scholar (2004) and the subscription-based Scopus (available 2004; licensed by UIC in 2012). In addition, open access journals began their launch, which made these scholarly articles available for free to all who had access to the Internet.

Data Collection

To explore the impact of library collections and additional online resources on faculty literature use and productivity, the following information was captured: collection size (measured by journal holdings), literature use (measured by number of references in the publications), grant funding (measured by whether the article was funded), co-authorship size (measured by number of co-authors), faculty productivity (measured by number of publications per faculty member), and faculty demographics (e.g., status and years at the institution). Retrospective journal publication data was collected to determine how publication patterns of faculty have changed over time, as access to journal articles and databases increased. Table 1 provides further details on the study variables, indicators (how variables were measured), and source of the data.

TABLE 1
Study Variables, Indicators, and Data Source

Variables	Indicators	Data Source
Collection size	• Number of journals available to faculty, reported in 5-year time periods	• ARL statistics • Internal collections data
All variables at the author level		
Literature Use	• Number of references included in publications by author in 5-year increments • Average number of references per article by author in 5-year increments • Number of total references used	• Scopus
Productivity	• Number of articles published in 5-year time periods	• Scopus
Co-authorship	• Average number of co-authors per article in 5-year increments	• Scopus

TABLE 1
Study Variables, Indicators, and Data Source

Variables	Indicators	Data Source
Demographics	• Discipline • Rank • Years at UIC • Author ID	• OIR
All variables at the publication article level		
Publication Info	• Journal title; Year of publication; page count	• Scopus
Literature Use	• Number of references in the article	
Co-authorship	• Number of co-authors	
Grant funding	• If article was funded (yes/no)	
Demographics	• Author ID • Discipline	• OIR

Faculty Data

The authors asked the Office of Institutional Research (OIR) for a list of tenure system faculty members who had been at the institution for at least 5 years. The records included faculty discipline (college and department), rank, and number of years at UIC. Several criteria were used to select the list of the faculty. Disciplines included in the study were: applied health sciences, business administration, dentistry, education, engineering, library, medicine, natural sciences, nursing, pharmacy, public health, social sciences (communication, psychology, sociology, gender and women's studies, economics, anthropology, criminology, political science, African American studies, and Latino studies), social work, and urban planning & public affairs. Given that the focus of this study was on active researchers and how their publication patterns had changed over time, some faculty data were excluded from the study. Faculty members in the humanities were excluded from the study because their productivity is more appropriately measured by book publication, rather than journal articles. Faculty who were appointed to UIC after 2015 were also excluded because they did not have five years in which to publish articles. Authors who did not have a consistent publication record (i.e., there were no publications in the last 5 years of the study and thus no longer actively engaged in research) were removed from the study. Faculty who did not have any publications were removed from the study.

Faculty were sorted into sets based on how long they had been at UIC; the authors did not consider any older publications by that author, to avoid confounding with publications written when faculty were at another institution (see Table 2).

TABLE 2
Faculty Productivity Explored Based on Years at UIC

Years at UIC	Cut-off for publications explored
5 years	No older than 2015
10 years	No older than 2010
15 years	No older than 2005
20 years	No older than 2000
25 years	No older than 1995

Faculty Publication Data

Each member of the research team received a list of the faculty members they were assigned. The research team used Scopus to retrieve the publications of each faculty member in the study. To retrieve the data from Scopus, the team member selected the author search tab and

entered the last name and first name of the faculty member. The team member would select the result(s) where the author's name displayed UIC as the affiliation. If more than one result was retrieved for an author by the same name and institution, then all were selected to obtain the full list of faculty publications. On the left side of the screen, the Year facet was used to exclude publications outside of the date range predetermined for the faculty member (Table 2). The Document Type facet was used to limit results to "articles" to eliminate most review articles, editorials, and conference papers. Review articles were excluded as they tend to include more references than research articles.[21] While this method did not completely exclude non-research articles, it did limit their inclusion.

Next, the team member selected all publications in the remaining list and exported the list of articles, including the citation information (authors, title, journal name, volume, issue, pages, DOI) and "funding details." The team member then copied the file contents and pasted them into a master file. An additional column was added to the spreadsheet for an assigned UIC author ID for author being searched, so publications by that author could be counted. To determine whether an article was grant funded, the disclosure made in the Scopus database were utilized. If funding information was provided in the Funding Details output, then the article was coded to be funded. Finally, the team member went back to the results in Scopus to harvest the number of references for each publication, entering the number manually into the spreadsheet. A second spreadsheet was created to summarize the publication data of each author into 5-year intervals. This spreadsheet included: author ID, rank, discipline, total articles in 5-year time periods, average references used in publications in 5-year time periods, average authors included on the authors' publications in 5-year time periods.

Data Analysis

The data in the Excel spreadsheets were entered and coded into SPSS 28. Both Excel and SPSS 28 were used to analyze and visualize the data. Descriptive statistics were employed to describe overall faculty publication patterns and faculty demographics. Correlations were used to examine the relationships between collection size, literature use, co-authorship size and faculty productivity. Partial correlation was used to explore the relationship between the library collection size (measured by number of journal holdings) and faculty's literature use (measured by number of references used in the publications) while controlling for number of authors involved in the publications. A one-way repeated measures Analysis of Variance (ANOVA) was conducted to compare the differences in literature use and productivity over time. A two-way between groups ANOVA was also conducted to examine difference in the effect of faculty's literature use on their research productivity for funded articles and unfunded articles. Prior to conducting multiple statistical analyses, tests of assumptions for each statistical analysis (e.g., homogeneity of variance) were checked.

Results

Publication Patterns and Library Collection Size

The overall publication patterns of all faculty included in the study were examined in relation to the number of journals held in the collection/licensed by UIC. The average number of publications per author has increased over the 25 years studied except for 2000–2004. As the number of journals available to faculty increased, the number of references included in their publications have also increased, suggesting that collection size might be related to collection

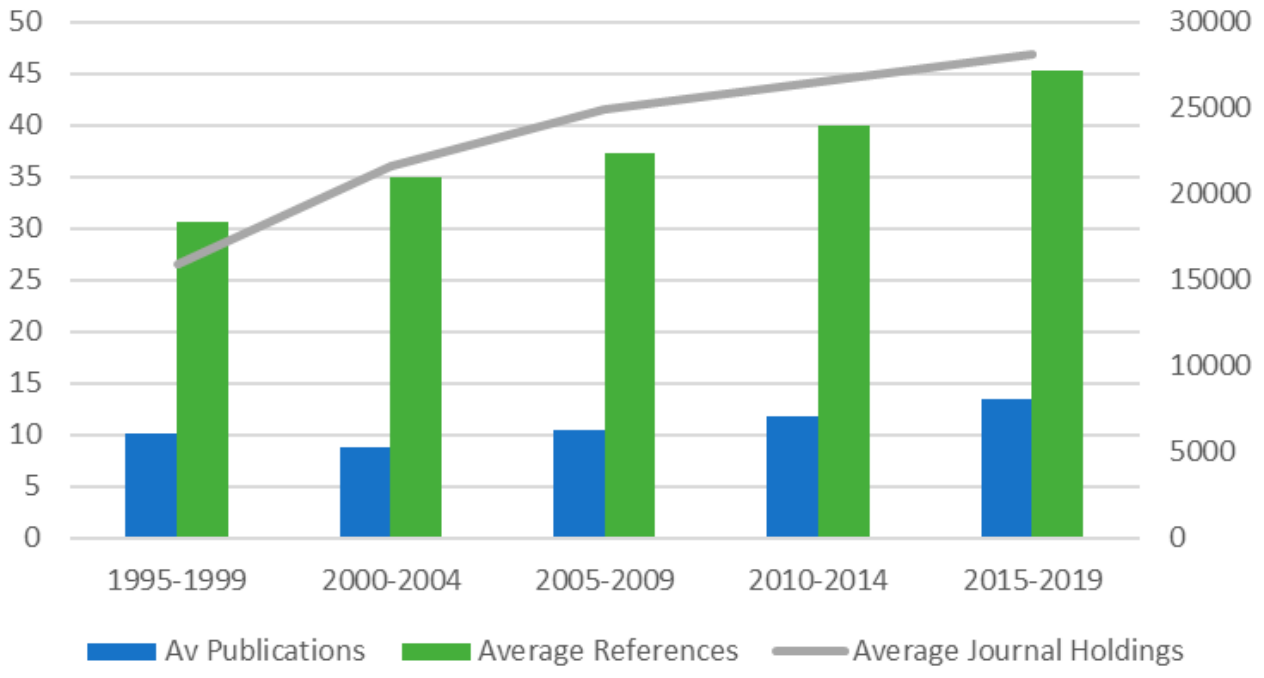
use (see Table 3 and Figure 1). It is important to acknowledge that in addition to library collections, faculty also had access to open access journals, interlibrary loan, and other means to gain access to the literature, so the actual influence of library collections growth can not be independently assessed.

TABLE 3
Productivity, Literature Use, and Collection Size—All Faculty Included in the Study (1995–2019)

	1995–1999	2000–2004	2005–2009	2010–2014	2015–2019
Productivity (Average publications per author)	10.05	8.86	10.49	11.79	13.45
Literature use (Average references per article)	30.56	34.94	37.24	39.90	45.28
Collection size (Average journal holdings)	15,947.40	21,683.20	24,921.60*	26,540.80*	28,160.00
N	117	223	375	581	802

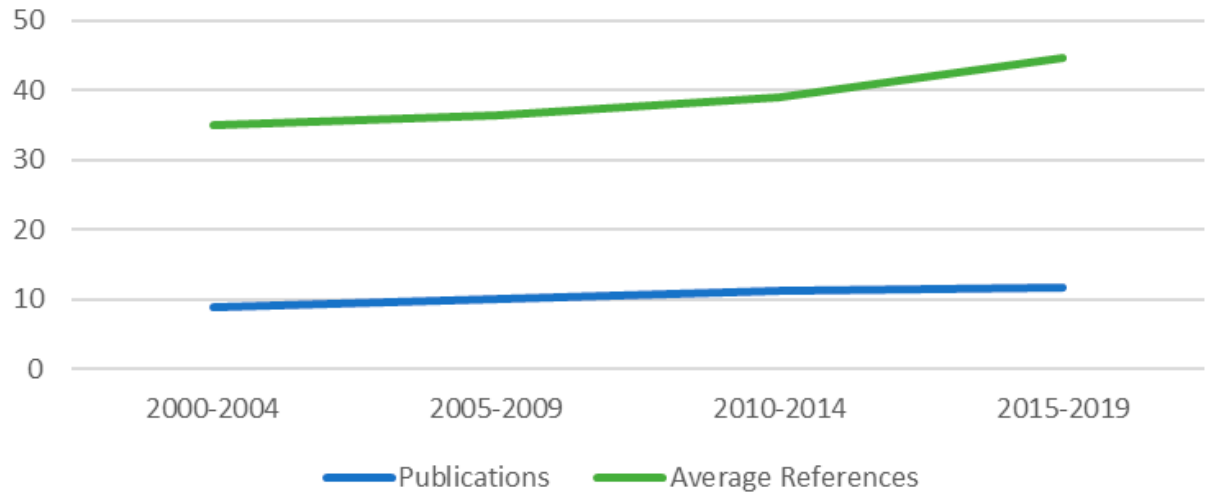
*2005–2009 and 2010–2014 data are estimates for journal holdings.

FIGURE 1
Publication Data and Journal Holdings — All Faculty Included in the Study (1995–2019)



Since the above analysis considers additional authors in each grouping of years, only the authors who had been at UIC since 2000 (n = 223) were examined. This approach kept the number of authors constant and eliminated the possibility that individuals new to the institution had different publishing habits, such as citing more journals and publishing more articles, which would impact the means. An increase in both productivity and use of references in publications was observed in the same faculty over time (Figure 2).

FIGURE 2
Publication Patterns of Faculty at UIC since 2000 (*n*=223)



A one-way repeated measures ANOVA was conducted to compare literature use (measured by the average number of references) and productivity (measured by the number of publications), respectively at Time 1 (2000–2004), Time 2 (2005–2009), Time 3 (2010–2014) and Time 4 (2015–2019). The means and standard deviations are presented in Table 4. There was a significant effect for time on the literature use (Wilks' Lambda = .67, F (3, 220) = 35.78, p <.001, multivariate partial eta squared = .33) and a moderate effect on the productivity (Wilks' Lambda = .92, F (3, 220) = 6.72, p <.001, multivariate partial eta squared = .08) using guidelines by Jacob Cohen.[22] This finding suggests that the number of articles written by faculty over the years has increased significantly over time, as has the average number of references that are included in the articles (see Table 4).

TABLE 4
One-Way Repeated Measures ANOVA Comparing Average Number of References (Literature Use) and Publications (Productivity) across Four Time Points (*n* = 223)

Variables	Time 1 (2000–2004)		Time 2 (2005–2009)		Time 3 (2010–2014)		Time 4 (2015–2019)					
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*df*	*F*	*p*	Partial Eta squared
References	34.94	15.15	36.50	14.67	39.06	15.98	44.74	17.74	3, 220	35.78	<.001	.33
Publications	8.86	6.83	10.16	8.30	11.36	9.87	11.71	13.20	3, 220	6.72	<.001	.08
*.01 small effect, **06 = moderate effect, ***.14 = large effect												

Publication Patterns by Discipline

The publication data was also explored by discipline to determine whether journal article publication patterns varied among different disciplines. On average, most colleges have increased in their publications over time (see Table 5, Figures 3). However, several colleges declined in the number of publications from 2010–2014 to 2015–2019 (Dentistry, Social Sciences, Social Work, and Urban Planning and Public Affairs). Except for Nursing, all disciplines increased the number of references in their publications over time (see Table 6, Figure 3). Differences in the number of references included in the publications also varied by discipline.

TABLE 5
Average Publications of Faculty at UIC since 2000 by Discipline

Discipline		2000–2004	2005–2009	2010–2014	2015–2019
Applied Health Sciences	Mean	9.80	14.64	16.40	20.93
	N	5	11	20	28
Business Administration	Mean	3.33	3.08	4.05	4.32
	N	9	13	19	28
Coll Medicine at Chicago	Mean	10.02	11.40	12.43	14.57
	N	82	136	228	322
Dentistry	Mean	8.00	7.87	15.08	12.57
	N	10	15	25	35
Education	Mean	3.67	5.56	3.59	5.30
	N	3	9	17	23
Engineering	Mean	9.86	13.30	14.82	18.61
	N	28	50	61	80
Library	Mean	5.00	3.00	3.17	4.75
	N	1	3	6	12
Sciences	Mean	10.66	10.79	10.38	12.35
	N	29	43	68	92
Nursing	Mean	11.00	9.83	13.77	15.85
	N	1	6	13	20
Pharmacy	Mean	11.89	14.17	18.19	19.58
	N	9	18	26	36
School of Public Health	Mean	6.33	10.42	13.06	14.88
	N	15	24	31	34
Social Sciences	Mean	5.95	7.72	7.46	6.97
	N	21	32	46	64
Social Work	Mean	5.67	5.40	8.00	6.88
	N	3	5	6	8
Urban Planning & Public Affairs	Mean	5.43	4.00	6.20	5.75
	N	7	10	15	20
Total	Mean	8.86	10.49	11.79	13.45
	N	223	375	581	802

FIGURE 3
Average Publications and Average References Included in Publications by Rank

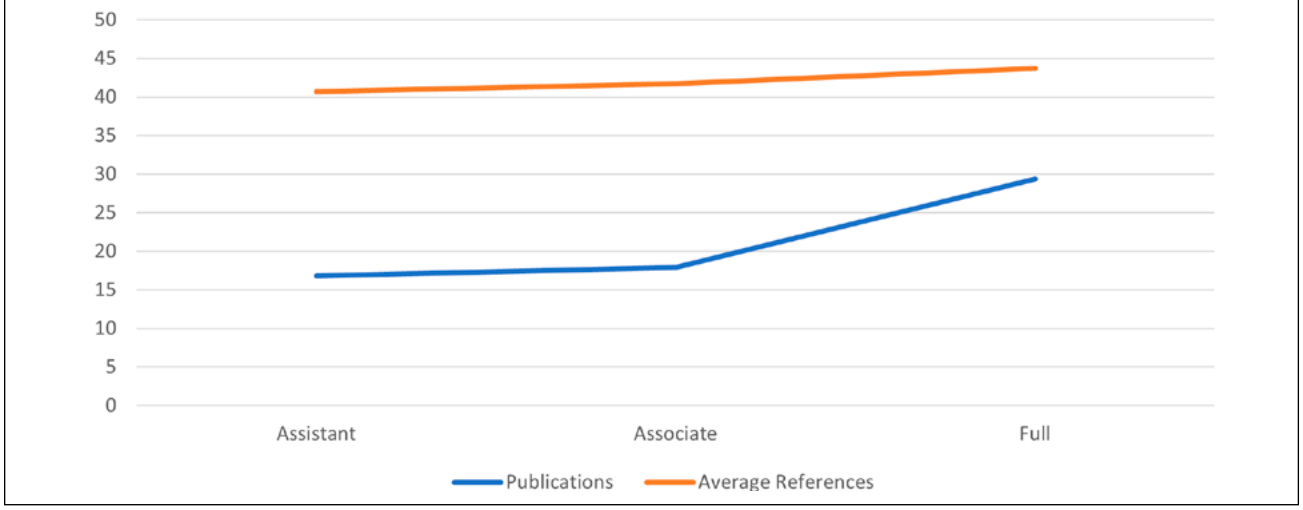


TABLE 6
Average References per Publication of Faculty at UIC since 2000 by Discipline

Discipline		2000–2004	2005–2009	2010–2014	2015–2019
Applied Health Sciences	Mean	35.27	39.75	41.17	42.90
	N	5	11	20	28
Business Administration	Mean	34.97	43.13	52.11	61.96
	N	9	13	19	28
Coll Medicine at Chicago	Mean	33.62	35.25	36.74	41.59
	N	82	136	228	322
Dentistry	Mean	36.40	36.13	38.03	41.36
	N	10	15	25	35
Education	Mean	40.93	58.35	46.37	52.12
	N	3	9	17	23
Engineering	Mean	25.03	30.71	32.09	43.38
	N	28	50	61	80
Library	Mean	17.60	12.44	16.76	35.06
	N	1	3	6	12
Sciences	Mean	39.65	40.57	41.62	46.99
	N	29	43	68	92
Nursing	Mean	42.82	47.07	48.69	47.36
	N	1	6	13	20
Pharmacy	Mean	26.81	36.55	44.70	46.01
	N	9	18	26	36
School of Public Health	Mean	31.96	35.19	36.36	39.90
	N	15	24	31	34
Social Sciences	Mean	48.43	44.65	53.38	57.49
	N	21	32	46	64
Social Work	Mean	33.42	33.10	38.08	48.23
	N	3	5	6	8
Urban Planning & Public Affairs	Mean	43.90	40.89	50.77	54.84
	N	7	10	15	20
Total	Mean	34.94	37.24	39.90	45.28
	N	223	375	581	802

Publication Patterns by Rank

Because faculty rank in the tenure system will change over time, only faculty at UIC since 2010 were examined. The rank was assigned based on their status at the time the list of tenure system faculty was received from the OIR. A one-way between groups ANOVA was conducted to explore the impact of publication patterns on faculty rank. As shown in Table 7, there was a statistically significant difference at the $p < .001$ level in publications for assistant, associate, and full professors, indicating that full professors wrote more articles than assistant or associate professors. However, there was no statistically significant difference in literature use ($p = .298$), suggesting that the average number of references included in the articles did not differ significantly based on rank (2010–2019) (see Table 7, Figure 3).

TABLE 7
Average Publications and Average References Included in Publications by Rank

	Assistant	Associate	Full	
Publications	16.83	17.89	29.35	F (2,578) = 17.79, p <.001
Average references	40.70	41.75	43.70	F (2, 578) = 1.21, p =.298

Correlating with Faculty Productivity and Literature Use

The above findings illustrate that faculty publication patterns differ over time, by discipline, and by rank, respectively. As the number of references included in publications increased, so too did faculty productivity. However, it is uncertain exactly how the number of references included in publications related to productivity. As such, the number of articles by author published between 2010 and 2019 were examined to determine whether productivity (number of publications) was statistically correlated with literature use (average number of references included in publications). There was a non-significant negative relationship between the number of articles written and the number of references included in articles (r (581) = –.029, p = .489). In looking only at 2015–2019 articles and excluding authors who wrote 5 or fewer articles, there was a statistically significant negative correlation between the number of articles published and references used in the publications. This suggests that the more faculty are likely to publish, the less they tend to use the references in the publications (r (607) = –.093, p = .022).

Correlations between productivity and reference use was examined within the disciplines for the 2010 to 2019 publications. Only within pharmacy was a negative correlation observed; the more productive a faculty member, the fewer references included in their publications (r (26) = –.391, p =.048).

These findings suggest that while the overall number of references per article are increasing over time, at an individual level, the more productive a faculty member, the less references are included in publications. To further explore how publication patterns were related to literature use, the authors who had been at UIC since at least 2005 were grouped into the following categories based on productivity from 2005 to 2019:

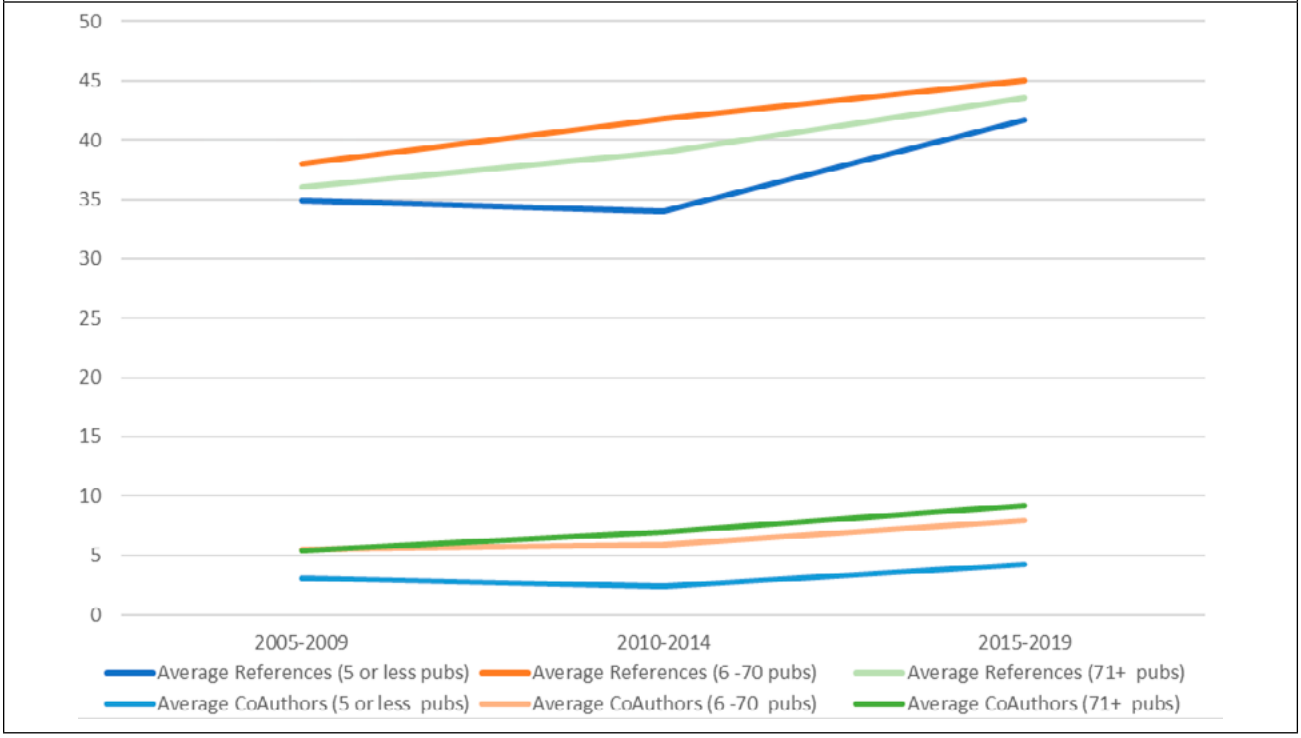
- Less productive – published 5 or fewer articles
- Productive – published 6 to 70 articles
- Prolific – published 71 or more articles

Note that the groups were formed based on the quartile of the faculty on their productivity; the middle groups were combined. As shown in Figure 4, although very prolific authors (published 71 or more articles) used fewer references than most of the productive authors (published 6 to 70 articles), the number of references used still increased over time. Less productive authors (published 5 or less) use fewer references in their publications overall compared to prolific and productive authors, but still appeared to increase the use of references in their publications over time. Productive authors used the most references in their publications, and their use of literature in publications also increased over time.

Correlations between Faculty Productivity and Co-Authorship Size

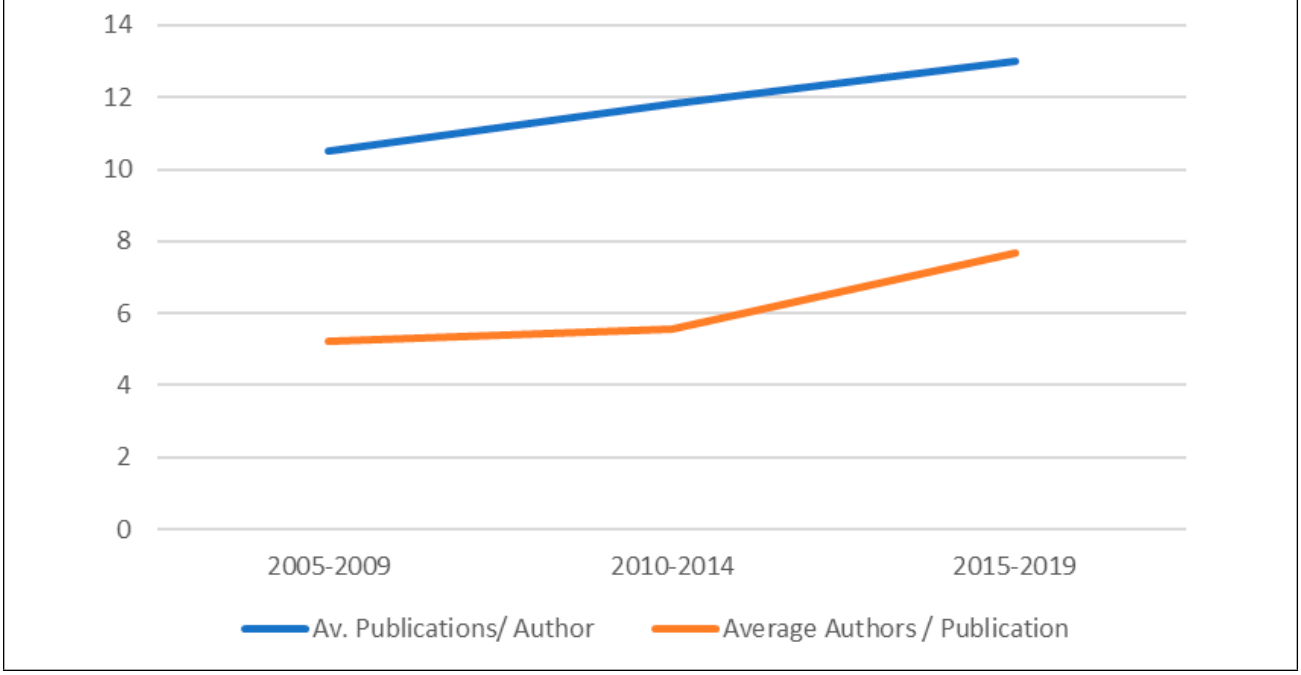
In general, the number of co-authors per article increased over time as did the number of articles per author (see Figure 5). There is a positive correlation between the number of articles written and the average number of co-authors on a publication (r (803) = .229, p =.001). The relationship between productivity and co-authorship size was also explored further by looking

FIGURE 4
Average References and Average Co-Authors by Productivity Level



at the level of faculty productivity. Productive faculty (6 to 70 articles) have fewer co-authors on average on publications compared to prolific authors (71 or more articles over 15 years) (see Figure 4). Less productive authors had fewer co-authors in their publications compared to productive and prolific authors.

FIGURE 5
Average Publications per Author and Average Authors Per Publications (all Faculty at UIC since 2005, n = 375)



Collection Size and Literature Use Controlling for Number of Authors

Partial correlation was used to explore the relationship between the library's collection size (measured by number of journal holdings) and faculty's literature use (measured by number of references used in the publications) while controlling for number of authors involved in the publications. There was a partial correlation between library's collection size and faculty's literature use, controlling for number of authors involved in the publications (r = .145, n = 24,692, p <.001), with library's collection size increase being associated with more literature use. An inspection of the zero-order correlation coefficient (r = .147) suggested that the observed relationship between library's collection size and literature use is not due merely to the influence of number of authors involved in the publication.

Impact of Faculty's Literature Use and Grant Funding on Research Productivity

To look more closely at articles that received grant funding versus those that did not, we compared articles that had grant funding compared to those that did not have grant funding, based on Scopus. Only publication data from 2010 to 2019 were explored in relation to an article being grant funded due to concerns of grant data accuracy through under-reporting in the Scopus database. (As noted previously, the overall number of publications at UIC increased over time. In the data comparing unfunded publications to funded publications from 2000 to 2019, it was observed that while the overall number of grant funded articles increased over time, the number of funded grants greatly increased between 2010 and 2014 and the number of unfunded grant publications greatly decreased over time. While it is logical to assume that as grant funding increases, the number of grant funded publications will increase, it seems less likely that unfunded grant publications will decrease significantly. In looking at the literature, we conclude that pressure increased in the scientific community to disclose funding information within the publication as a way to address potential conflicts of interest.[23] The NIH Public Access Policy would also have likely led to greater grant funding reporting. The funding details provided by Scopus most likely comes from disclosures in the articles, so as disclosures became more prominent in publications around 2010, grant reporting for indexed articles increased in Scopus as well. For this reason, only publications published since 2010 were explored in relation to the grant data provided by Scopus). A 2020 article also found there were inaccuracies in the funding data reported in the Scopus database.[24] Thus, it is likely that the number of articles that were noted to be grant funded remains under reported in Scopus. As such the comparisons using funding data provided through Scopus from 2010 to 2019 were used to explore but not confirm publication patterns.

Exploring publication data since 2010, it is observed that grant funded articles include significantly more references than do unfunded articles (t (14075) = 12.55, p < .001) (see Table 8). Grant funded publications also had a significantly higher number of co-authors, compared to non-grant funded articles (t (14075) = 9.84, p < .001).

TABLE 8
Average Number of References and Average Number of Authors per Publication by Funding Since 2010

Funding	Average Number of References	Average Number of Authors
Unfunded (N = 5,628)	39.77	6.18
Funded (N = 8,450)	46.05	13.83

To explore the impact of faculty's literature use on their research productivity, a two-way between-groups ANOVA was conducted. Faculty was grouped into four groups based on the number of references on average used in publications: Group 1: Average references used from 1–32; Group 2: Average references used from 33–41; Group 3: Average references used from 42–51; and Group 4: Average references used from 52 or more.

There was a statistically significant difference in the average number of publications for the four groups of their literature use: F (3, 522) = 8.374, $p < .001$, eta-squared effect size = .05 (medium effect guided by Cohen's criteria, see Table 9). Post-hoc comparisons using the Tukey HSD test indicated that the mean publications for Group 1 (literature use from 1–32, $M = 19.08$, $SD = 18.80$) was significantly lower than those of Group 2 (literature use from 33–41, $M = 29.92$, $SD = 27.40$) and Group 3 (literature use from 42–51, $M = 29.23$, $SD = 24.00$). Group 4 (literature use 52 or higher, ($M = 20.92$, $SD = 18.10$) was significantly lower than both Group 2 and Group 3. However, Group 4 did not differ significantly from Group 1. This finding suggests that for some researchers (Groups 2 & 3), their literature use positively impacted productivity, however, for those researchers that include a very low or very high number of references in their publications, their research productivity is not influenced by their use of the literature.

TABLE 9
One-Way Between Groups ANOVA Comparing Productivity across Four Groups of Literature Use, 2010–2019 (*n*=526)

Variables	Group 1 1–32 references		Group 2 33–41 references		Group 3 42–51 references		Group 4 52/above references					
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*w*	*df*	*F*	*p*	Eta squared
Productivity	19.08	18.80	29.92	27.40	29.23	24.00	20.92	18.10	3, 522	8.374	<.001	.05

Confounding Variables

This study has observed changes in publication patterns over time, including increased faculty productivity and increased references in publications. At the same time, the size of the library's journal collection has grown. Unfortunately, it is not possible to conclude a relationship between library collection use and faculty productivity due to several confounding variables including unknown sources of the references included in publications, increased grant funding, increased co-authorships, a general increase in faculty members at UIC, and greater access to online abstracting and indexing tools. (See Table 10.)

TABLE 10
Faculty at UIC for at Least 15 years (*n* = 375)

	2005–2009	2010–2014	2015–2019
Publications	10.49	11.80	13.02
Average references	37.24	39.37	45.46
Average co-authors	5.22	5.56	7.69
HERD funding ($000)*	$338,257	$369,626	$361,823
Average journal holdings*	24,921.6	26,540.8	28,160
Average teaching faculty (ARL)*	1,170	1,333	2,143
*Data specific to all of UIC.[25]			

Sources of the references: Over time, journal holdings increased at the institution, the number of open access journals increased, and the availability of indexing and abstracting tools increased, all of which can increase the identification and use of articles in publications. However, the sources of the articles that were used in publications were not known. Articles may have been accessed through the library's collection, inter library loan, colleagues, or other means. To ascertain a level of understanding related to the references that faculty could potentially have accessed through the library's collections, we compared the references included in 2016–2019 publications identified in Scopus to our holdings, using a report from our link-out tool to identify journals the library licenses or that were freely available. Approximately 4,860 journals were identified from the references used in the Scopus publications, and 725 (15%) were not found to be part of the collection or through open access. In addition, there was a positive correlation between full-text article downloads through the Serials Solutions link-through reports and the references included in publications between 2016 and 2019 (r (4874) = .546, $p < .001$). This suggests that UIC researchers likely relied on the library for access to journal articles that are used in their publications, but it is not possible to conclude this definitively. A 2019 study exploring how faculty seek and read articles noted that although most articles read are still in online journals from the library or their departments, researchers are finding other ways to discover and access articles.[26]

Access to online information: Improvement in online access to information including both online journals and indexing and abstracting databases also likely influenced the increase in the use of references in publications, in addition to the increase in the number of journals available through UIC.

Increased Grant Funding: The annual grant funding that UIC received increased over time, based on the Higher Education Research and Development (HERD) Survey data (higher education R&D expenditures). The increase in grant funding would likely have an impact on the number of publications produced, which makes it difficult to explore the impact of the collections on productivity.

Co-authorship: Co-authorship is also increasing, perhaps because of a greater focus on collaboration, interdisciplinary research, and team science, but also potentially because of an increase in the overall faculty at UIC. Co-authorship influenced both productivity and the use of references in publications.

Discussion and Future Directions

Over a 25-year period, grant funding, the number of journals available to researchers, the average number of journal publications of faculty members, the average number of references included per article, and the average number of authors contributing to the articles all increased. Grant-funded publications tend to include more references and co-authors than non-grant funded articles.

The findings of this study demonstrate a relationship between availability of online journals and an increase in the use of literature in faculty publications, as illustrated by the increase of references in papers. This study also suggested that as the size of the journal collections increased, so did faculty productivity. However, it is not possible to conclude that a larger journal collection led to greater faculty productivity. While there is an apparent causal mechanism for references increasing when more journals are available online, it is confounded by the increase in online databases, both free and subscription based, and the ease of access to online journals and databases.

This study also demonstrated that as access to the literature increased, so did faculty productivity and co-authorship on faculty publications. We did find that the most productive faculty also had the greatest number of co-authors on the publications, and the least productive faculty had the least number of co-authors on their publications, suggesting that co-authorship plays a role in faculty productivity. The increase in co-authorship is likely influenced by several factors, such as an increase in the number of faculty at UIC and a focus on team science and interdisciplinary research. It is also possible that technology and the internet have made it easier for faculty to collaborate within and across institutions.

We also found the increase in the use of articles in publications increased as the size of the library's collections and access to additional online resources increased, and this finding was not merely due to the influence of number of authors involved in a publication. While the most prolific authors were not the largest users of references, the productive authors did use the largest number of references in their publications. It was also observed that the least productive faculty used the fewest references in their publications. This suggests that there is a relationship between the use of the literature and faculty productivity. Increasing numbers of references may show that research is more thorough in the context of expanding information. However, large numbers of references might also be a strategy for less well-known authors to establish their credentials, whereas established authors at institutions with high productivity can be published with a more concise list of references.[27] Further research comparing data at institutions with varying rates of publication could clarify this connection. In general, most disciplines increased in the number of publications over the years and the number of references used in publications.

One of the greatest limitations of this study was that the data was limited to one institution. In order to explore the potential impact of online journals, a retrospective longitudinal study was conducted to explore the impact of the growth of available journals on faculty research. The next steps are to explore more recent data with other ARL libraries with different budgets, collection size, and grant funding to further explore how the size of journal collections may impact the use of the literature in publications, and potential faculty productivity.

Conclusion

Journal articles remain an important source of scholarly information for researchers in many disciplines, and their use of references in journal articles has increased over time. In addition, faculty productivity has increased. While it is challenging to demonstrate the availability of and use of journal literature in relation to faculty productivity, the use of scholarly literature remains paramount in faculty research. There are some disciplinary differences, and also differences in literature use relevant to faculty productivity, although in general all faculty increased their use of the literature in their publications. Academic libraries must continue to justify funding access to electronic journals as subscription fees rise above inflation. The challenge for libraries remains demonstrating the impact of the library among so many other variables that play a role in access to and use of information, and faculty productivity.

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