A LOOK AT RESEARCH PRODUCTIVITY: EXAMINING THE RELATIONSHIPS BETWEEN PUBLICATIONS, CITATIONS, AND RESEARCH AND DEVELOPMENT EXPENDITURES

By
Yoke Dellenback

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Abstract

A faculty member’s publications are one of the most important pieces of evidence of research output. They serve as a form of communication of scientific discoveries, innovations and findings while demonstrating the authors are subject matter experts in their fields. At the same time, research institutions view the number and quality of publications on a faculty member’s curriculum vitae as a critical return on investment and a measure of the faculty member’s research productivity, impact and academic achievements for the tenure and promotion process. There were two research objectives for this thesis. The first objective was to look at the research productivity at the institutional level by examining research & development (R&D) expenditures and publication output. The second objective was to look at research productivity at the faculty level by exploring a faculty member’s publication output, citations of the publications and R&D expenditures. The questions explored were: Were R&D expenditures related to publication count at the institutional level? Were a faculty member’s R&D expenditures related to his/her publications and citations? Were there direct correlations among these variables: publications, citations, and R&D expenditures? The relationships among the variables were explored using regression analysis. The analyses indicated significant relationships between R&D expenditures and publications at the institutional level and among R&D expenditures, publications and citations at the faculty level.

Primary Reader: Jeffrey E. Kantor
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1. INTRODUCTION

1.1 Institutional View

With the ever-changing landscape and environment surrounding federal funding and the decline in state appropriations, research institutions are compelled to compete globally to seek out other funding sources to diversify their revenue portfolio to cover expenditures (See Figure 1) such as salaries and wages, the biggest expense category. At same time, they are also hoping to improve the institution’s prestige, reputation and rankings to attract “cream of the crop” students and new faculty. A research institution bears the fiduciary responsibility and is accountable to the stakeholders (e.g., federal, state or local government, private foundations, donors and taxpayers) when accepting external funding for sponsored projects. The research institution must also ensure the funds are spent appropriately while complying with federal and state law, regulations and statutes, institutional policies and sponsors’ terms and conditions.

Figure 1
Examples of Revenue and Expenditure Types.

1.2 Faculty View

Meanwhile, the faculty member, as the principal investigator, must conduct the work ethically and with integrity while considering the principles of responsible conduct of research.
They are scientifically and programmatically responsible for the research project and are also responsible for disseminating and publicizing any scientific findings and discoveries from the project while balancing other duties and responsibilities such as teaching, doing public service and mentoring undergraduates, graduate students and post-doctoral scholars. A faculty member’s numbers and the quality of publication are some of the most important pieces of evidence of research output. It is an opportunity for the faculty member to prove to themselves and others that they are subject matter experts in their fields while presenting “a description of the work undertaken, report of the results, and an honest and open assessment of the findings” (Steneck, 2007, p. 134).

1.3 Why Publish Scientific Findings?

There are several salient factors to publishing scientific findings since a faculty member’s publications are also the vehicle for the “communication and the exchange of research findings and results” (Ramsden, 1994, p. 207), and one of the factors is to promote and ensure accountability. Since the public often supports the research when the research is federally funded, they should be able to access information on the research to see how the funding is being used. Another salient factor to publishing results is that it allows for researchers and scientists to share and communicate their findings and discoveries. Another aspect of publications is that it establishes a researcher’s reputation and professional standing, which could lead to opportunities to collaborate with other researchers as well as industry. Finally, when scientific results are published in peer-reviewed journals, other researchers can replicate those published results and cite the publications to support their own research thus increasing the original author’s visibility and influence in the scientific community. The frequency of a faculty member’s publication being cited (i.e., citation count) can be used to assess the level of research impact for his/her
specific research discipline. For that reason, citation counts are an important contributing factor for grant applications, employment, tenure, promotion, collaborating and publishing opportunities.

1.4 Reported R&D Expenditures and Publication Output

The National Science Foundation published the R&D expenditures on its website and reported that the R&D expenditures for Fiscal Year (FY) 2018 increased by 5% from FY 2017, reaching a total of approximately $79 billion dollars, and that is 118% increase from FY 2002. Figures 2, 3, 4 and 5 display the FY 2018 R&D expenditures by major R&D fields and sub-fields. Then, in December 2019, the National Science Board’s Science and Engineering Indicators reported that the global publication output was 2.6 million for 2018 and the United States’ publication output was 422,808 or 16.54% of the global total publication output. Figures 6 and 7 show the United States’ 2018 publication output by fields in percentages and in numbers.

1.5 Closing Statement

Two datasets were created by utilizing available data to explore research productivity at the institutional level (Table 1) and at the per faculty level (Figure 8). Both datasets were analyzed using regression analysis at a .05 level of probability to determine whether the relationships among the variables were statistically significant.
Figure 2

R&D Expenditure by Major R&D Fields

![Pie chart showing R&D expenditure by major fields: Science, Engineering, and Non-S&E.](image)

Figure 3

R&D Expenditure by R&D Sub-Fields in Sciences

![Pie chart showing R&D expenditure by sub-fields in sciences: Computer and information sciences, Geosciences, atmospheric sciences, and ocean sciences, Life sciences, Mathematics and statistics, Physical sciences, Psychology, Social sciences, Sciences, nec.](image)
Figure 4

R&D Expenditure by R&D Sub-Fields in Engineering

Figure 5

R&D Expenditures by R&D Sub-Fields in Non-Science and Engineering
Figure 6

Publication Output by Fields in Percentages FY 2018

- Agricultural sciences
- Astronomy and astrophysics
- Biological and biomedical sciences
- Chemistry
- Computer and information sciences
- Engineering
- Geosciences, atmospheric, and ocean sciences
- Health sciences
- Materials science
- Mathematics and statistics
- Natural resources and conservation
- Physics
- Psychology

Figure 7

Publication Output by Fields in Numbers FY 2018

- Agricultural sciences
- Astronomy and astrophysics
- Biological and biomedical sciences
- Chemistry
- Computer and information sciences
- Engineering
- Geosciences, atmospheric, and ocean sciences
- Health sciences
- Materials science
- Mathematics and statistics
- Natural resources and conservation
- Physics
- Psychology
2. REVIEW OF THE LITERATURE

In an institution’s faculty “selection, appointment, promotions and research grants approval processes” (Jawaid, 2016, p. 1), the number of publications is viewed as a critical return on investment measure on a faculty member’s productivity, achievements and “academic distinction” (Ramsden, 1994, p. 207). According to Schimanski and Alperin (2018), an institution’s tenure and promotion requirements and processes have evolved to emphasize research and publications. The authors referenced a survey with faculty in an R1 institution where the faculty perceived that the relative importance of research was weighted at 65%, teaching at 25.6% and service at 8.7% during the tenure and promotion review process. In that instance, faculty may feel the pressure to publish and focus their attention on research and neglect the other two areas even though the institution may have policies on fair, equitable and transparent review on teaching, research and service. In addition, the faculty felt that those percentages should be changed to 49.3% for research, 37.3% for teaching and 13.5% for service, shifting the emphasis towards teaching and service.

There are institutions that have explicit publication and performance expectations that a faculty member is required to meet for tenure and promotion. For instance, the University of Missouri expects their faculty “to produce an average of 2 publications per year in high quality refereed scholarly journals” (University of Missouri, 2020). The University of South Florida (USF) have a tenure probationary period of 7 years and expects its humanities faculty to “publish 2-4 high quality, predominantly refereed book chapters or articles and should have approximately 10 high quality, predominantly refereed publications” (University of South Florida, 2014). Virginia Tech did not specify the number of publications required for faculty promotion and tenure; however, there is an emphasis on publishing in elite journals and
“research publication must be of enough substance to garner growing national recognition for the faculty member’s program of research” (vt.edu, 2020).

Schimanski and Alperin (2018) further asserted that research institutions may have standard guidelines and checklists pertaining to the major areas (i.e., research, teaching and service) essential to the review and evaluation process of a faculty’s tenure and promotion. Those guidelines and checklists appeared to place higher weight on research as compared to teaching and service. Linfield College, for example, has a faculty handbook on tenure and promotion where there is a focus on teaching effectiveness. However, there is an extensive section on professional achievement that specifies the necessary items “for tenure and promotion for both associate and full professor” (Linfield College, 2016, p. 4) with the first item as “research and scholarship leading to peer-reviewed publication of books (including textbooks or articles or chapters in edited books), monographs, or professional journal articles in Sociology or Anthropology, or interdisciplinary work in related fields” (Linfield College, 2016, p. 4)

Research institutions would also use publication output as an indicator to determine an institution’s and its faculty’s research productivity and performance for resources and infrastructure planning and allocation. McAllister and Wagner (1981) utilized two large data sources from the National Science Foundation and CHI Research to study the link between research expenditures and research output (i.e., quantity of scientific journal articles). The authors pointed out that there was a study done to investigate “the relationship between NIH funding and biomedical publication output for major NIH funded institutions” (McAllister & Wagner, 1981, p. 4), and there was a positive correlation between the variables of NIH funding and publication output. For their study, McAllister and Wagner analyzed their data using
correlation and regression analysis and found a strong correlation between research expenditures and publication output.

Additionally, Teodorescu (2000) did a study on the publication productivity of faculty across 10 countries (Australia, Brazil, Chile, Hong Kong, Israel, Japan, Korea, Mexico, the United Kingdom and the United States). The author found that faculty members in research institutions are expected to conduct research as part of their academic performance evaluation while cultivating and producing new ideas and training students in research methods. He further asserted that most of the studies on research productivity occurred in developed countries such as the United States, United Kingdom and Australia. For his study, he developed a survey for respondents to provide information on “the number of journal articles and chapters on academic books that had been published in the three years prior to the survey” (Teodorescu, 2000, p. 206). He then did the analysis based on three blocks of variables - Individual Attributes (e.g., age and gender), Individual Accomplishments (e.g., tenure status or amount of research funding received) and Institutional Attributes (e.g., salary or institutional financial and research support) - and discovered that individual accomplishments and achievement has a strong correlation with publication productivity. Teodorescu concluded that while there may be a distinct difference on the variables that correlates to publication productivity across research institutions globally, he found that accessibility to research grant funding and network opportunities in international professional conferences had a positive effect on publication productivity.

Sivertsen (2010) described a system implemented in Norway in 2005 using publication output as a performance indicator for funding and resource allocation and distribution. The main goal of this system was to have a multi-purpose database with all the “scientific and scholarly publications” (Sivertsen, 2010, p. 25) so that it can be accessed by institutions and the
government when making funding decisions and preparing annual reports, curriculum vitae and grant applications. The author further elaborated that each institution shares ownership of the database to ensure that the publication records are complete and consistent with the definitions and guidelines agreed by the institutions. The publications are counted with points given at the institutional level and that information is used to allocate “direct block funding” (Sivertsen, 2010, p. 26). The author concluded that institutions have the shared responsibility to facilitate research for their faculty members and research scientists, and the system is implemented to stimulate and encourage scientific output from institutions.

To complement publication output, research institutions could also use citation count as a performance indicator to measure a faculty member’s reach, impact, influence and visibility in the scientific community. Carpenter, Cone and Sarli (2014) provided insights into a variety of metrics derived from publication data for measuring academic productivity. They added that these metrics provide “meaningful narrative” (Carpenter, Cone & Sarli, 2014, p. 1162) of a faculty member’s “research and scholarly activities” (Carpenter, Cone & Sarli, 2014, p. 1162), and institutions can use them for various purposes such as academic promotions, recruitment, grant applications and departments’ or institutions’ annual reports.

Carpenter, Cone and Sarli (2014) continued with a discussion on what publication metrics are currently being used: publication numbers, author status (solo, first or last author), journal impact factor score, and citation numbers. Both the journal impact factor impact score and citation numbers are most commonly used to assess an author’s research impact and influence. The authors then described citation analysis as a tool to determine “how often subsequent publications cite a specific publication” (Carpenter, Cone and Sarli, 2014, p. 1165). However, they cautioned the use of citation counts since there are more time for older
publications to build up citations counts as compared to newer publications. Another peculiar characteristic of citation count is that it “can be manipulated by deliberate self-citation or reciprocal citations by colleagues” (Carpenter, Cone and Sarli, 2014, p. 1166). They then introduced document-level metrics which captures data “to determine how a work is read online, downloaded, shared among others, commented upon, recommended, viewed and saved in online reference managers” (Carpenter, Cone & Sarli, 2014, p. 1168).

In the end, each performance indicator discussed has its nuance and usefulness for measuring research output, impact and productivity; however, one size does not fit all. Therefore, it is important for a research institution to be flexible and thoughtful when implementing and integrating various types of performance indicators, such as total R&D expenditures, publication output and citation count to measure research impact and productivity. This is to ensure fairness, transparency and consistency during an institution’s review of its policies and also during its faculty members’ academic performance evaluation.
3. PROBLEM STATEMENT

For this thesis, available data were used to explore research productivity at the institutional level by examining R&D expenditures and publication output and to also explore research productivity at the faculty level by exploring a faculty member’s publication output, citations of the publications and R&D expenditures to answer the questions: Are R&D expenditures associated with research output (publications) at the institutional level? Are a faculty member’s R&D expenditures related to publications and citations? Are there significant relationships among these variables: publication numbers, citation numbers, and R&D expenditures?
4. METHODOLOGY

4.1 Dataset No. 1: Institutional View

The first dataset, shown in Table 1, was created to look at the research productivity landscape at the institutional level and has the column headings: Year, Fractional Publication Count (i.e., fractional credit given for a publication for each institution proportion to the participating authors from each institution), Whole Publication Count (i.e., full credit given for a publication for each institution type that is on the author’s list) and R&D Expenditures. This combination of variables – Total R&D expenditures with total whole publication count and total R&D expenditures with total fractional publication count – was analyzed through regression analysis. The data for the first dataset was taken from the National Science Board’s Science and Engineering Indicators and the National Science Foundation’s Higher Education Research and Development Survey.

Table 1

Publication Count, R&D Expenditures and Faculty Count: 2002-2018

<table>
<thead>
<tr>
<th>Year</th>
<th>Fractional Publication Count</th>
<th>Whole Publication Count</th>
<th>R&amp;D Expenditures (Dollars in million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>319,308</td>
<td>358,181</td>
<td>36,383</td>
</tr>
<tr>
<td>2003</td>
<td>329,399</td>
<td>379,446</td>
<td>41,470</td>
</tr>
<tr>
<td>2004</td>
<td>353,853</td>
<td>407,443</td>
<td>44,839</td>
</tr>
<tr>
<td>2005</td>
<td>384,573</td>
<td>443,943</td>
<td>47,535</td>
</tr>
<tr>
<td>2006</td>
<td>385,515</td>
<td>448,696</td>
<td>49,645</td>
</tr>
<tr>
<td>2007</td>
<td>391,910</td>
<td>459,143</td>
<td>51,590</td>
</tr>
<tr>
<td>2008</td>
<td>393,979</td>
<td>463,386</td>
<td>54,114</td>
</tr>
<tr>
<td>2009</td>
<td>399,350</td>
<td>472,771</td>
<td>57,288</td>
</tr>
<tr>
<td>2010</td>
<td>408,817</td>
<td>486,363</td>
<td>61,287</td>
</tr>
<tr>
<td>2011</td>
<td>423,959</td>
<td>506,948</td>
<td>65,274</td>
</tr>
<tr>
<td>2012</td>
<td>427,997</td>
<td>517,473</td>
<td>65,873</td>
</tr>
<tr>
<td>2013</td>
<td>429,570</td>
<td>525,373</td>
<td>67,145</td>
</tr>
<tr>
<td>Year</td>
<td>R&amp;D Expenditures</td>
<td>Total Faculty</td>
<td>Faculty Publications</td>
</tr>
<tr>
<td>------</td>
<td>------------------</td>
<td>---------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>2014</td>
<td>433,192</td>
<td>535,617</td>
<td>67,351</td>
</tr>
<tr>
<td>2015</td>
<td>429,989</td>
<td>537,423</td>
<td>68,695</td>
</tr>
<tr>
<td>2016</td>
<td>427,265</td>
<td>541,080</td>
<td>71,894</td>
</tr>
<tr>
<td>2017</td>
<td>432,216</td>
<td>552,148</td>
<td>75,328</td>
</tr>
<tr>
<td>2018</td>
<td>422,808</td>
<td>548,847</td>
<td>79,436</td>
</tr>
</tbody>
</table>

4.2 **Dataset No. 2: Per Faculty View**

The second dataset, shown in Figure 8, was created by randomly selecting 75 institutions from 646 institutions from the National Science Foundation’s Higher Education Research and Development Survey for Fiscal Year 2018 using the function `{=rand()}` in Excel. The purpose of this smaller dataset was to explore the relationships between R&D expenditures, publication count and citations at the individual faculty level. The faculty count (with faculty status) for each institution was taken from the human resources data in Institute of Education Sciences-National Center for Education Statistics’ Integrated Postsecondary Education Data System.

The total publication number was taken from the institution output from Web of Science’s Advanced Search option based on the following criteria specified in the Advanced Search option. The citation numbers for each institution was taken from the Create Citation Report option available in Web of Science. Next, the publication (Web of Science) per faculty ratio was calculated for the 75 sampled institutions. The R&D expenditures per faculty was also calculated followed by the citation (Web of Science) per faculty. A regression analysis was done...
on the second data set to determine if there was a statistically significant relationship at the .05 level among this combination of variables: R&D expenditures per faculty with publication count per faculty and R&D expenditures per faculty with citation per faculty.

Figure 8

75 Sampled Institutions ranked by R&D expenditures with Ratios: Publication per faculty, R&D Expenditures per faculty and Citation per Faculty
5. DATA ANALYSIS

5.1 Analysis of Dataset No. 1

Table 1 showed an average annual increase of 2% in the total fractional publication count (i.e., fractional credit given for a publication for each institution proportion to the participating authors from each institution) beginning FY 2002 and then an average decrease of 1% for FYs 2015, 2016 and 2018. The total whole publication count (i.e., full credit given for a publication for each institution type that is on the author’s list) showed an average annual increase of 3% until FY 2017 with a 1% decrease for FY 2018. Finally, the total R&D expenditures showed an average annual increase of 5% from FY 2002 to FY 2018. The relationships among the variables - total R&D expenditures, total whole publication count and total fractional publication count - from the first dataset were tested for statistical significance using regression analysis at the significance value of .05.

The total R&D expenditures and the total whole publication count were first analyzed using the regression data analysis add-in feature in Excel and resulted in an $R^2$-value of 0.9551 and a significance $F$ of $1.6075 \times 10^{-11}$, which meant that there was a statistically significant relationship (See Summary Output in Table 2 and Line Fit Plot in Figure 9). Regression analysis was also done on the total R&D expenditures and the total fractional publication count, and it revealed a statistically significant relationship with an $R^2$-value of 0.8499 and a significance $F$ of $1.447 \times 10^{-7}$, (See Summary Output in Table 3 and Line Fit Plot in Figure 10).
Table 2

Summary Output: Total R&D expenditures and Total Whole Publication Count

<table>
<thead>
<tr>
<th>Regression Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple R</td>
</tr>
<tr>
<td>R Square</td>
</tr>
<tr>
<td>Adjusted R Square</td>
</tr>
<tr>
<td>Standard Error</td>
</tr>
<tr>
<td>Observations</td>
</tr>
</tbody>
</table>

ANOVA

<table>
<thead>
<tr>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Significance F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>5.4939E+10</td>
<td>5.4939E+10</td>
<td>319.192536</td>
</tr>
<tr>
<td>Residual</td>
<td>15</td>
<td>2581764920</td>
<td>172117661</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>5.752E+10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 9

Line Fit Plot with Variables: Total R&D expenditures and Total Whole Publication Count
Table 3

Summary Output: Total R&D expenditures and Total Fractional Publication Count

<table>
<thead>
<tr>
<th>Regression Statistics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple R</td>
<td>0.92189907</td>
</tr>
<tr>
<td>R Square</td>
<td>0.8498979</td>
</tr>
<tr>
<td>Adjusted R Square</td>
<td>0.83989109</td>
</tr>
<tr>
<td>Standard Error</td>
<td>14422.0399</td>
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<tr>
<td>Observations</td>
<td>17</td>
</tr>
</tbody>
</table>

ANOVA

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Significance F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>1.7665E+10</td>
<td>1.7665E+10</td>
<td>84.9319782</td>
<td>1.447E-07</td>
</tr>
<tr>
<td>Residual</td>
<td>15</td>
<td>3119928503</td>
<td>207995234</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>2.0785E+10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 10

Line Fit plot with Variables: Total R&D Expenditures and Total Fractional Publication Count
5.2 **Analysis of Dataset No. 2**

The second dataset (Figure 8) was analyzed using regression analysis and was created to look at the per faculty data on R&D expenditures, publications and citation numbers. Regression analysis was first done on the variables: R&D expenditures per faculty and publication per faculty (Web of Science) and returned an $R^2$-value of 0.4753 and a significance $F$-value of $7.9147 \times 10^{-12}$ (see Summary Output in Table 4 and Line Fit Plot in Figure 11), which was less than the significance value of .05, thus indicating a statistically significant relationship between R&D expenditures per faculty and publication per faculty (Web of Science). The next variables that were tested were: R&D expenditures per faculty and citation per faculty (see Summary Output in Table 5 and Line Fit Plot in Figure 12). The resulting $R^2$-value was 0.7992 and the significant $F$-value was $3.7129 \times 10^{-27}$ demonstrated a statistically significant relationship existed.
Table 4

Summary Output: R&D expenditures per Faculty and Publication per Faculty (Web of Science)

<table>
<thead>
<tr>
<th>Regression Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple R</td>
</tr>
<tr>
<td>R Square</td>
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<tr>
<td>Adjusted R Square</td>
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<tr>
<td>Standard Error</td>
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<tr>
<td>Observations</td>
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<td>df</td>
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<tr>
<td>-----</td>
</tr>
<tr>
<td>Regression</td>
</tr>
<tr>
<td>Residual</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Figure 11

Line Fit Plot with Variables: R&D Expenditures per Faculty and Publication per Faculty (Web of Science)
Table 5

*Summary Output: R&D expenditures per Faculty and Citation per Faculty (Web of Science)*

<table>
<thead>
<tr>
<th>Regression Statistics</th>
<th></th>
</tr>
</thead>
<tbody>
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<td>0.79916435</td>
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**Figure 12**

*Line Fit Plot with Variables: R&D Expenditures per Faculty and Citation per Faculty (Web of Science)*
6. DISCUSSION OF DATA RESULTS

6.1 Research Objectives

The two research objectives for this thesis were to first explore research productivity at the institutional level by examining R&D expenditures and publication output and then to also explore research productivity at the faculty level by looking at a faculty member’s publication output, citations of the publications and R&D expenditures. The regression analyses revealed that there were direct correlations between R&D expenditures and publication numbers at the institutional level and between R&D expenditures, publication numbers and citation numbers at the per faculty level.

6.2 Discussion: Dataset No. 1

The first dataset, shown in Table 1, looked at research productivity at the institutional level for FY 2002 to 2018 by examining the total R&D expenditures and total publication count. The regression analysis on the first dataset revealed that there were positive significant relationships among the variables: Total R&D Expenditures, Total Whole Publication Count and Total Fractional Publication Count. The analysis further revealed that the total R&D expenditures was predictive of the total whole publication count and total fractional publication count. Therefore, R&D expenditures were strongly related with scientific literatures or publications. These positive relationships suggest that institutions getting more funding generate more publications. Therefore, the investment in funding pays off by increasing the productivity of the institution.

However, it was surprising to see such a high $R^2$ values from the analysis on the first dataset since the publication counts were relatively flat beginning FY 2011 with dips in FYs 2015, 2016, 2018 while total R&D expenditures showed an average annual increase of 5%.
There were some possible reasons for those flat years and dips in publications. One of those reasons could be due to the time lag from R&D expenditures to project completion to actual publications. Another reason could be the R&D expenditures were for research activities that may not result in peer-reviewed publications (e.g. conference and training grants). One other reason could be an institution’s shifting priorities (e.g., commercializing basic research) on research funding and activities, emphasizing patents, technology and product development as a way to diversify its core revenue.

6.3 Discussion: Dataset No. 2

The second dataset, shown in Figure 8, explored research productivity by looking at the per faculty data in R&D expenditures, publications and citations. The analyses revealed that there were positive significant relationships and that the R&D expenditures per faculty was predictive of publications per faculty and citations per faculty. So, a faculty member’s R&D funding was strongly associated with more publications (output) and citations (impact). These positive relationships suggest that researchers receiving more funding are generating more publications and those publications are being cited by other researchers more often. This also shows that those researchers successfully winning more funding are both more productive and have a greater impact.

Although R&D expenditures was predictive of publications and citations per faculty, those relationships should be interpreted cautiously. As previously discussed, citations have peculiar characteristics. For example, older publications will have more time to accumulate the necessary citation counts as opposed to the newer publications. Another example is a faculty member could engage in self-citation where the faculty member cites his/her own work excessively to drive up his/her citation counts. A faculty member can manipulate how he
published, for example, publishing the same scientific results/finding in different journals. Another example is “salami slicing” where the scientific results/findings are broken up into sections and those individual sections are published in different journals.

6.4 Closing Statement

In the end, R&D expenditures, publications and citations are just some of the indicators for examining research/academic productivity. It is possible for a faculty member without R&D funding to have high publication and citation numbers while also contributing to an institution’s publication and citation numbers as they may have other types of support instead of R&D funding, such as equipment loan, laboratory space usage and availability of special reagents or software, to perform research activities. They can also seek out available publication funding assistance in their institutions to support their publishing efforts. Another possibility is that they could agree to collaborate with colleagues who have R&D funding and publish the research findings jointly. Finally, faculty members can be selective in their choice of journals (e.g., high impact journals) for publishing their research and thus generating citations for those publications.
7. CONCLUSION

7.1 Finals Results

This study revealed statistically significant relationships existed among the variables for both datasets (Table 1 and Figure 8) which meant that one variable was strongly associated with the other variables. The more interesting relationship to take note of was in the per faculty data, shown in Figures 11 and 12, on publications (output) and citations (impact) as it revealed that R&D expenditures per faculty were predictive of publications per faculty and citations per faculty.

7.2 Final Thoughts

These positive relationships made sense since more productive research institutions and faculty members who received more R&D expenditures would have more publications and generate more citations for those publications. Consequently, research institutions and faculty members who had track records of being successful in receiving R&D funding are more likely to continue to be successful. However, this could create a “Matthew effect” meaning that a faculty member’s past success in receiving R&D funding has a positive effect for future funding, so the concentration of R&D funding is directed or allocated only to those who in past were successful. This could also create a fierce competitive research environment in a declining and an uncertain funding landscape and faculty members who were unsuccessful in the past may be discouraged to try to break into the process of getting R&D funding. Research institutions may need look at their resource allocation process so that financial resources are distributed to a wider range of researchers as a push and to encourage them to seek out R&D funding which could drive up publication numbers and eventually citation numbers.
7.3 *Future Studies and Actions*

This study also provided important insights by exploring one critical aspect of a faculty member’s productivity through R&D expenditures and limiting to peer-reviewed publications. It is important to acknowledge that a faculty member could also be productive in other critical aspects, such as teaching, public service and mentorship of undergraduate and graduate students and post-doctoral scholars. Therefore, these are some aspects with other document types (e.g., abstracts, book chapters and books) that should be explored in future studies to see the whole picture. To that end, research productivity should be explored with objectivity as R&D expenditures, publications and citations counts are just some of the variables that can be used as measures. These variables should be implemented with others, such as the total numbers of proposals submitted, patents, teaching, mentoring and peer review activities, to appropriately measure a faculty member’s research output and impact while providing a meaningful and compelling story of a faculty member’s academic performance.
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U.S. Department of Education. National Center for Education Statistics. Integrated


CURRICULUM VITAE

Yoke Dellenback
Research Administrator
University of California Davis
Davis, CA 95616
Telephone: (530) 752-3146
Email: ypdellenback@ucdavis.edu

Professional Profile
Research administrator with over 15 years of experience supporting faculty members, researchers and graduate students with pre- and post-award logistics in contracts and grants.

Education

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<td>San Jose State University</td>
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<td>Environmental Studies</td>
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<tr>
<td>Johns Hopkins University</td>
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<td>Research Administration</td>
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Certifications

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Work Experience

Dec 2010 – Present
University of California, Davis • Research Administrator 4

- Provide recommendations and implementation of new procedures to improve business processes through analysis and creative solution design and identify individual training needs and provide guidance and training on all aspects concerning contracts and grants
- Provide direction for all divisional research and special accounts including purchase approval, re-budgeting and closure, transfer of funds, and approval, initiation and/or supervision of financial transactions
- Establish a departmental budget review process to analyze and assess budget submissions according to impact, type of funding, and alignment with any existing programmatic objectives
- Interpret funding source guidelines and advise faculty, principal investigators and divisional personnel regarding proper account management required by University and sponsors

Apr 2008 – Dec 2010
University of California, Davis • Business Office Manager

- Prepared all grant proposals and contracts for paper submission and electronic submission to various private, state and federal sponsors
- Responsible for coordinating and administering all the department’s grants and contracts activities
- Provided analyses of department’s base/current funding, contracts and grants activities, recharge operation and rate schedules

Nov 2006 – Apr 2008
University of California, Davis • Account Manager

- Prepared all grant proposals and contracts for paper submission and electronic submission systems to various private, state and federal sponsors
- Acted as fiscal officer for numerous extramural accounts and for the department’s recharge account
- Acted as a resource for Department Chair and MSO regarding staff appraisal, merit and promotion review process, and recruitment in matters of policy and procedure interpretation

Professional Affiliations

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