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

International Interest

EU2009.CZ

EUROISIA Conclusions and Recommendations
The European Research and Development Impact Assessment (EURISIA) will cover the EU’s Research, Development and Demonstration Programmes (R&D&I) that contribute to the formation of the EU’s Innovation Union and the Lisbon Agenda. EURISIA is designed to inform the EU’s research and innovation policies, with a focus on the impact of its member states on science and innovation.

The global challenge
As world leaders gather in Paris to discuss the climate crisis, a report on the impact of science on the world’s future is timely. The report, published by the European Commission, highlights the importance of science and innovation in addressing global challenges.

What science is really worth
Spending on scientific research is one of the best ways to generate jobs and economic growth, say research advocates. But as Colin MacBean reports, the evidence behind such claims is patchy.
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
- **Research Project**
  - Papers
  - Patents
- **Start-Up**
  - Kids
- **Acquisition and Analysis**
  - Direct Benefit Analysis
  - Intellectual Property Benefit Analysis
  - Innovation Analysis
- **Jobs, Purchases, Contracts Benefit Analysis**
- **Detailed Characterization and Summary**

**Detailed Characterization and Summary**
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>1</td>
<td>De-identified Employee ID #</td>
<td>University</td>
<td>Individual</td>
<td>Job Metrics</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Federal Award ID #</td>
<td>University</td>
<td>Award</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>University Award ID #</td>
<td>University</td>
<td>Award</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Overhead charged</td>
<td>University</td>
<td>Award</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Occupational Classification</td>
<td>Individual</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Proportion of time allocated to award</td>
<td>Individual</td>
<td>Individual</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>FTE status</td>
<td>Individual</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>9</td>
<td>Federal Award ID #</td>
<td>University</td>
<td>Award</td>
<td>Secondary Economic Impact</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>University Award ID #</td>
<td>University</td>
<td>Award</td>
<td>Secondary Economic Impact</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Duns #</td>
<td>University</td>
<td>Vendor</td>
<td>Secondary Economic Impact</td>
</tr>
<tr>
<td>Subcontracts and subawards</td>
<td>12</td>
<td>Federal Award ID #</td>
<td>University</td>
<td>Award</td>
<td>Secondary Economic Impact</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>University Award ID #</td>
<td>University</td>
<td>Award</td>
<td>Secondary Economic Impact</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Duns #</td>
<td>University</td>
<td>Subcontractor</td>
<td>Secondary Economic Impact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Amount of Contract</td>
<td>University</td>
<td>Subcontractor</td>
<td>Secondary Economic Impact</td>
</tr>
</tbody>
</table>

**Local Economic Impact**

For University of Massachusetts Dartmouth

Total Jobs (SIMULATED DATA)

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>
</tr>
<tr>
<td>BERKSHIRE</td>
<td>3</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<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>
</tr>
<tr>
<td>ESSEX</td>
<td>9</td>
<td>268.7</td>
<td>268.7</td>
<td>268.7</td>
</tr>
<tr>
<td>MIDDLESEX</td>
<td>17</td>
<td>123.8</td>
<td>123.8</td>
<td>123.8</td>
</tr>
<tr>
<td>NANTUCKET</td>
<td>19</td>
<td>5.8</td>
<td>5.8</td>
<td>5.8</td>
</tr>
<tr>
<td>NORFOLK</td>
<td>21</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>643</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,404</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,474</td>
</tr>
</tbody>
</table>

Source: STAR Metrics - Jobs

### 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
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
Developing Metrics: Engage Domain and Social Scientists

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