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Looking for Links: How Faculty Research Productivity Correlates with Library Investment and Why Electronic Library Materials Matter Most

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Abstract

Objective – This paper summarizes two studies that share the same research question: do universities produce more scholarly research when they invest more in their libraries? Research libraries spend a great deal of effort reporting their expenditures, collections statistics, and other measures that serve as a basis for interlibrary comparison and even rankings. The straightforward assumption implied by this activity is that libraries better serve their student and research communities when they are well-funded and well-resourced. The studies examined here both ask if that notion can be validated empirically, not because research libraries require some sort of justification, but because in an environment of tough budget decisions and shifting opinions about the changing role of libraries, it may be useful to demonstrate that sustained investment in libraries offers tangible returns or that the failure to do so can result in tangible costs.

Methods – A cross-sectional design featuring ordinary least squares regression analysis was used in both studies to estimate the relationship between scholarly research productivity at U.S. doctoral institutions and an array of institutional characteristics presumed to influence that productivity. The concept of research productivity is operationalized as the total number of scholarly journal articles produced by each institution over a five year period – as journal articles represent the most common form of scholarly expression across the greatest number of academic fields. Serving as the dependent variable, this data was regressed against a variety of institutional

characteristics including faculty size, research expenditures, and grant awards, and several library variables centered mostly on expenditures. The concept behind this design is that to realistically explore the relationship between levels of library investment and research productivity, all other institutional drivers of research productivity must also be represented in the dataset. While the design was similar for both studies, they each drew on different data sources and marginally different populations.

Results – Both studies found that an institution's research productivity is positively and significantly correlated with the level of investment it makes in its libraries. Furthermore, both studies found electronic library material expenditures to be particularly associated with increased productivity. This relationship was so strong that an institution's level of research productivity appears to be sensitive to how its library's collection budget is allocated between print and electronic materials. As the portion of the budget dedicated to non-electronic material grew, research productivity decreased in statistically significant fashion in both studies.

Conclusion – While both studies succeeded in demonstrating the existence of an empirical relationship between library investment and research productivity, the most intriguing finding is that both studies observed a decrease in number of journal articles being produced as expenditures for non-electronic library materials increased. The conclusion is that the efficiencies of electronic resources offer such advantages over the use of traditional library materials in supporting scholarly research that productivity suffers as institutions dedicate a greater portion of their collection budgets to print materials at the expense of electronic materials.

Introduction

A 2009 membership survey conducted by the Association of College and Research Libraries identified "concern about demonstrating library value and effectiveness" as one of the most important considerations on the minds of responding library directors. According to Michael Germano (2010), "the ultimate goal is a demonstrable strengthening of support from user populations that will translate into the avoidance of deeper or ongoing cuts during the current economic climate." Yet, the call to demonstrate library value can be a gauntlet cast down more often than picked up, due to the difficulty in linking a library's contributions to campus-wide outcomes that are more manifold than manifest. This paper summarizes two studies conducted by the author in 2012 and 2013 that were designed to overcome this challenge by incorporating representative measures of as many of the drivers of scholarly productivity as practicable for more than 200 institutions. This approach allows for the examination of how library characteristics relate to scholarly output while also accounting for other relevant campus factors that are likely influences. By using this type of design, both studies can offer insight into how libraries contribute to scholarly productivity in an empirical sense – something that cannot be achieved by examining any single institution. While finding a linkage between library investment and scholarly productivity can only imply a return on investment to the institution (no research design can prove causality so long as we are unable to confine libraries and universities to a laboratory), an empirically established relationship is still preferable to the absence of evidence. Furthermore, if a reasonable theory can establish a context for interpreting the correlation, it can provide a reasonable basis for the claim that the correlation being measured represents an actual impact of libraries' services.

Literature Review

Many studies have explored the relationship between library resources and faculty research productivity. The two research projects featured in this paper are what Oakleaf has categorized as "input/output assessments" of library impact on faculty research productivity (ACRL, 2010, p. 48). Other examples of this type of approach include Budd's work in the 1990s that compared the number of journal publications produced by institutions to their library's volume count (1995, 1999). More recently, Wilson and Tenopir (2008) conducted local citation analysis that compared library holdings to faculty member citations to determine the percentage of referenced items that were available from the faculty member's library. Further examples of input/output assessment studies related to research productivity can be found in *The Value of Academic Libraries* (ACRL, 2010, p. 48).

While these works examine the relationship between library resources and faculty research productivity, no U.S. studies have focused explicitly on how electronic library material expenditures relate to research productivity or other institutional outcomes. There are two groups in the United Kingdom, however, who have launched empirical investigations analyzing the link between electronic resources and higher education outcomes in that nation. CIBER Research Ltd conducted a study that found a strong correlation between e-journal spending and usage at U.K. universities (CIBER, 2008). The study found e-journal spending was correlated with such "downstream" effects as the number scholarly journal publications, PhDs awarded, and research grant awards at each institution. These results were corroborated by another U.K. study conducted the following year by the Research Information Network (RIN), a policy organization funded by the U.K. Higher Education Funding Council (RIN, 2009). RIN later developed a structural modelling technique to test the directionality of the relationship between spending and use, determining that spending drove usage (RIN, 2011).

The studies presently examined in this paper were largely influenced by Budd's work linking research productivity to volume counts, mentioned earlier, and Weiner's work examining the library's impact on institutional reputation. Budd's work relied on citation indexes to attribute the number of journal articles produced by individual research universities and then compared that total to each institution's volume count using ARL and ACRL library survey data (Budd, 1995, 1999). Budd also accounted for the effect of faculty size on productivity by standardizing scholarly output on per-faculty basis. However, Budd did not account for the effect that other institutional characteristics – such as research expenditures, financial strength, and grant awards – might have on research productivity. Weiner, on the other hand, employed a variety of institutional characteristics to explore the relationship between libraries and institutional reputation, as ranked by the *U.S News and World Report* (2009). She used regression analysis whereby an institution's ordinal ranking served as the dependent variable and a variety of library and non-library measures served as the independent variables. Her goal was to determine if any library characteristics were positively correlated with institutional reputation, but she also recognized that the prestige of a university is not centered solely on the library. Therefore she included expenditure data for instruction, research, and student services; levels of alumni, corporate, and foundation giving; measures for graduate rate, retention rate, and the number of grants received; as well as library expenditures, staffing, and transactional data. The two studies explored in this paper essentially amalgamate Budd's comparison of library characteristics to scholarly output with Weiner's use of a regression model that features both library and non-library institutional characteristics to determine their relation to a campus-wide outcome.

This type of research design has a precedent in the field of economics, where actual firm-level output data for a particular industry is regressed against firm-level inputs to form an industry-specific production function equation. Known as the Cobb-Douglas model, this approach is used to study the relationship between a set of inputs and the quantity of output produced, which in turn can be used to measure production efficiency, including the impact of technological improvements (Biddle, 2011). The two studies examined in this paper take a similar approach by identifying the institutional inputs that go into producing scholarly research and regressing those measures against actual scholarly output – producing an industry production function of sorts for academic scholarship. Furthermore, both studies' findings regarding the potential efficiencies that electronic library materials introduce into the scholarly production process are consistent with the Cobb-Douglas model's ability to identify the impact of technological improvements on production.

Methodology and Results

First Study

The original study sought any evidence suggesting that libraries confer value to the research mission of their host institutions when properly resourced. At the time, there was no particular focus on the role of electronic library materials. Instead, a wide array of library measures was assembled to determine which aspects, if any, of libraries are correlated with scholarly output. This array of library variables was drawn from ACRL's *Annual Trends and Statistics Survey* using Counting Opinion's *ACRLMetrics* service (www.acrlmetrics.com) and included such measures as total expenditures, library material expenditures, electronic library material expenditures, volume counts, staffing levels, interlibrary loan borrowing, and others. Non-library institutional characteristics that might also influence scholarly productivity were collected using the U.S. Department of Education's Integrated Post-Secondary Education Data System (IPEDS). These variables included such measures as research expenditures, grant funding, faculty count, total university revenue, year-end value of the endowment, the number of PhDs awarded, and others. All told, more than 25 different library and non-library institutional measures were represented in the study as potential explanatory variables for scholarly research productivity at each doctoral institution.

The concept of scholarly research productivity was operationalized using the total number of scholarly journal articles produced by each U.S. doctoral institution. Journal articles were selected over other forms of scholarly expression because they are common to most academic fields. The number of journal articles attributable to each doctoral institution was established using Thomson Reuter's *ISI Web of Knowledge* citation index. The article count for each school could then be linked to that institution's library and non-library explanatory variables for analysis.

The choice was made to aggregate the data over a period of five years, rather than relying on data from one particular year. The decision was based on the rationale that it is too imprecise to tie a specific year's inputs to a specific year's outputs. Instead, by examining a short range of years, it is possible to get a more representative indication of the amount of resources that each institution typically dedicates to scholarly research as well as the amount of productivity that it typically achieves. For the IPEDS and ACRL data, this involved collecting the reported figures for each measure from 2005 through 2009 and then calculating an average (e.g., average library expenditures per year or average number of faculty per year). This average was compared to the total number of journal articles produced from 2006 to 2010. The range of years was staggered between the explanatory variables and the dependent variable data based on the assumption that inputs must necessarily precede outputs.

The Carnegie Classifications (2010) were used as the basis for identifying doctoral institutions, though several were excluded due to a lack of reported data. Ultimately, 234 institutions were included in the study. A full discussion of this study, including an exhaustive list of the variables, data limitations, and iterative details, can be found in the *Proceedings of the 2012 Library Assessment Conference* (Rawls, 2013).

Potential correlations were explored using ordinary least squares regression analysis, where the number of journal articles served as the dependent variable and the institutional characteristics served as the explanatory variables. After exploring several different combinations of explanatory variables in a number of iterations, the factors deemed to be most strongly, consistently, and significantly related to journal article output were as follows: total university revenue, number of faculty members, research expenditures, the number of professional librarians, electronic library material expenditures, and non-electronic library material expenditures. Other explanatory variables also proved to be significantly related to journal article output, but had to be excluded due to the issue of multicollinearity. This occurs when two or more explanatory variables are so highly related to each other that the scope of their relationship with the dependent variable cannot be precisely measured. For example, both total library material and electronic library material expenditures had statistically significant relationships with journal article output. Both variables, however, increased or decreased from one institution to the next in a very similar manner. This similarity was so strong that when both variables were included simultaneously in the same model, the analysis was unable to distinguish the effect that one variable had from the other on the corresponding changes in each institution's article count. This development meant that some variables needed to be excluded in order to gain an understanding of the degree to which different characteristics related to scholarly productivity. Level and consistency of statistical significance as well as size of standardized coefficients were used as a basis for which significant variables were excluded or retained.

Finally, it was necessary to include an indicator variable for Harvard University to control for the outlier effects that that institution's unparalleled personnel expenditures and staffing levels were exerting on the rest of the dataset. Prior to adding this "dummy" variable, the regression results had mostly indicated that the library variables were not significant. After it was introduced into the dataset, however, most major library expenditures categories were consistently significant. Another option would have been to exclude Harvard altogether, as both methods would have reduced the residual effect of Harvard to zero. The decision was made to retain Harvard, however, because it seemed appropriate to include the highest-spending library, given the goals of the study.

The unstandardized coefficient for each variable contained in the regression results represents its estimated relationship to the number of journal articles produced by an institution (see Table 1). For example, these results estimate that for each dollar dedicated to electronic library materials, a U.S. doctoral institution is expected to produce .00052 journal articles. Likewise, it estimates the publication of .78292 journal articles per faculty member. When the coefficients for the model's variables are multiplied by the actual numbers belonging to a particular institution and then added together, it provides an estimate for the total number of journal articles that the institution is predicted to produce given these inputs. The implication is that a change to any one of these variables should result in a corresponding change to the number of journal articles that an institution produces. For example, this model suggests that a $1,000,000 increase in electronic library materials spending should result in 520 additional articles.

The model produced an adjusted r-squared value of .925, which was roughly consistent with other iterations. Among the library-related

Table 1
"Best fit" model from first study

Independent Variables*	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-1401.94136	303.274		-4.623	.000
Total University Revenue	0.00000212	.000	.21251	3.961	.000
Faculty FTE	0.78292	.355	.10485	2.203	.029
Research Expenditures	0.00002	.000	.33949	8.250	.000
Number of Professional Librarians	30.98683	7.519	.21828	4.121	.000
Electronic Library Material Expenditures	0.00052	.000	.18403	4.661	.000
Non-Electronic Library Material Expenditures	-0.00026	.000	-.09610	-2.739	.007
Harvard	21924.60497	3282.390	.17972	6.679	.000

*Dependent variable: total number of articles published by faculty and other researchers associated with each US doctoral institution from 2006 to 2010 according to *ISI Web of Knowledge.*

measures, the number of professional librarians had the largest standardized coefficient, suggesting that this measure was more strongly associated with increased scholarly productivity than electronic material expenditures (.218 to .184). While this finding was very encouraging, and deserving of additional study, the second study was unable to replicate a linkage between staffing levels and productivity.

Second Study

After the positive results of the first study, a follow-up study was conducted to determine if similar results would be replicated using a different data source. To achieve this, the new study relied on the Academic Analytics (www.academicanalytics.com) database tool. Academic Analytics (AA) is a subscription-based system that university administrators can use to measure faculty scholarly productivity. It attempts to do this by attributing scholarly works, citations, grants awards, and honorific awards to individual faculty members and then aggregating that information at the PhD program level and again at the institutional level. This allows administrators to analyze the faculty scholarly productivity of each PhD program or the overall university within the context of other programs and institutions around the nation.

The general methodology of this study was very similar to its predecessor. The main differences were that the AA system provided a different source of journal count data (CrossRef), a slightly different time frame (2008-2011), and it drew from a subpopulation of researchers at each institution (only those faculty members associated with PhD programs are tracked in AA) instead of the entire research community. The second study also necessitated changes in the explanatory variable data. The IPEDS and ACRL data used to represent library and other institutional characteristics were re-collected for the years 2007 to 2010 to synchronize with the new time frame of the dependent variable data.

Additional explanatory variable data from AA was also introduced into the dataset. This included the system's own count for faculty, grants awards, and grant dollars – all of which were lower than similar measures from IPEDS due to AA's singular focus on just those

professors associated with doctoral programs. The reason for adding this additional data from AA was that it was more proportionally scaled to the dependent variable data. In other words, given that only journal articles published by faculty members associated with a PhD program were being counted at each institution, it was logical to count only those faculty members associated with such programs, instead of the entire faculty, when measuring how faculty size relates to this study's measure of scholarly output. Likewise, the same logic applies for the grant-related measures collected from AA over IPEDS grant and research expenditures data. In this way, variations in the size of each university's PhD enterprise relative to the overall institution's size would not skew results.

Again, ordinary least squares regression analysis was used to test the relationship between journal output and the variety of institutional and library characteristics represented in the dataset. The results of the final model bore a resemblance to those of the first study, particularly where electronic and non-electronic material expenditures were concerned, though some notable differences occurred as well. The combination of independent variables observed to most strongly correlate with journal article output were: grant dollars, number of PhD faculty, number of PhDs awarded in research fields, electronic library material expenditures, and non-electronic library material expenditures. The model produced an adjusted r-squared value of .969.

The grant dollars and PhD faculty count variables in this model can be seen as more relevant substitutes for the research expenditure and faculty count variables found in the first study. The variables for total university revenue and the number of professional librarians were not statistically significant. Both revenue and the number of librarians are more realistically driven by overall institution size than by the number of PhD programs, suggesting that these measures could simply be out of synch with the dependent variable data used in the study. Likewise, once professional librarians were no longer included in the model, the indicator variable for Harvard proved unnecessary and was dropped.

Electronic and non-electronic materials expenditures each had a similar relationship to journal articles as in the first study, with the former being positively correlated and the latter being negatively correlated, with both relationships being statistically significant. The coefficients were lower, but this too could be a result of scale, produced by comparing overall material expenditures to a subset of each institution's scholarly output, as opposed to all scholarly output in the first study. A more detailed discussion of the second study is available in the *Proceedings of the 10th Northumbria Conference on International Performance Measurement in Libraries and Information Services* (Rawls, 2014).

Discussion

The inverse correlation between non-electronic material expenditures and journal article output was unforeseen, in that the general expectation for explanatory variables was that each one would have a relationship that was either significantly positive or one that was not statistically significant at all. But these results suggest that for each additional dollar invested in traditional library materials, scholarly productivity decreases. How could this be? It is not as though print materials offer no usefulness to researchers, let alone serve as a hindrance. Furthermore, volume counts and other measures of the physical collections did not register a significant or negative correlation. Instead, a plausible interpretation is that electronic library resources are more efficient in supporting research needs than print materials. To illustrate the obvious, think of a researcher in her office conducting a single, well-worded search on the library's website and gaining instant access to a dozen relevant titles for her literature search. Contrastingly, think of her at a poorly resourced institution, finding only some

Table 2
"Best fit" model from Academic Analytics study

Independent Variables*	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-317.09038	89.028		-3.562	.000
PhD Faculty Count	2.32040	.287	.29340	8.077	.000
Grant Dollars	.00002	.000	.57484	23.070	.000
PhDs Awarded - Research Fields	2.40900	.669	.11100	3.598	.000
Electronic Library Material Expenditures	.00011	.000	.07997	3.210	.002
Non-Electronic Library Material Expenditures	-.00005	.000	-.03317	-1.983	.049

*Dependent variable: total number of journal articles published by faculty members associated with a PhD program at US doctoral institutions from 2008 to 2011, according to CrossRef.

of her needed articles and having to work through interlibrary loan or make a trip to the library to wade through the bound periodicals in order to access the remaining portion of the same titles. The time difference between these two scenarios is likely measured in hours or days. Likewise, access to digital archives, databases, and secondary datasets may preclude a trip to far-flung archives or the need to collect data, potentially speeding up a research project by days, weeks, or months, or even allowing the research project to take place at all. When all of these time savings, however great or small, are multiplied by each member of the institution's research community, it is not surprising that those institutions that are better endowed with electronic materials are able to produce more scholarship over a given period of time than those that are not.

Yet, the efficiency alone does not entirely explain why print expenditures would be significantly negative. To illustrate why this is the case, it is important to point out that non-electronic library materials expenditures is a not a measure collected in the ARL or ACRL surveys. Rather the variable was derived by subtracting each institution's reported electronic library material expenditures from their total library material expenditures. This means that the non-electronic and electronic materials variables serve as two components that comprise the library's overall collection budget. Therefore, as electronic material expenditures grew as a total portion of the budget from one institution to the next, the non-electronic material expenditures necessarily shrank. Conversely, as the ratio of non-electronic library materials grew, it was at the expense of electronic materials. The suggestion is that those institutions deciding to invest more in non-electronic materials – or perhaps those that experienced a slower transition from print to electronic during the span of this study – paid an opportunity cost in terms of journal article production. Thus those universities that spent more on non-electronic library materials experienced a loss in scholarly productivity instead of realizing a potential gain. These results are in line with the manner in which the Cobb-Douglas model detects production efficiency in economic production theory. The model does this by identifying firms that are producing more output than the sum of their inputs suggest that they should be able to produce, when compared to an industry average as established by a regression equation (Biddle, 2011). This suggests that the excess production is

attributable to a technological efficiency that the highly productive firm is employing and that the average and lower producing firms are not. In the case of these two studies, the institutions allocating more of their collection budgets toward electronic resources experienced greater productivity – presumably because they offered their research communities more efficient inputs that reduced the time needed to complete the research cycle.

The nature of the relationship between non-electronic materials and scholarly output offers unique evidence in support of the study's original hypothesis. Recalling that the initial intent was to demonstrate empirically whether well-supported libraries are generally associated with higher levels of scholarly production, the strong positive correlations that both electronic library materials and the number of professional librarians exhibited with journal articles arguably achieved that goal (total library material expenditures and total library expenditures were also strongly related to journal articles, but again, were removed due to multicollinearity). While these results realize the original objective of detecting linkages between library inputs and scholarly output, they cannot prove causality – as is the case with a quasi-scientific research design. In fact, were it not for the negative coefficient associated with the print materials, it would be simple to challenge these results with the argument that the findings only prove that well-off doctoral institutions have more of everything than less well-to-do universities. It follows that institutions of greater prestige and deeper funding are simultaneously in a better position to support research, to spend more lavishly in support of their libraries, and to produce more scholarship. That all of these factors can be identified to correlate with one another in a regression equation could be interpreted simply as a rising tide that lifts all boats. The print material expenditure results, however, confound this notion of a rising tide by going in the opposite direction of every other statistically significant measure associated with scholarly productivity. When coupled with the theory that print material expenditures represent an opportunity cost to scholarly productivity, a basis is provided for contending that some degree of causality is being measured between electronic materials and scholarly output in this model.

Conclusion

The studies described here each provide empirical evidence that scholarly research productivity increases at U.S. doctoral institutions as they invest more in their libraries. The primary finding both studies share in common is that growth in electronic library material expenditures has an especially strong association with growth in research productivity. These findings satisfy the original research question and provide a credible argument that universities can realize a detectable return on their investment in libraries, depending on how that investment is spent. This argument would be less plausible if print materials had not proven to be so spectacularly less productive than electronic resources. But because scholarly productivity seems to ebb and flow so significantly based on how an institution comprises its collections budget, the contention that scholarly output is actually affected by library spending is much more persuasive.

Applying regression analysis to the question of whether universities produce more scholarship when they invest more in their libraries allowed both studies to control for other important institutional characteristics that also drive scholarly productivity. This means that the effects that an institution's faculty size, research expenditures, or grant awards might have on scholarly output were accounted for and incorporated into the study alongside the library-related variables. This approach makes the results more meaningful than simple correlations. As such, it may have applications in other areas where libraries would like to demonstrate their value, yet face the challenge

of being one factor among many that contribute to an important institutional outcome.

Because both studies found such a sharp contrast between how electronic and print materials expenditures each relate to scholarly research productivity, this topic merits further inquiry. One approach may be to explore the relationship between library investment and scholarly productivity at the discipline level, to determine if these relationships persist across different subject areas. Such a study might also benefit from substituting other forms of scholarly expression in place of journal articles in order to further develop this line of inquiry.

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