Full paper

STI 2022 Conference Proceedings

Proceedings of the 26th International Conference on Science and Technology Indicators

All papers published in this conference proceedings have been peer reviewed through a peer review process administered by the proceedings Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a conference proceedings.

Proceeding Editors

Nicolas Robinson-Garcia
Daniel Torres-Salinas
Wenceslao Arroyo-Machado

OPEN ACCESS

Citation: Melkers, J., & Welch, E.(2022). Academic Research Competitiveness: Theorizing and Operationalizing a New Research Evaluation Framework. In N. Robinson-Garcia, D. Torres-Salinas, & W. Arroyo-Machado (Eds.), *26th International Conference on Science and Technology Indicators*, STI 2022 (sti22237). https://doi.org/10.5281/zenodo.6957591

Collection: https://zenodo.org/communities/sti2022grx/

Academic Research Competitiveness: Theorizing and Operationalizing a New Research Evaluation Framework [1]

Julia Melkers[*] and Eric Welch[**]

[*] *jmelkers@gatech.edu*
School of Public Policy, Georgia Institute of Technology, Cherry Street, Atlanta, GA 30033, USA

[**] *ericwelch@asu.edu*
Center for Science, Technology and Environmental Policy Studies, School of Public Affairs, Arizona State University, Phoenix, AZ, USA

Background

The funding of science for knowledge sake is no more, creating an increasingly complex charge for the research evaluation community in developing evaluative systems that support formative and summative information. Elected officials demand evidence that national scientific investment matter for society and the economy, including having relevant impacts to their specific constituencies. We focus on the mechanisms and structure of evaluation processes for federal research funding specific to the academic research environment, particularly large center-based and other team projects that typically have a broader charge beyond the core research. A large proportion of federal research dollars go to academic institutions (>$64 billion research grants in 2015) (NSF, 2018), yet the type of evidence appropriate to demonstrate the quality and outcomes of academic research activities, and to advance national competitiveness, is uneven. We argue that a comprehensive research evaluation system requires a framework that effectively sets the conduct, production, and outcomes of federally funded academic research programs in context.

One challenge for U.S. research funding agencies is the lack of an accepted framework for the theory of change specific to academic research activities and outcomes. Drawing from a multidisciplinary theoretical and empirical foundation, we present a multi-layered Academic Research and Competitiveness Framework (ARC) that incorporates the context, complexity, and temporal nature of academic research activities. We take a *systems oriented* approach in our argument for an improved approach to research evaluation, where institutions, academic and other organizations and groups interact to produce key knowledge, innovation and social outcomes (Bronfenbrenner, 1994). The system is non-linear and includes multiple feedback and feedforward pathways. In the education field, Bronfenbrenner's work (1979, 2005, 2009) on ecological systems theory posits four subsystems – micro, meso, exo, macro – that operate dynamically such that changes in anyone subsystem affects the others over time. The micro

subsystem refers to individual level experiences, meso captures an organizational dimensions, exo can be broadly understood to

[11] *We would like to acknowledge Fengxiu Zhang and Quintin Kreth for their assistance at early stages of this project. Ms. Zhang and Mr. Kreth are PhD students at ASU and Georgia Tech, respectively. We would also like to acknowledge feedback from the 2M project team and the input and advice received from four members of the project advisory board.*

address the network structures and relations that operate to connect and influence micro and meso structures, and the macrosystem comprises the broader social and institutional context within which the others are nested.

Similar to other systems approaches, these subsystems interact over time to shape a complex learning environment (Pickett & Cadenasso, 2002). Similarly, Edquist and others use an innovation systems approach to explain how institutional and organization factors interact to produce critical innovation outcomes (Edquist, 2009) In the systems of innovation (SI) approach, institutions include the laws, rules, regulations, norms and expectations that guide innovative behavior and outcomes from organizations, which include the universities, companies and government institutes that conduct research. The SI approach recognizes that institutions set resilient and enduring innovation pathways that result in national level innovation cultures. This approach also validates the contextual factors that affect outcomes of program investments.

We aim to contribute theoretically and conceptually to developing the ARC concept, design a theory of change (TOC) model that incorporates multiple dimensions of academic research competitiveness, and address implementation issues relevant to research evaluation processes and approaches. We ask:

- What is academic research and competitiveness? How can we integrate the relevant literature into a meaningful framework that recognizes system level complexities and multiple types of research outcomes?
- How can the framework be conceptualized as a theory of change that incorporates multiple dimensions relevant to the conduct and outcomes of academic research?
- How can we demonstrate the value of the framework and theory of change for evaluation of large team science and engineering research projects and portfolios?

We formulate this literature into a framework, which we then develop into a set of theory of change models that reflect the multilayered context in which academic research is conducted. **In the full version of this paper, we also use two large U.S. funding programs as examples of how this framework may be applied. We conclude with implications and a charge for improved practice and empirical research to the research evaluation community.

Complexities of Academic Research Evaluation

The nature of government funding of science in the U.S. presents challenges for evaluation, that are not currently addressed in existing evaluation guidelines nor norms in federal research agencies. Development of a more comprehensive approach to evaluation requires acknowledgement of several characteristics of the academic research funding context.

First, federal funding of STEM research has for some time focused on large teams and centerbased models, often involving multiple institutions and disciplines. Therefore, inclusion of characteristics of team development, cohesion, knowledge exchange, and structure

developed in the team science and organization literatures is important (Hall et al., 2018). *Second,* teams include faculty at various career stages as well as trainees who benefit from engagement in research. STEM workforce development is a central expectation in many of the National Science Foundation's center and large team-based programs but these are often not adequately or appropriately incorporated in evaluation approaches.

Third, public investment in large team-science research initiatives typically also carry expectations for broader impacts of research outcomes through various different forms of stakeholder engagement and science communication. *Fourth*, and perhaps most critical, is that while the majority of U.S. research funding is concentrated at the nation's most competitive institutions (NSF, 2018), the U.S. system includes almost 4,000 colleges and universities, with highly variable resources and missions, and located in geographic areas that offer different opportunities and constraints. The vitality of the U.S. academic research system depends both on federal government investment in research and the fundamental capacity of institutions and jurisdictions of all types to compete for and carry out research.

Methods

To inform both the policy and research evaluation communities, we propose a conceptual representation and flexible framework for articulating "academic research competitiveness" (ARC) to inform improved evaluative processes in the United States. To develop the framework, we conducted an environmental scan of the academic and grey literature. Our motivation was based on the observation that the policy dialogue specific to competitiveness is robust, yet measures of competitiveness are often narrow and typically linked to grantgetting ability and related successes. Our review identified academic journal articles focused on innovation, entrepreneurship, STEM education, gender and diversity, sociology of science, economic development, science policy, team science, research competitiveness, and highereducation. We also gathered reports from U.S. and International national policy organizations, state agencies, as well as university reports on competitiveness. Using a system common in literature synthesis(Belcher, Rasmussen, Kemshaw, & Zornes, 2016), we then organized this literature by common themes, incorporating an internal and external advisory expert review process. The results of our literature review sources and findings will be provided in the full conference paper and presentation.

This collection provided a comprehensive foundation for the study, identifying multiple characterizations, definitions and descriptions of research competitiveness. For example, research competitiveness is recognizable in some literatures as resource acquisition, attractiveness to key sources of knowledge and experience, dynamic knowledge and workforce production, and social impact and economic development including innovation and entrepreneurship. Using a key word-based tagging schema to code each article, our review produced several definitions and concepts related to academic research competitiveness articulated in the literature.

ARC Subsystems

From our review, we identified four different subsystem levels of analysis in the competitiveness literature. Using a systems-based approach, we depict the multi-faceted ecosystem in which academic research is conducted, embedded within institutions and jurisdictions or states.

Ecosystem Research Competitiveness (ERC) captures the macro-dimension of the ARC framework, which may correspond with political jurisdictions, such as states.
University/Institution Research Competitiveness (URC) recognizes that the unit of analysis is often a specific type of organization, such as a university, company or government laboratory.
Project Research Competitiveness (PRC) relates to the collaborative or team level of analysis.
Individual Research Competitiveness (IRC) addresses the researcher as a unit of analysis.

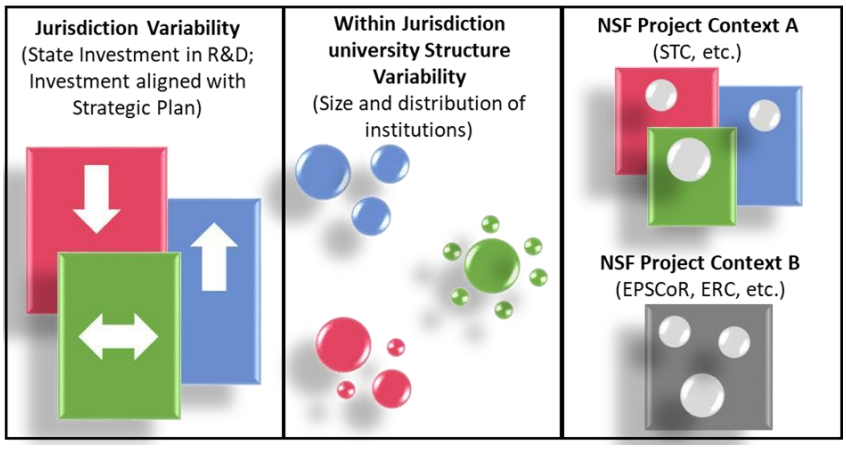
Given our systems-based approach, the theory of change based logic models at the ecosystem, university and project levels are embedded in each other as shown in Figure 1.
The rate of outcome driven change occurring in each subsystem differs significantly, such that capacity development, excellence and competitiveness is more rapidly achieved at the project/team level than at the university level, and so on. The development of theory of change based, embedded logic models is a critical step to identifying the relevant contextual factors and their interaction.

Figure 1: Embedded Systems for U.S. Academic Research

Ecosystem	University	Project/Team
Highly stable, cumulative impact on research capacity, excellence and competitiveness on a 20-50 year time frame	Stable, cumulative impact on research capacity, excellence and competitiveness on a 10 to 20 year time scale	Developing, impact on capacity, excellence and competitiveness on a 3-10 year time scale

Particularly relevant to the context of multi-institutional research funding programs, the composition and distribution of academic *institutions* within a jurisdiction also vary. As shown in the middle box of Figure 2, some states, such as California or Massachusetts have large systems with a number of high quality and productive universities. Other states, such as Wyoming, have exactly one public university. For institutions with lower research capacity emphasis may be placed on increasing credit hours to generate funds rather than more risky strategies of pursuing research grants.

Figure 2 Embeddedness of system components



ARC Framework Elements

From the literature review and key word schema, we also identified five primary dimensions of academic research competitiveness. These dimensions take different forms within the various layers of the ecosystem, and will be elaborated upon in the full conference paper:

Resource acquisition captures the ability to obtain funding and other resources at any level of analysis.
Knowledge production and workforce development represents the ability to leverage existing capacities and new investments to produce new knowledge and innovation.
Attractiveness recognizes the ability of actors at different levels of the ARC to compete in enticing others to join them.
Visibility/reputation involves the relative prominence of an entity at any of the different ARC levels.
Economic development considers competence and capacity for commercialization and potential contribution of research to industry.

Conclusion

An important product of this study is the development of a multidimensional framework for academic research competitiveness. The framework goes beyond the usual consideration of grant dollars the primary indicator of competitiveness, as it articulates the context and multiple factors that contribute to enhanced capacity to acquire resources in a competitive environment. The examples of the NSF EPSCoR and NSF CoPes programs illustrate these embedded complexities, laying the ground work for the development of improved metrics that account for the complex and varied contexts in which scientific research takes place.

References

Altbach, P. G., & Salmi, J. (2011). *The Road to Academic Excellence*. https://doi.org/10.1596/978-0-8213-8805-1

Belcher, B. M., Rasmussen, K. E., Kemshaw, M. R., & Zornes, D. A. (2016). Defining and assessing research quality in a transdisciplinary context. *Research Evaluation*, *25*(1), 1– 17. https://doi.org/10.1093/reseval/rvv025

Bozeman, B., Dietz, J. S., & Gaughan, M. (2001). Scientific and technical human capital: an alternative model for research evaluation. *International Journal of Technology Management*, *22*(7–8), 716–740.

Brint, S. (2006). *Can Public Research Universities Compete?* Berkeley, CA: ERIC.
Bronfenbrenner, U. (1994). Ecological models of human development. In *Readings on the development of children 2* (pp. 37–43).

Burris, V. (2004). The Academic Caste System: Prestige Hierarchies in PhD Exchange Networks. *American Sociological Review*, *69*(2), 239–264. https://doi.org/10.1177/000312240406900205

Capello, R., & Lenzi, C. (2014). Spatial heterogeneity in knowledge, innovation, and economic growth nexus: Conceptual reflections and empirical evidence. *Journal of Regional Science*, *54*(2), 186–214. https://doi.org/10.1111/jors.12074

Charlier, H. D. (2010). *The attraction of adjunct faculty to rural community colleges* (Old Dominion University). Retrieved from https://search.proquest.com/docview/304705453?pq-origsite=gscholar

Cohen, W. M., & Levinthal, D. A. (1990). *Absorptive Capacity : A New Perspective on and Innovation Learning*. *35*(1), 128–152.

Coryn, C. L. S., Noakes, L. A., Westine, C. D., & Schröter, D. C. (2011, June). A systematic review of theory-driven evaluation practice from 1990 to 2009. *American Journal of Evaluation*, Vol. 32, pp. 199–226. https://doi.org/10.1177/1098214010389321

Deiaco, E, Holmén, M., & McKelvey, M. (2009). What does it mean conceptually that universities compete? *Learning to Compete in European Universities: From Social Institution to Knowledge Business*, *3*(139), 300–328.

Deiaco, Enrico, Hughes, A., & McKelvey, M. (2012). Universities as strategic actors in the knowledge economy. *Cambridge Journal of Economics*, *36*(3), 525–541. https://doi.org/10.1093/cje/bes024

Edquist, C. (2009). Systems of Innovation: Perspectives and Challenges. *The Oxford Handbook of Innovation*. https://doi.org/10.1093/oxfordhb/9780199286805.003.0007

Feldman, M. P., Lanahan, L., & Lendel, I. V. (2014). Experiments in the Laboratories of Democracy: State Scientific Capacity Building. *Economic Development Quarterly*, *28*(2), 107–131. https://doi.org/10.1177/0891242413490018

Feller, I. (2000). *30 Strategic Options to Enhance the Research Competitiveness of EPSCoR Universities*.

Fritsch, M., & Franke, G. (2004). Innovation, regional knowledge spillovers and R&D cooperation. *Research Policy*, *33*(2), 245–255. https://doi.org/10.1016/S00487333(03)00123-9

Fumasoli, T., & Huisman, J. (2013). Strategic agency and system diversity: Conceptualizing institutional positioning in higher education. *Minerva*, *51*(2), 155–169.

García, C. E., & Sanz-Menéndez, L. (2005). Competition for funding as an indicator of research competitiveness. *Scientometrics*, *64*(3), 271–300.

Gazni, A., Larivière, V., & Didegah, F. (2016). The effect of collaborators on institutions' scientific impact. *Scientometrics*, *109*(2), 1209–1230. https://doi.org/10.1007/s11192016-2101-4

Ghinamo, M. L. (2012). Explaining the variation in the empirical estimates of academic knowledge spillovers. *Journal of Regional Science*, *52*(4), 606–634. https://doi.org/10.1111/j.1467-9787.2012.00764.x

González-Pernía, J. L., Kuechle, G., & Peña-Legazkue, I. (2013). An Assessment of the Determinants of University Technology Transfer. *Economic Development Quarterly*, *27*(1), 6–17. https://doi.org/10.1177/0891242412471847

Grimaldi, R., Kenney, M., Siegel, D. S., & Wright, M. (2011). 30 years after Bayh-Dole: Reassessing academic entrepreneurship. *Research Policy*, *40*(8), 1045–1057. https://doi.org/10.1016/j.respol.2011.04.005

Hall, K. L., Vogel, A. L., Huang, G. C., Serrano, K. J., Rice, E. L., Tsakraklides, S. P., & Fiore, S. M. (2018). The science of team science: A review of the empirical evidence and research gaps on collaboration in science. *American Psychologist*, *73*(4), 532–548. https://doi.org/10.1037/amp0000319

Hearn, J. C., Lacy, T. A., & Warshaw, J. B. (2014). State research and development tax credits: The historical emergence of a distinctive economic policy instrument. *Economic Development Quarterly*, *28*(2), 166–181.

Herrera, L., Muñoz-Doyague, M. F., & Nieto, M. (2010). Mobility of public researchers, scientific knowledge transfer, and the firm's innovation process. *Journal of Business Research*, *63*(5), 510–518.

Horwitz, S. K., & Horwitz, I. B. (2007). The Effects of Team Diversity on Team Outcomes: A Meta-Analytic Review of Team Demography. *Journal of Management*, *33*(6), 987–1015. https://doi.org/10.1177/0149206307308587

Knowlton, L. W., & Phillips, C. (2012). *The Logic Model Guidebook: Better Strategies for Great Results*.

Lambright, W. H. (2000). Catalyzing Research Competitiveness: The Georgia Research Alliance. *Prometheus*, *18*(4), 357–372. https://doi.org/10.1080/08109020020008488

Lanahan, L. (2016). Multilevel public funding for small business innovation: a review of US state SBIR match programs. *Journal of Technology Transfer*, *41*(2), 220–249. https://doi.org/10.1007/s10961-015-9407-x

Leonard, D., & Sensiper, S. (1998). The Role of Tacit Knowledge in Group Innovation. *California Management Review*, *40*(3), 112–132. https://doi.org/10.2307/41165946

Leslie, L. L., & Ramey, G. (1988). Donor Behavior and Voluntary Support for Higher Education Institutions. *The Journal of Higher Education*, *59*(2), 115–132. https://doi.org/10.2307/1981689

Mayer, H. (2010). Catching Up: The Role of State Science and Technology Policy in Open Innovation. *Economic Development Quarterly*, *24*(3), 195–209. https://doi.org/10.1177/0891242410366563

Melkers, J., & Wu, Y. (2009). Evaluating the improved research capacity of EPSCoR states: R&D funding and collaborative networks in the NSF EPSCoR program. *Review of Policy Research*, *26*(6), 761–782.

Mukherji, N., & Silberman, J. (2013). Absorptive Capacity, Knowledge Flows, and Innovation in U.S. Metropolitan Areas*. *Journal of Regional Science*, *53*(3), 392–417. https://doi.org/10.1111/jors.12022

Münch, R., & Baier, C. (2012). Institutional Struggles for Recognition in the Academic Field: The Case of University Departments in German Chemistry. *Minerva: A Review of Science, Learning & Policy*, *50*(1).

Nagle, M. (2007). Canonical Analysis of University Presence and Industrial Comparative Advantage. *Economic Development Quarterly*, *21*(4), 325–338. https://doi.org/10.1177/0891242407304022

Nahapiet, J., & Ghoshal, S. (1998). Social capital, intellectual capital, and the organizational advantage. *Academy of Management Review*, *23*(2), 242–266.

Owen-Smith, J., & Powell, W. W. (2001). To patent or not: Faculty decisions and institutional success at technology transfer. *The Journal of Technology Transfer*, *26*(1), 99–114.
Parent, O., & Lesage, J. P. (2012). Determinants of knowledge production and their effects on regional economic growth. *Journal of Regional Science*, *52*(2), 256–284. https://doi.org/10.1111/j.1467-9787.2011.00732.x

Perkmann, M., King, Z., & Pavelin, S. (2011). Engaging excellence? Effects of faculty quality on university engagement with industry. *Research Policy*, *40*(4), 539–552. https://doi.org/10.1016/j.respol.2011.01.007

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., … Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university-industry relations. *Research Policy*, *42*(2), 423–442. https://doi.org/10.1016/j.respol.2012.09.007

Pickett, S. T. A., & Cadenasso, M. L. (2002). The Ecosystem as a Multidimensional Concept: Meaning, Model, and Metaphor. *Ecosystems*, *5*(1), 1–10. https://doi.org/10.1007/s10021001-0051-y

Pietilä, M. (2014). The many faces of research profiling: academic leaders' conceptions of research steering. *Higher Education*, *67*(3), 303.

Piro, F. N., Rørstad, K., & Aksnes, D. W. (2016). How does prolific professors influence on the citation impact of their university departments? *Scientometrics*, *107*(3), 941–961. https://doi.org/10.1007/s11192-016-1900-y

Porter, M. E. (2003). The economic performance of regions. *Regional Studies*, *37*(6–7), 549–578. https://doi.org/10.1080/0034340032000108697

Rafols, I., & Meyer, M. (2010). Diversity and network coherence as indicators of interdisciplinarity: case studies in bionanoscience. *Scientometrics*, *82*(2), 263–287.

Smilor, R., & O'Donnell, N.; Stein, G. Welborn, R. S. (2007). The research university and the development of high-technology centers in the United States. *Economic Development Quarterly*, *21*(3), 203–222. https://doi.org/10.1177/0891242407299426

Stephens, H. M., Partridge, M. D., & Faggian, A. (2013). Innovation, entrepreneurship and economic growth in lagging regions. *Journal of Regional Science*, *53*(5), 778–812. https://doi.org/10.1111/jors.12019

Swartz, J. E., Swartz, T. A., & Liang, P. (2007). Market meltdown: Recruiting qualified business faculty. *Journal of Education for Business*, *82*(6), 337–342.

Trauth, E. M., DiRaimo, M., Hoover, M. R., & Hallacher, P. (2015). Leveraging a Research University for New Economy Capacity Building in a Rural Industrial Region. *Economic Development Quarterly*, *29*(3), 229–244. https://doi.org/10.1177/0891242415581053

Valdivia, W. D., & Clark, B. Y. (2015). *The politics of federal R&D: A punctuated equilibrium analysis*.
Vogel, A. L., Stipelman, B. A., Hall, K. L., Nebeling, L., Stokols, D., & Spruijt-Metz, D. (2014). Pioneering the Transdisciplinary Team Science Approach: Lessons Learned from National Cancer Institute Grantees. In *J Transl Med Epidemiol* (Vol. 2).

Vuori, J. (2016). Towards Strategic Actorhood? The Execution of Institutional Positioning Strategies at Finnish Universities of Applied Sciences. *Higher Education Quarterly*, *70*(4), 400–418.

Youtie, J., & Shapira, P. (2008). Building an innovation hub: A case study of the transformation of university roles in regional technological and economic development. *Research Policy*, *37*(8), 1188–1204. https://doi.org/10.1016/j.respol.2008.04.012

Zuckerman, H. (1977). *Scientific elite: Nobel laureates in the United States*. New Brunswick: Transaction Publishers.