Understanding Universities’ Scientific Performance: Virginia Commonwealth University and its Peer Institutions

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Overview

- Introduction
- Research Questions
- Data & Methods
- Analysis & Findings
- Implications
- Further Study
Why this study?

- Besides student retention and graduation, faculty’s research activities has been drawing more and more attention from
  - University administrators (concerns about producing new knowledge, institutional rankings, and ability to attract more funding)
  - Federal and state agencies (effective investments on research, national competitive advantages)
Ties directly to VCU’s mission and strategic plan (Quest for Distinction 2011-2017): a premier urban, public research university distinguished by its commitment to student success and research/knowledge discovery.

This necessitates a better understanding of research activities at VCU and how well VCU is doing against its peers in terms of scientific performance.
1. How do institutional revenue and R&D expenditure streams affect research activities (measured by numbers of journal publications) at public research universities at the institutional level?

2. How well does VCU do in terms of research activities as compared to its peer institutions in STEM areas?
Question 1 - Data and Methods

- Population:
  73 public research universities with Very High Research Activity designation (Carnegie Foundation 2015)

- Data (1985-2014):
  - **Publications**: English-language peer-reviewed journal articles (total articles and natural sciences articles) from Thomson-Reuters Web of Science
    - Co-authorship: if an article had authors from multiple institutions, it would appear in the count for each of these institutions.
Data and Methods (Cont.)

- **Revenues**: tuition & fees, appropriations, grants & contracts, sales of services, gifts, and other (from IPEDS Finance Survey)

- **R&D expenditures**: federal, state and local, industry, institutional, and other (from NSF Survey of R&D Expenditures)

  → Difference in institutional sizes is controlled by fall student FTE (from IPEDS Fall Enrollment Survey).

- **Numbers of doctoral degrees awarded annually** (from NSF Survey of Earned Doctorates)
Data and Methods (Cont.)

- Technical adjustments:
  - **Time lapse between revenues/expenditures and publications**: the length of publishing cycle varies by disciplines and journals. Most research in this area used 2- or 3-year time lag between actual research activities and publications (Daim, 2007). This study uses a time lag of 3 years.
  - **Adjusting for inflation**: all institutional revenues and R&D expenditures are adjusted by the Consumer Price Index (from Bureau of Labor Statistics) to account for changes in nominal values over time.
Data and Methods (Cont.)

- **Statistical methods and software**
  - Log-log regression with time trend, using STATA statistical software.
  - Response and predictor variables are transformed by natural logarithm.
  - Easy interpretation: estimated coefficients can be interpreted as elasticities. (For example, 10% increase in tuition and fees is associated with 5% increase in the number of publications.)
Data and Methods (Cont.)

General form of log-log regression with time trend:

\[ \log(Y) = \alpha + \beta_1 \log(X) + \beta_2 t + \varepsilon \]

- **Y** = dependent variable
- **\alpha** = constant
- **\beta_1** = coefficients of independent variables
- **\beta_2** = coefficient of time trend
- **X** = independent variables
- **t** = time trend
- **\varepsilon** = error term
## Effects of Revenues on Publications

<table>
<thead>
<tr>
<th>Source</th>
<th>Total Publications</th>
<th>SCI Publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuition</td>
<td>0.144***</td>
<td>0.148***</td>
</tr>
<tr>
<td>Grants</td>
<td>0.289***</td>
<td>0.372***</td>
</tr>
<tr>
<td>Sales</td>
<td>0.077***</td>
<td>0.085***</td>
</tr>
<tr>
<td>Appropriations</td>
<td>0.147***</td>
<td>0.182***</td>
</tr>
<tr>
<td>Gifts</td>
<td>0.022*</td>
<td>0.044***</td>
</tr>
<tr>
<td>Other</td>
<td>0.034***</td>
<td>0.031**</td>
</tr>
<tr>
<td>No. of PhD Degrees</td>
<td>0.666***</td>
<td>0.636***</td>
</tr>
<tr>
<td>Time trend (t)</td>
<td>0.006***</td>
<td>0.006**</td>
</tr>
<tr>
<td>Constant</td>
<td>-2.334***</td>
<td>-3.539***</td>
</tr>
<tr>
<td>Observations</td>
<td>1,881</td>
<td>1,881</td>
</tr>
<tr>
<td>Adj-R²</td>
<td>0.81</td>
<td>0.76</td>
</tr>
</tbody>
</table>

*p< 0.05, **p< 0.01, ***p< 0.001
Effects of Revenues on Publications

- Grants are the largest positive driver for publications.
- Tuition (half the magnitude of grants) is also positively correlated with academic publishing activities.

→ The positive relationship between tuition and publications suggests that students bear part of the costs of research (Ehrenberg et al, 2007).

→ Lehming (1997) also shows that research universities pay part of their research expenditures out of tuition as:
Effects of Revenues on Publications

• they did not attract enough research money for research activities
• federal regulations required cost-sharing
• to compensate under-recovery of indirect costs (construction/maintenance of buildings, labs, field stations...)

→ Although students bear at least some costs of research, they also benefit from the process as universities can use part of tuition to employ more and better faculty (Leslie et al, 2012).
Effects of Revenues on Publications

- Sales of services contribute to academic publishing activities modestly as these sales are mainly used to cover expenses of producing the services (Leslie et al, 2012).
- The impact of appropriations on publications is also of small magnitude as the majority of appropriation money is used for teaching activities at public institutions.
<table>
<thead>
<tr>
<th></th>
<th>Total Publications</th>
<th>SCI Publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal</td>
<td>0.395***</td>
<td>0.486***</td>
</tr>
<tr>
<td>State/Local</td>
<td>-0.051***</td>
<td>-0.042***</td>
</tr>
<tr>
<td>Industrial</td>
<td>0.057***</td>
<td>0.081***</td>
</tr>
<tr>
<td>Institutional</td>
<td>0.139***</td>
<td>0.186***</td>
</tr>
<tr>
<td>Other</td>
<td>-0.003</td>
<td>-0.004</td>
</tr>
<tr>
<td>No. of PhD Degrees</td>
<td>0.610***</td>
<td>0.560***</td>
</tr>
<tr>
<td>Time trend (t)</td>
<td>0.012***</td>
<td>0.009***</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.313**</td>
<td>-1.363***</td>
</tr>
<tr>
<td>Observations</td>
<td>1,559</td>
<td>1,559</td>
</tr>
<tr>
<td>Adj-R²</td>
<td>0.81</td>
<td>0.77</td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01, ***p < 0.001
Effects of R&D Exp. on Publications

- Federal R&D expenditures are the most significant predictors for publications.
- State and local R&D expenditures are negatively correlated with publishing activities.
- Federal and state investments in higher education are different in nature. Federal funds account for a major part of universities’ R&D funds, whereas state and local funds primarily pay for general operations (Urahn et al., 2015).
Effects of R&D Exp. on Publications

- Institutional R&D expenditures are also positively correlated with publications, but with a much smaller magnitude.

- R&D expenditures from the industry have modest relationship with publications.

  - Big corporations have their own research arms and therefore funding of university research from the industry is not as much as from the federal government.

  - The industry is also a competitor of universities for federal research funding.
Summary

- On the revenue side, grants and tuition are the major predictors for publications. Sales of services, although generating a lot of revenue, contribute little to research activities. Similarly, appropriations are modestly correlated with publications.

- On the R&D expenditure side, federal R&D funds play the major role in predicting publications. Public universities receive a lot of funds from state/local government, but most of these funds are not spent on research activities. Likewise, institutional and industrial R&D expenditures have modest impact on academic publications.
### Key Metrics on Student Success

<table>
<thead>
<tr>
<th>University</th>
<th>First-year retention (F2014 cohort)</th>
<th>Six-year graduation (F2009 cohort)</th>
<th>High-school GPA (F2015 cohort)</th>
<th>Student/Faculty Ratio (F2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virginia Commonwealth University</td>
<td>86% (4)</td>
<td>62% (4)</td>
<td>3.64 (4)</td>
<td>16:1 (1)</td>
</tr>
<tr>
<td>University of Alabama, Birmingham</td>
<td>79%</td>
<td>55%</td>
<td>3.66</td>
<td>18:1</td>
</tr>
<tr>
<td>University of Cincinnati</td>
<td>88% (1)</td>
<td>65%</td>
<td>3.48</td>
<td>18:1</td>
</tr>
<tr>
<td>University of Illinois, Chicago</td>
<td>82%</td>
<td>60%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Louisville</td>
<td>79%</td>
<td>53%</td>
<td>3.60</td>
<td>16:1 (1)</td>
</tr>
<tr>
<td>University of South Carolina</td>
<td>88% (1)</td>
<td>72% (1)</td>
<td>4.07 (1)</td>
<td>18:1</td>
</tr>
<tr>
<td>University of South Florida, Tampa</td>
<td>88% (1)</td>
<td>68%</td>
<td>3.94</td>
<td>24:1</td>
</tr>
</tbody>
</table>

(All numbers were obtained from 2015-16 Common Data Set.)
Question 2 - Data

- **Population**: VCU and its 6 Quest peers (Univ of Alabama-Birmingham, Univ of Cincinnati, Univ of Illinois-Chicago, Univ of Louisville, Univ of South Carolina-Columbia, Univ of South Florida-Tampa)

- **Data**: CWTS Leiden Ranking 2015 [http://www.leidenranking.com](http://www.leidenranking.com)
  
  (Thomson-Reuters, Leiden, Scopus, Google Scholar, Academic Analytics)
  

- **Three major metrics**: publication output, impact, and collaboration indicators
Leiden Ranking obtains data exclusively from Thomson-Reuters Web of Science and is based on core publications:

- Written in English
- Having at least one or more authors (i.e., no anonymous publications allowed)
- Was not retracted
- Appeared in core journals. (Book publications, conference proceedings, and publications in journals not indexed in Web of Science are not included.)

(http://www.leidenranking.com/methodology/)
Three major metrics of scientific performance:

- **Output** (based on publication counts): full counting (equal weight to all publications) vs. fractional counting (less weight to collaborative publications). Publication counts do not reveal the quality of the publications.
- **Impact indicators** (based on citations): self-citations excluded. Impact indicators can be used as a proxy of quality of publications.
- **Collaboration indicators** (based on co-authorship)
Two perspectives to look at scientific performance:

- **Size-dependent** (absolute numbers): universities with a larger publication output tend to perform better than universities with a smaller publication output.

- **Size-independent** (proportions, or percentages): corrected for the size of the publication output of a university → both larger and smaller universities may perform equally well.
# of publications per full-time faculty

**Total Journals**

1. Illinois, Chicago
2. Cincinnati
3. Alabama, Birmingham
6. VCU

**SCI Journals**

1. Illinois, Chicago
2. Cincinnati
3. Alabama, Birmingham
6. VCU
# of publications per full-time T/TTR faculty

**Total Journals**

1. Cincinnati
2. Illinois, Chicago
3. South Florida
5. VCU

**SCI Journals**

1. Cincinnati
2. Illinois, Chicago
3. Alabama, Birmingham
5. VCU
% of publications in top 1% most frequently cited

### All Sciences
1. Alabama, Birmingham
2. Cincinnati
3. South Florida
4. VCU

### Biomedical and Health Sciences
1. Alabama, Birmingham
2. Cincinnati
3. South Carolina
4. VCU

### Life and Earth Sciences
1. Illinois, Chicago
2. Alabama, Birmingham
3. South Carolina
7. VCU

### Mathematics and Computer Science
1. Alabama, Birmingham
2. South Carolina
3. South Florida
7. VCU

### Physical Sciences and Engineering
1. VCU
2. Alabama, Birmingham
3. South Florida

### Social Sciences and Humanities
1. Illinois, Chicago
2. South Carolina
3. South Florida
4. VCU
% of publications in top 10% most frequently cited

### All Sciences

- **1** Alabama, Birmingham
- **2** Cincinnati
- **3** VCU

### Biomedical and Health Sciences

- **1** Cincinnati
- **2** Alabama, Birmingham
- **3** VCU

### Life and Earth Sciences

- **1** Alabama, Birmingham
- **2** Illinois, Chicago
- **3** South Carolina
- **7** VCU

### Mathematics and Computer Sciences

- **1** South Florida
- **2** Illinois, Chicago
- **3** South Carolina
- **4** VCU

### Physical Sciences and Engineering

- **1** South Florida
- **2** VCU
- **3** Cincinnati

### Social Sciences and Humanities

- **1** Illinois, Chicago
- **2** VCU
- **3** Alabama, Birmingham
% of publications with short-distance co-authorship

- **All Sciences**
  1. Cincinnati
  2. Illinois, Chicago
  3. South Florida
  4. VCU

- **Biomedical and Health Sciences**
  1. Cincinnati
  2. Illinois, Chicago
  3. South Florida
  4. VCU

- **Life and Earth Sciences**
  1. Cincinnati
  2. Illinois, Chicago
  3. VCU

- **Mathematics and Computer Sciences**
  1. Louisville
  2. Illinois, Chicago
  3. Cincinnati
  4. VCU

- **Physical Sciences and Engineering**
  1. Illinois, Chicago
  2. Cincinnati
  3. Alabama, Birmingham
  4. VCU

- **Social Sciences and Humanities**
  1. Illinois, Chicago
  2. Cincinnati
  3. Alabama, Birmingham
  4. VCU
% of publications with long-distance co-authorship

<table>
<thead>
<tr>
<th>All Sciences</th>
<th>Biomedical and Health Sciences</th>
<th>Life and Earth Sciences</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 South Carolina</td>
<td>1 Louisville</td>
<td>1 South Carolina</td>
</tr>
<tr>
<td>2 Illinois, Chicago</td>
<td>2 Alabama, Birmingham</td>
<td>2 Louisville</td>
</tr>
<tr>
<td>3 Louisville</td>
<td>3 VCU</td>
<td>3 Alabama, Birmingham</td>
</tr>
<tr>
<td>7 VCU</td>
<td></td>
<td>6 VCU</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mathematics and Computer Sciences</th>
<th>Physical Sciences and Engineering</th>
<th>Social Sciences and Humanities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Louisville</td>
<td>1 Illinois, Chicago</td>
<td>1 South Carolina</td>
</tr>
<tr>
<td>2 Cincinnati</td>
<td>2 Cincinnati</td>
<td>2 VCU</td>
</tr>
<tr>
<td>3 Illinois, Chicago</td>
<td>3 South Carolina</td>
<td>3 South Florida</td>
</tr>
<tr>
<td>7 VCU</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# of patents granted (source: USPTO)

1. Illinois, Chicago
2. South Florida
3. South Carolina
7. VCU
# of patents granted per million R&D dollars

1. Illinois, Chicago
2. South Florida
3. South Carolina
6. VCU
Findings

- VCU has been steadily increasing its overall publication output in all observed fields, between 2006 and 2013.
- Numbers of publications per full-time faculty/full-time T&TR faculty reveal that VCU has a significant number of non-T&TR faculty.
- VCU ranks in the lower half as compared with its peers in terms of number of publications in all 5 fields.
- In terms of average number of citations, VCU is in the upper half of the peer group in biomedical, physical/engineering, and social sciences.
VCU has an average rank in terms of industrial collaboration. This may have several implications as VCU is an urban university with a very-high research activity designation.

Physical/engineering is the only field at VCU that ranks in the upper half of its peer group in terms of % of publications in top 1%. As a comparison, VCU has 3 fields that rank in the upper half in terms of % of publications in top 10% (biomedical, physical/engineering, and social sciences).

VCU seems to lag behind its peers in terms of the number of patents granted.
Further Study

- Analysis can be run at the departmental level as it is where research work is conducted.
- Did not examine the patterns of private research universities, which might be different from those of public research universities due to differences in revenue and expenditure streams.
Thank You
References

- Daim, T. et al. (2007). Time lag assessment between research funding and output in emerging technologies. DOI: http://dx.doi.org/10.1108/14636680710773812

