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Working Paper

Science metrics: The issues and new approaches

Working Paper Series des Rates für Sozial- und Wirtschaftsdaten, No. 159

Provided in Cooperation with:
German Data Forum (RatSWD)

Suggested Citation: Lane, Julia (2010) : Science metrics: The issues and new approaches, Working Paper Series des Rates für Sozial- und Wirtschaftsdaten, No. 159

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Science Metrics:
The Issues and New Approaches

Julia Lane

September 2010
The *RatSWD Working Papers* series was launched at the end of 2007. Since 2009, the series has been publishing exclusively conceptual and historical works dealing with the organization of the German statistical infrastructure and research infrastructure in the social, behavioral, and economic sciences. Papers that have appeared in the series deal primarily with the organization of Germany’s official statistical system, government agency research, and academic research infrastructure, as well as directly with the work of the RatSWD. Papers addressing the aforementioned topics in other countries as well as supranational aspects are particularly welcome.

*RatSWD Working Papers* are non-exclusive, which means that there is nothing to prevent you from publishing your work in another venue as well: all papers can and should also appear in professionally, institutionally, and locally specialized journals. The *RatSWD Working Papers* are not available in bookstores but can be ordered online through the RatSWD.

In order to make the series more accessible to readers not fluent in German, the English section of the *RatSWD Working Papers* website presents only those papers published in English, while the German section lists the complete contents of all issues in the series in chronological order.

Starting in 2009, some of the empirical research papers that originally appeared in the *RatSWD Working Papers* series will be published in the series *RatSWD Research Notes*.

The views expressed in the *RatSWD Working Papers* are exclusively the opinions of their authors and not those of the RatSWD.

The RatSWD Working Paper Series is edited by:

Chair of the RatSWD (2007/2008 Heike Solga; since 2009 Gert G. Wagner)

Managing Director of the RatSWD (Denis Huschka)
This paper documents the presentation slides of the 1st Distinguished Lecture of the German Data Forum (RatSWD), held on 15th September 2010 at the DIW Berlin.
Science Metrics: The Issues and New Approaches

Julia Lane

This presentation represents the views of the author and not of the institution she represents.

Overview

- Why Metrics Matter
- Conceptual Framework
  - The scientific challenge
  - The empirical challenge
- What’s Being Done in the US: STAR METRICS
  - What it is
  - Structure
  - Measuring outcomes: The Role of Incentives
  - Examining impact: The Role of Social and Domain Scientists
Why metrics matter

- Government
  - Advance basic science
  - Improve wellbeing of citizens
  => Affects level of funding
- Funding agencies
  - Want to identify and fund good science
  => Affects type of funding
- Academic institutions
  - Want to hire and retain good scientists
  - Want to demonstrate impact
  => Affects who does science

Administration Interest

- **Investment in Science**
  - American Recovery and Reinvestment Act
  - The National Academy of Sciences Speech, April 2009
- **Openness and transparency**
  - data.gov; open.gov; etc.
- **Evidence based policy**
  - Joint memo on “Science and Technology Priorities for the FY2012 Budget” : Science of Science Policy (is the only program listed by name – also in 2011)
- **Accountability**
  - ARRA Reporting Guidelines
  - Putting Performance First: Replacing PART with a new performance improvement and analysis framework
Administration Interest

Agencies, in cooperation with OSTP and OMB, should develop and sustain datasets to better document Federal science, technology, and innovation investments and to make these data open to the public in accessible, useful formats. Agencies should develop and regularly update their data sharing policies for research performers and create incentives for sharing data publicly in interoperable formats to ensure maximum value, consistent with privacy, national security, and confidentiality concerns.

Agencies should develop outcome-oriented goals for their science, technology, and innovation activities, establish timelines for evaluating the performance of these activities, and target investments toward high-performing programs in their budget submissions. Agencies should support the development and use of “science of science policy” tools that can improve management of their R&D portfolios and better assess the impact of their science, technology, and innovation investments.

FY12 Orszag-Holdren Memo, July 21 2010; reiterates August 4, 2009 memo; Science of Science Policy is only program mentioned by name

Congressional Interest
Public Interest

Jobs Matter

Mean what you say

THE WALL STREET JOURNAL

SCIENCE Stimulus Funds Called Wasteful

GLOU OE RAOPOEF

Science stimulus funds for scientific research are becoming a political issue for Republican skeptics who say they have identified some grants in evidence of wasteful spending.

The National Institutes of Health and National Science Foundation received a total of $5.2 billion between March and May for stimulus projects for fiscal 2009, agency records show. The National Institutes of Health received $3.5 billion, and the National Science Foundation received $1.7 billion. This amount includes thousands of grants totaling billions of dollars, including grants to universities and research institutions.

The National Institutes of Health have received 43,000 applications for stimulus funding, and the National Science Foundation has received 17,000 applications for stimulus funding.

The stimulus projects are intended to help the economy by creating jobs and encouraging research.

International Interest

EU2009.CZ

The global challenge

What science is really worth

Spendng on science is one of the best ways to generate jobs and economic growth, say research advocates. But as Colin Macotan reports, the evidence behind such claims is spotty.
Scientists Can Provide a ‘Black Box’ Answer

Or…Start To Develop A Scientific Framework

- Science of Science Policy Interagency Task Group
- The SoSP Roadmap
  - Published in November, 2008
  - Four guiding themes
  - Ten key questions
- December, 2008 Workshop
  - Engage the current community of practice
  - Interactive evaluation of Roadmap
Research Challenge: Conceptual

Need to describe and measure the creation, transmission and adoption of knowledge

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Defining the Set of Hypotheticals or Counterfactuals</td>
<td>A Scientific Theory</td>
</tr>
<tr>
<td>2</td>
<td>Identifying Causal Parameters from Hypothetical Population Data</td>
<td>Mathematical Analysis of Point or Set Identification</td>
</tr>
<tr>
<td>3</td>
<td>Identifying Parameters from Real Data</td>
<td>Estimation and Testing Theory</td>
</tr>
</tbody>
</table>


Research Challenges: Conceptual

- How to describe creation of knowledge?
  - Unit of analysis
  - Input measures
- How to describe transmission?
  - Networks
  - Technology
- How to describe adoption?
  - Lags
  - Proximal causes
- What structural model?
  - Linear
  - Outcome measures
- Fundamental challenge: Establishing counterfactuals
  - Selection bias
  - Random assignment not an option
Research Challenges: Empirical

- **Data Infrastructure**
  - Science agencies have balkanized proposal and award administration systems
  - Unit of analysis is awards – while appropriate unit is individuals
  - Typically limited data on postdocs, graduate students, undergraduate students
  - Limited data on subawards
  - Information captured only during funding period
  - Information typically captured manually, sporadically and in unstructured format
  - Outputs not linked to inputs or infrastructure investments in a systematic way.
  - Data not captured on people who DON’T get funded, so difficult to establish counterfactual
- **Heterogeneous sources of outcomes**
- **Changing nature of scientific communication**
- **Scientific Attribution**
  - Name disambiguation
  - Global enterprise

If we can automate the DNA sequencing, we can describe science investments!
STAR METRICS

Science and Technology in America’s Reinvestment – Measuring the Effects of Research on Innovation, Competitiveness and Science

What is STAR METRICS?

1. Data Infrastructure to capture impact of science investments.
2. Collaborative identification of data and data sources.
3. Explicit integration of domain and social scientists in development of metrics.
Basic Approach

Creating the Frame

- Start with basic unit of analysis
  - Science is done by scientists. Need to identify universe of individuals funded by federal agencies (PI, co-PI, RAs, graduate students etc.)
- Capture Inputs using existing data

Measuring outcomes

- Scientific
- Social
- Economic
- Workforce
Based on Existing Record Reporting

**STAR Pilot Project**

- **Agency**
  - Budget
  - Award
  - Record
- **Institution**
  - Endowment Funding
- **Financial System**
  - Disbursement
- **HR System**
  - Personnel
  - Hire
- **Procurement System**
  - Vendor
  - Buy
- **Subcontracting System**
  - Contractor
  - Engage
- **Existing Institutional Reporting**
- **Start-Up**
- **Papers**
- **Patents**

**Innovation Analysis**
- Jobs, Purchases, Contracts Benefit Analysis

**Detailed Characterization and Summary**

**STAR**
- Acquisition And Analysis
  - Direct Benefit Analysis
- Intellectual Property Benefit Analysis
Creating the Frame (and measuring jobs)

14 administrative data elements from awards, grants, HR or finance systems are provided to STAR Metrics on a quarterly basis...

- Award data
- Payroll Staff Information
- Non-Payroll Charges
- Sub-awards
- Indirect Cost Rate Proposal

...will yield these Quarterly pre-calculated reports...

- **Stimulus FTE Jobs** (ARRA) – with and without Overhead Job calculations
- **FTE Jobs and Positions** – All awards (with and without Overhead)
- **FTE Sub-awards** – All awards (with and without Overhead)
- **Vendor FTE’s (Jobs)** – All awards
- **Overhead Jobs** (calculated from Indirect Costs)
## Star Metrics Phase 1 – 14 Requested Data Elements

<table>
<thead>
<tr>
<th>Description</th>
<th>Element ID</th>
<th>Item</th>
<th>Data Source</th>
<th>Unit of Analysis</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information on Scientists and Awards</td>
<td></td>
<td>De-identified Employee ID #</td>
<td>University</td>
<td>Individual</td>
<td>Job Metrics</td>
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<tr>
<td></td>
<td>2</td>
<td>Federal Award ID #</td>
<td></td>
<td>Award</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>University Award ID #</td>
<td></td>
<td>Award</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Overhead charged</td>
<td></td>
<td>Award</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Occupational Classification</td>
<td></td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Proportion of time allocated to award</td>
<td></td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>FTE status</td>
<td></td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td>Information on Overhead</td>
<td>8</td>
<td>Proportion of overhead associated with salaries (from overhead cost proposal)</td>
<td>University</td>
<td>University</td>
<td>Job Metrics</td>
</tr>
<tr>
<td>Payments to vendors</td>
<td></td>
<td>Federal Award ID #</td>
<td>University</td>
<td>Award</td>
<td>Secondary Economic Impact</td>
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<td></td>
<td>9</td>
<td>University Award ID #</td>
<td></td>
<td>Award</td>
<td></td>
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<tr>
<td></td>
<td>10</td>
<td>Duns #</td>
<td></td>
<td>Vendor</td>
<td>Secondary Economic Impact</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Amount of Contract</td>
<td></td>
<td>Vendor</td>
<td></td>
</tr>
<tr>
<td>Subcontracts and subawards</td>
<td></td>
<td>Federal Award ID #</td>
<td>University</td>
<td>Award</td>
<td>Secondary Economic Impact</td>
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<td></td>
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<td>Award</td>
<td></td>
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<tr>
<td></td>
<td>13</td>
<td>Duns #</td>
<td></td>
<td>Subcontractor</td>
<td></td>
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<tr>
<td></td>
<td>14</td>
<td>Amount of Contract</td>
<td></td>
<td>Subcontractor</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** STAR Metrics - Jobs
### Local Economic Impact for UNIVERSITY OF MASSACHUSETTS DARTMOUTH

#### Total Jobs (SIMULATED DATA)

<table>
<thead>
<tr>
<th>County Name</th>
<th>County Code</th>
<th>Sub-Awards &amp; Vendor Jobs</th>
<th>Award FTEs, Sub-Award &amp; Vendor Jobs</th>
<th>Total Jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARNSTABLE</td>
<td>1</td>
<td>76</td>
<td>76</td>
<td>76</td>
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<tr>
<td>BERKSHIRE</td>
<td>3</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
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<tr>
<td>BRISTOL</td>
<td>5</td>
<td>100.7</td>
<td>861.4</td>
<td>931.1</td>
</tr>
<tr>
<td>DUKES</td>
<td>7</td>
<td>49.5</td>
<td>49.5</td>
<td>49.5</td>
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<tr>
<td>ESSEX</td>
<td>9</td>
<td>268.7</td>
<td>268.7</td>
<td>268.7</td>
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<tr>
<td>MIDDLESEX</td>
<td>17</td>
<td>123.8</td>
<td>123.8</td>
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<tr>
<td>NANTUCKET</td>
<td>19</td>
<td>5.8</td>
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<tr>
<td>NORFOLK</td>
<td>21</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
</tr>
</tbody>
</table>

Source: STAR Metrics - Jobs

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### Initial Jobs Impact of Science Expenditures for 5 universities Total Jobs

Source: STAR Metrics - Jobs Q3 2009 - Q2 2010 (fuzz factor applied)

Note: Map excludes Alaska, Hawaii, and Puerto Rico.
Measuring Outcomes: The Role of Incentives

1. Reduce Burden
2. Leverage Existing Data
3. Describe Impact
Reducing Burden: Use Existing Reports

Reducing Burden: The Brazilian Experience
“Facebook for Scientists”

- Information in VIVO can be used to create
  - Biosketches
  - Vitas
  - Annual reports
  - Department and research group web sites

- Information can be used to populate profiles in collaborative tools – portals, wikis, …

Leverage Existing Data:
- e.g. Developing Patent Database

Institutional Support:
- NSF SciSIP: 0830287, 0965259
- HBS: Department of Research
Visual Exploration - Overview

Visual Exploration - Drill Down
1. Knowledge Diffusion
Three links out
(Singh 2005)

2. Sources of Links
- Student graduation
- Inventor mobility
- Direct collaboration
(Fleming 2007)
Capturing Outcomes

Scientists create tags on their websites, collaborate through VIVO, or register through a LATTES like process.

New approaches discussed and validated with FDP.

STAR METRICS
1. Inhales information from scientists
2. Creates Progress Report for scientists to validate
3. Exhales information to agency reports

Agencies identify fields that can be inhaled from STAR METRICS.

Practical Application

Accelerating Innovation Research (AIR)

PROGRAM SOLICITATION
NSF 10-608

National Science Foundation
Directorate for Engineering
Industrial Innovation and Partnerships

Letter of Intent Due Date(s) (required) (due by 5 p.m. proposer’s local time):
December 01, 2010

Full Proposal Deadline(s) (due by 5 p.m. proposer’s local time):
February 01, 2011
D. Project Description:

Cannot exceed 15 pages, and must include the following:

- How the partnership will enable innovation that neither party could do as well or rapidly alone.
- How the partnership leverages the research and technology of the research alliance to accelerate innovation.
- How the partnership is expected to impact the development of an innovation ecosystem.
- A strategic plan and milestone chart with specific tasks and deliverables.
- Information on management and staffing.
- An assessment plan that will gauge the success of the partnership in creating an innovation ecosystem that includes the development of and justification for appropriate metrics. Proposers participating in the OSTP/NSF/NIH Federal Demonstration Partnership’s STAR METRICS program, (http://sites.nationalacademies.org/PGA/PGA_057188) are encouraged to contact their institutional representatives to identify ways in which the program could support this requirement.
- An education plan that shows how participating students will learn about innovation, entrepreneurship, and technology translation process.

Option 1 and Option 2 Assessment

OMB/OSTP Memorandum M-09-27 directed science and technology agencies to describe the expected outcomes from their research in relation to these four practical challenges and cross-cutting areas, providing quantitative metrics where possible, and describe how they plan to evaluate the success of various techniques to increase support for high-risk research.

In compliance with this memorandum, each annual and final project report should provide an explanation of the quantitative and qualitative metrics that have been used in evaluating the impact of their activities.

In order to reduce reporting and administrative burden, proposers are encouraged to use administrative records where possible. Universities participating in the OSTP/NIH/NSF/Federal Demonstration Partnership’s (FDPP) STAR METRICS program (http://sites.nationalacademies.org/PGA/PGA_057188) are encouraged to contact their institutional representatives to identify ways in which the program could support the evaluation of their activities.

The report should be filed in the activities and findings section of the annual and final reports.

Current Status

- NIH, NSF and OSTP MOU signed, DOE and EPA joining
- Partnership with Federal Demonstration Partnership, and engagement with AAU, APLU, COGR
- Over 100 academic institutions at various degrees of participation
- European Union engagement and emulation
What does this entail?

- Partner with Pis to
  - develop flow-based annual and final reports/biosketches
    - [http://ideas.repec.org/e/pla36.html](http://ideas.repec.org/e/pla36.html)
    - [http://citeseerx.ist.psu.edu/](http://citeseerx.ist.psu.edu/)
  - Visualizations of networks and impact
  - Collaborative tagging of research outputs etc.
  - Partner with university administrators to develop flow-based impact of science funding
Ultimate Goals for Development of Science Metrics

- Fully fledged academic field
- Fully fledged analytical tool set in government: Science policy in same analytical tier as tax policy
- Common, automated, empirical infrastructure available to all universities and science agencies to quickly respond to State, Congressional and OMB requests
- Incentive compatible structure
- Common scientific infrastructure for researchers to develop and study science metrics

Why metrics matter

- You can`t manage what you can`t measure
- And what you measure is what you get