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Socio-economic impacts and public value of government-funded research: Lessons from four US National Science Foundation initiatives

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ABSTRACT

Interest in evaluating non-economic *social* outcomes of science and technology research has risen in policy circles in recent years. The interest in social impacts of research has not yet given rise to a great proliferation of useful, valid techniques for evaluating such impacts. This study presents detailed case studies of four US National Science Foundation (NSF) programs/initiatives to provide a framework for understanding diverse efforts at addressing social impacts, and to suggest some important gaps in our research approaches for assessing socio-economic impacts of research. The four cases studied − the Experimental Program to Stimulate Competitive Research (EPSCoR), the Innovation Corps (I-Corps), the Arizona State University Center for Nanotechnology in Society, and the NSF "Broader Impacts" criteria—were chosen for their diversity in intent and modality but operating within a single agency. The cases are compared based on criteria important for assessing socio-economic outcomes: the initiative's modality, enabling policy vehicle, benefit guarantor, distribution and appropriability of benefits, specificity of beneficiary, social-economic range, and timing of the benefit stream. The paper concludes with a discussion of the most pressing methodological and theoretical issues that need addressing for greater progress in assessing social impacts.

1. Introduction

The history of evaluation of research is a diverse one, focusing on processes, outputs and, occasionally, on outcomes. With respect to the research outcomes of interest, most studies heretofore have focused on economic outcomes or knowledge outcomes. With respect to the former, a wide variety of economic approaches has been developed, including input-output analysis, simulations, case studies and, especially, cost-benefit analysis. Very different approaches have been employed for evaluating knowledge outcomes. While peer review, either open-ended or structured, remains an important approach to assessing the quality of knowledge outcomes, in past decades researchers and policy-makers have made increasing use of a variety of rapidly developing bibliometric techniques.

Recently, interest in evaluating non-economic *social* outcomes has spiked. In most cases, initiatives aimed at measuring science- and technology-based social outcomes come from high-level policy councils. Thus, the European Commission's (2014) Horizon 2020 Research and Innovation Programme explicitly focuses on social outcomes in its "Science with and for Society" section, as well as in other sections. In the U.S., the National Science Foundation's (NSF) new "Broader Impacts" criteria, i.e, criteria related to socio-economic impacts emerged from the National Science Board, the governing and advisory body for the NSF. According to a 2011 document (NSB, 2011), research proposal review criteria should include not only scientific quality but also "contribute more broadly to achieving societal goals." Particularly relevant for present purposes is the NSB admonition that "assessment and evaluation of NSF projects should be based on appropriate metrics, keeping in mind the likely correlation between the effect of broader impacts and the resources provided to implement projects."

The newfound interest in social impacts of research has not yet given rise to a great proliferation of useful, valid techniques for evaluating such impacts. One reason for the undersupply is simply that insufficient time has elapsed. Economic approaches to research evaluation have at least fifty years of development and bibliometric approaches at least thirty. But the other reason, arguably, is that it is simply much more difficult to measure social impacts. In the case of bibliometric approaches, tracing causal paths is rarely a focus. In almost all cases, bibliometric studies seek to measure outputs not impacts. If the focus is on patents, or publications or citations, bibliometric studies may sometimes correlate with socio-economic outcomes but do not provide causal hypotheses about the mechanisms that lead to these

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outcomes. With respect to economic studies, there is almost always the allure of commodification and monetization of outcomes. In some cases this may actually deflect from understanding the outcome of interest (since even some important economic outcomes are not well captured by monetary indicators), but in most instances the precision of economic data, when taken with assumptions from economic theory, at least permit some robust causal hypotheses about effects of research.

Measuring the social impacts of research seems an order of magnitude more difficult. Why? First, there is a terminology problem, with terms such as "socio-economic" impacts, "social impacts," "societal impacts," and "broader impacts" being used, sometimes interchangeably. Some of these terminologies emerged from enabling policy vehicles of a program or initiative of the cases presented in this paper. For example, the 21st Century Nanotechnology Research and Development Act (P.L. 108–153), which was an enabling vehicle for the Center for Nanotechnology in Society at Arizona State University, used the term "societal" throughout the act to refer to "improvements in quality of life" from nanotechnology research. As previously discussed, the term "broader impacts" represents terminology used by the National Science Foundation in its new criterion regarding the contribution of research toward societal goals. The term "social impacts" itself has been used to indicate an emphasis on non-economic impacts of public R & D programs to achieve social goals (Bozeman and Sarewitz, 2011). However, the most important problem, one not entirely foreign to economic analysis, is not necessarily the terminology, but rather the "over-determined" causality involved in any large-scale social change. Partly as a result of the difficulty of partitioning the impacts of research from all other exogenous factors affecting highly complex social outcomes, most approaches to measuring social impacts have been qualitative in nature, relying especially on case studies, interviews, or narratives. For example, the UK Research Excellence Framework (REF) performed a cross-case and text mining analysis of 6679 case studies of impacts from UK universities (HEFCE, 2015); but even with this large number of case studies which cover a broad range of disciplines and types of impacts, partitioning difficulties have been indicated, such as distinguishing impacts involving teaching, public engagement, and commercial beneficiaries, the latter due in part to an inability to disclose confidential information (Manville and Grant, 2015). In some cases peer review approaches have been used to evaluate social impacts of research, typically with little or no modification from approaches used to assess scientific quality. Methodological innovation or methodological synthesis has not been common in studies of social impacts of research, though some (Jordan, 2010 Hyvärinen, 2011) have suggested or applied approaches based on mapping or logic models.

1.1. Objectives

The overall objective of our study is to identify gaps in previous efforts to deal with the socio-economic impacts, particularly the social impacts, of research so as to suggest possible approaches to remedying these shortcomings. Currently, the literature on social impacts of science and technology programs remains quite modest. Thus, rather than reviewing literature, criticizing it and suggesting new alternatives we instead review four policy initiatives, all from the US NSF, their respective policy approaches and intents, and we use an analytical framework we develop here to examine the relationships among program components and possible approaches to evaluating social impacts.

The four cases we examine include:

1. The Experimental Program to Stimulate Competitive Research, much better known by its acronym EPSCoR, which, since its initial authorization in 1978, has aimed to build research capacity at universities in states that historically have not been competitive in open research solicitations.
2. The Innovation Corps (I-Corps). I-Corps began in 2011 with the objective of accelerating commercialization of science-intensive research.
3. The Arizona State University Center for Nanotechnology in Society, one of two NSF-sponsored centers tasked with developing and diffusing research related to the social implications of nanotechnology.
4. The NSF "Broader Impacts" criteria initiative. While not a program, the Broader Impacts initiative is a policy change requiring grant proposers to focus not only on the content and quality of the science in their proposals but also socio-economic impacts.

We employ an analytical framework for comparing these four very different cases and, in doing so, we hope to understand specific challenges involved in assessing the social impacts of "on the ground" science and technology policy programs. Application of this framework suggests gaps in current approaches. Reflecting on the cases, the authors' experience as evaluators and such modest literature as exists on evaluation of social impacts of science and technology policy, we suggest in the concluding section not only the apparent gaps but some possible resolutions.

The analytical framework we use for comparing these very different programs, presented in detail in a later section, seeks to characterize science and technology programs in terms of their institutional, economic and policy attributes. Since few such analytical devices have been developed for comparing science and technology policy programs, we draw from the general public policy literature, frameworks developed in other policy areas and our previous work in research and evaluation. We feel that our systematic, analytically based comparison of these four cases potentially presents cues as to what may be required for progress in assessing the social impacts of science and engineering research. Some of the requirements for such assessments differ little from those for virtually any evaluation research target. However, after examining these four cases we shall argue that they illustrate some of the particular needs and challenges of evaluating the broader impacts of science and engineering research at the level of the solicitation policy, capacity-development program, commercialization program, and a societal research center, as opposed to, say, school nutrition programs, or welfare benefit studies or other such topics that have been the sustained focus of evaluation researchers.

We do *not* present here an overview of approaches to conceptualizing and measuring the social impacts of research. In part this is because there are already very useful assessments of this literature (Bornmann, 2013; Gaunand et al., 2015; Joly et al., 2015), but in part this is owing to the desire to keep the verbiage in a paper that is a four-case comparison to tolerable limits. Moreover, we refer to relevant literature throughout the paper.

2. Four NSF socio-economic impact program initiatives

In this section we examine the four US NSF program initiatives aimed at enhancing socio-economic impact of science and engineering research, specifically with an aim to understand how the content and objectives of these programs present implications for *evaluation* of impacts from research.

While we feel these four cases provide an excellent basis for understanding different programmatic approaches to social impacts, we cannot infer a great deal from their respective evaluations and approaches; the programs vary greatly in the extent to which they have been evaluated. The EPSCoR program has often been a focus of systematic evaluations and the evaluations have to some extent focused on social impacts, but also economic impacts. The I-Corps program has been evaluated but almost always using traditional economic approaches, not focusing on social impacts except from the standpoint of assuming social value flowing from economic impacts. The Nanotechnology in Society center began in 2005. An evaluation was conducted in 2017. Finally, the Broader Impacts criteria initiative is not truly a program but rather an initiative. While controversial it has not yet been submitted to a systematic evidence-based evaluation. Moreover, while these programs are at very different points in their evaluation histories, we choose to examine such evaluations as exist since they provide some indication into current approaches to evaluating social impacts.

2.1. Why these four cases?

Since we are examining four cases we do not have the pretense of a sampling methodology. However, we do have reasons for selecting these cases. In the first place, there are few to choose from and these are among the more prominent ones. In the second place, while most "mission oriented" science and technology agencies (e.g. the Agricultural Research Service, the National Institute of Standards and Technology, most Department of Energy programs) include socio-economic impact criteria as part of their mandate, the one agency tasked with supporting basic scientific research for its own sake is the NSF. Thus, we feel the NSF is a good place to start because the culture of the agency has long focused on discovery objectives and matters internal to science rather than social impacts. If we examine the NSF's efforts to obtain socio-economic objectives, the programs and policies seeking to do so are relatively few in number and include not only the ones we examine here but also such programs as the ADVANCE program (focused on enhancing careers of women researchers) and, arguably, some of the Centers programs, including the Advanced Technology Manufacturing Centers program and the Engineering Research Centers Programs. We chose to focus on the four we include because they are quite diverse in intent and in program modality— policy, capacity-development program, commercialization program, and research center. We felt we could learn more by examining a set of divergent programs but operating in a single agency.

One could construe as either an advantage or disadvantage that some of these programs do not focus specifically (and none exclusively) on social impact. It is an arguable disadvantage because our concern is with social impacts. However, in US science policy programs social impact is almost never the primary reason for developing any science policy program. However, that fact does not imply that programs have no social impacts or that program designers and managers are uninterested in social impact. It is also important to understand that, in US science policy, almost all programs are rationalized in terms of economic impacts, including some that have considerable potential for both social benefit and social harm. Moreover, the program we discuss immediately below is typical of another important element of US science policy programs- the tendency to treat economic impact as, essentially, either a surrogate, an indicator or as identical to social impact.

Finally, if one were hoping to focus on science and technology programs driven only by social impact motives, one would not have a null set, but nearly so.

The structure of these four cases includes the aims of the program or initiative, a description of how it operates to produce socio-economic impacts, results of internal and external assessments of program impacts where available, and insights into the limits of these assessments.

2.2. EPSCoR

The Experimental Program to Stimulate Competitive Research (EPSCoR) was an NSF program established in 1979 to build research infrastructure, addressing inequities, and thereby broadening the distribution of NSF award funds. (US Congress, 1978; NSF, 2015). Researchers in U.S. states or territories are eligible additional funding through EPSCoR if the state's/territory's total NSF research support is no more than 0.75 percent of the total NSF research budget over a three year period. As of fiscal year 2015, 37 states/territories are EPSCoR eligible on a budget of $158 million (which is up 7% over the previous year). The funding goes toward researcher-initiated projects, not administrator or policy-maker programs, and must include collaborators from at least two of the eligible ESPSCoR jurisdictions. EPSCoR objectives have expanded beyond the program's initial research infrastructure building mandate to include S & T human capital development, economic development, and minority inclusion (Dietz, 2000; Bozeman et al., 2001; Yin and Feller, 1999; Lambright, 1996; Lambright, 2000).

Controversies about the benefits of EPSCoR are two-fold. The first concerns the clash of the need for greater geographic equality in NSF awards versus the value of merit review of NSF proposals based on scientific and technical quality, not social impact, as determined by peer researchers (see Bozeman, 1979; Chubin and Hackett, 1990; Guston, 2003). The second concerns whether EPSCoR has achieved its goal of leveling the playing fields of university researchers pursuing their research award aspirations (Lambright, 1996).

The longevity of the EPSCoR program has had the benefit of providing time for a number of evaluations (e.g. Lambright, 2000; Waugaman and Tornatzky, 2001; Hauger, 2004; Wu, 2009; Melkers and Wu, 2009). These evaluations are quite different from one another, with some focusing on case studies and qualitative data, some on survey or interviews, and others on statistical analysis of aggregate data. Most evaluations have focused on the growth of EPSCoR states' share of federal R & D awarded. This is quite understandable because such an approach accords with the initial Congressional and NSF policy rationales. But it also permits the analysts to focus on more precise indicators, albeit often at high levels of aggregation. One early study (Yin and Feller, 1999) shows a modest gain in federal R & D share for the period 1980–1994. Hauger (2004) and Waugaman and Tornatzky (2001) present compatible results. In the same vein, Wu 2009; Wu, 2010Wu, 2010 presents findings from a fixed effects model for a panel of 50 states during the period 1979–2006. Wu examines states' shares of federal academic R & D expenditures and finds that EPSCoR funding has no significant impact on the states' respective shares. Echoing Dietz (2000), who reported that the early EPSCoR states accounted for 7.5% of federal funding for university R & D in 1975 but only 6.7% in the 1990s, Wu explains that this is not surprising inasmuch as the EPSCoR funds represent a small percentage of the federal research money provided to higher education institutions. Moreover, Wu finds that EPSCoR funding does have a small positive effect over time. For every year participating in EPSCoR, the EPSCoR state's (Wu did not examine territories) share of all federal academic R & D increases, but only by 0.003%. This is a trace amount in terms of aggregates, but noticeable over years of change.

Those using different approaches have presented somewhat different results, largely because of a focus on non-economic indicators. Thus Payne and Siow (2003) found a positive effect of university participation in EPSCoR on the university's research activities. Rogers (2012) provides a more expansive comparative study, examining the effects of EPSCoR and other institutions in changing research cultures and providing new designs for research. While Hauger's (2004) approach is in many ways a standard economic analysis, there is also a focus on spillovers in the states' approaches to economic development. In contrast, Payne et al. (2006) study of EPSCoR, examines the program as type and token of science-policy-by-earmark.

Despite the general recognition (Dietz, 2000; Wu, 2010) that one of the most valuable aspects of EPSCoR may well lie in its ability to affect individual and aggregated scientific and technical human capital, no one has yet provided a systematic and comprehensive analysis of such impacts. EPSCoR potentially offers this capacity-building value to a specified beneficiary group of states and universities within them even as evaluations may under-emphasize its scientific and technical human capital merits.

2.3. I-Corps

Innovation Corps (I-Corps) is a program started at the NSF in 2011 to accelerate commercialization of science-intensive research. The $20.5 million program (as of fiscal year 2014) has three primary components: Nodes, Teams, and Sites. I-Corps Nodes are regional locations at universities that deliver entrepreneurship training using the I-Corps curriculum (Blank, 2013). The I-Corps curriculum is based on the Business Canvas Model (Osterwalder and Pigneur, 2010) which focuses on nine factors in the construction of a viable business model.

The training is delivered to three person teams comprised of the NSF principal investigator, the entrepreneurial lead (often a student or post-doctoral fellow), and the mentor (often with university research commercialization experience). The team is asked to develop "hypotheses" or assumptions about who is the customer of a given product or service, what the customer values, how money can be made—the "value proposition"—and other elements of the Model. The most important aspect of the training is the requirement to interview potential customers, investors, and business partners. After each set of meetings, the team reviews and modifies its hypotheses to obtain a better match between customer needs and product offerings. At the end of the six-month period, the team decides if a startup business can be formed, if the technology should be licensed to another firm, or if the model should not be pursued, i.e., the "go-no go" decision.

I-Corps Sites are funding awards designed to enhance the entrepreneurial infrastructure at U.S. universities (Swamidass, 2013). This support includes funding for curriculum development, prototyping, networking, and funding. It is hoped that these awards will lead to the creation of more I-Corps Teams.

Evaluation of I-Corps draws on two standard approaches. The first uses NSF's normal annual reporting mechanism. I-Corps participants must address commercialization results such as patent applications and grants, licensing agreements and royalties, companies established, and financing received; to this conventional list of economic outcomes, I-Corps also allows participants to report on curriculum developed. The second is focused on activity reporting and post course training surveys. NSF contracted with National Collegiate Inventors and Innovators Alliance (known since 2014 as VentureWell) to develop, administer, and analyze participant activity reports and post training questionnaires. The questionnaires ask participants to rate course components, likelihood to undertake steps to start a company, and further use of course components in university instruction. Results from activity reporting and the post-participant surveys for the 2012–2013 period indicate that knowledge of how to apply the business canvas model in the customer discovery process more than tripled after I-Corps (Weilerstein, 2014). The same post customer surveys indicate that 57% of the 2011–2012 cohort went on to found companies of which 10% receive equity financing (Grose, 2014). One case study described how an I-Corps participant influenced the campus's entrepreneurial climate (University of Wisconsin-Milwaukee, 2015). Yet whether these outputs would have occurred without the program has not been assessed. These evaluations use standard survey research comparisons and case studies; no bibliometric or econometric methods are used. Moreover, although I-Corps is available to all NSF PIs, grant recipients are pre-selected after an internal review, but the evaluation does not consider selection-bias nor are comparison groups used. In addition, the evaluations tend to be done by internal VentureWell staff or participants; there are no independent external evaluations of the program.

From the perspective of socio-economic impacts, I-Corps speeds the transfer of knowledge from basic research into products and services. The program thus takes the classic perspective that equates economic and social impacts. The I-Corps view of broader impacts is focused on economic benefits, emphasizing upstream-to-downstream flows and shortening of commercialization timeframes. One criticism with a focus on economic impacts is that simple evaluation designs are under-specified, unable to distinguish the impacts of the program from other factors in the economy such as time lags, downstream influences such as external customer purchases and production initiated domestically, and external factors such as regulatory changes or business cycles (Youtie et al., 1999). A second, more germane criticism is that broader impacts extend beyond these narrow economic development factors.

2.4. Center for nanotechnology in society at Arizona State University

Involvement of social science and the humanities scholars in technology assessment has been observed at least since the Human Genome Project. The emergence of nanotechnology saw new considerations of societal effects based in part on the desire to avoid societal backlashes experienced by other technologies such as genetically modified foods. The 21st Century Nanotechnology Research and Development Act (P.L. 108–153), which became law in 2003, had a clear objective for societal issues to be integrated into nanotechnology research including through nanoscale science and engineering research centers (NSECs).

NSF created two NSECs devoted to the examination of societal issues: the Center for Nanotechnology in Society at Arizona State University (CNS-ASU) and the Center for Nanotechnology in Society at the University of California at Santa Barbara. In addition to these centers, NSF supported societal research into nanotechnology at the individual project level, in larger teams, and in its user facility network.

The mission of CNS-ASU has been not only to conduct research into the societal implications of nanotechnology, but also to train scholars in how to perform societal assessments, engage with various sectors in dialogues about societal issues, and partner with nanoscience laboratories to seeks to influence their research processes. CNS-ASU applied a societal assessment methodology outlined in Guston and Sarewitz's (2002), real time technology assessment (RTTA).

RTTA involved a research program comprised of four methodologies: (1) research and innovation systems analysis, (2) public opinion and values research, (3) deliberation and participation, and (4) reflexivity assessment and evaluation. In addition, the center focused on three thematic topical areas: equity and responsibility; human identity, enhancement, and biology; and nanotech and the built environment. Research and innovation systems analysis used analysis of publications and patents (and other data sources such as interviews and analysis of company websites) to understand which actors were engaged in what kinds of nanotechnology research and commercialization, how nanotechnology's contribution to broad social goals could be measured, and what regional concentrations and prospects could be characterized (Youtie et al., 2016). Public opinion and values used surveys of citizens and scientists and media studies to understand what people and scientists understand and feel about nanotechnology and how the media influences these perspectives (Cacciatore et al., 2009). Deliberation and participation involved scenario development workshops, citizens' panels and tours, and student design courses to explore plausible futures, responsible nanotechnology products, and public decision making (Davies et al., 2012). Reflexivity assessment and evaluation placed social scientists in nanotechnology laboratories to understand and steer activities with societal implications (Fisher and Schuurbiers, 2013).

NSF awarded $6.33 million to CNS-ASU from October 2005 to September 2010, and the center was renewed for an additional five years at $7.18 million. CNS-ASU was headquartered at Arizona State University and had major partnerships with Georgia Institute of Technology and University of Wisconsin-Madison, and smaller ones with other universities. The center used a distributed model not only across these partner universities but also through its visitors (roughly 200 per year); engagement with the public, policy makers, business leaders, and researchers, students; and multiple dissemination methods ranging from traditional scholarly papers to a "winter school" around RTTA methods to programs for science museums and for engaging students and policymakers in Washington DC.

With the exception of the standard review panels and annual reporting required of any NSF-funded center, there have been no external evaluations of CNS-ASU. NSF has funded two external studies of CNS-ASU and other nanotechnology societal research. The first is an external study of interdisciplinary collaboration between scientists and social scientists at CNS-ASU and the other center at University of California at Santa Barbara based on on-site observation and personal interviews at the two centers (Zehr, 2011). Although this study is focused on interdisciplinarity, it also includes an element to examine the effect of public engagement, which presumably addresses some social impacts. The second is a study of NSF investments in research into the social and ethical implications of nanotechnology, which would include, but also go beyond, CNS-ASU (Tourney, 2015). This study is based on 60–80 interviews with US stakeholders in multiple societal sectors such as law, business, and science policy that are designed to capture the utility of this social and ethical research to these stakeholders. An additional round of interviews is to be conducted with stakeholders in Canada and the European Union to obtain a comparative perspective. These studies are underway so no publicly available results are on hand as of the writing of this paper.

Despite the lack of published evaluations of CNS-ASU, several implications for understanding social impacts can be gleaned from this case. CNS-ASU seeks to accelerate consideration of social issues while scientific research is being performed, thus providing social, public domain benefits. It also uses a distributed and experimental structure to deliver these social benefits. However, economic impacts on companies are not emphasized in the center's mission, although the center has had some engagement with businesses. Moreover, the timing and extent of delivery of these benefits is diffuse due to the diversity and dispersion of beneficiaries to appropriate them, including other social scientists studying emerging technologies, nanoscience researchers, private non-profit organizations, and certain government agency administrators.

2.5. The NSF broader impacts criteria

As mentioned above the NSF Broader Impacts Criteria (hereafter BIC) constitutes an administrative policy, but not a program. As such it is obviously different from the three program initiatives but at the same time provides an interesting point of comparison.

BIC policy was developed in 1997, when "broader impacts" was adopted as required element for NSF proposals, taking its place alongside the more familiar "intellectual merit" criterion that had dominated funding decisions since the inception of the Foundation. In 2007, the NSF clarified the criteria, especially as they pertain to "transformative research" (Rothenberg, 2010). The specific wording of the two criteria (NSF, 2011):

Intellectual Merit: The intellectual Merit criterion encompasses the potential to advance knowledge; and

Broader Impacts: The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.

To a large extent, the interpretation of both criteria is left to the grant proposers and reviewers. There is some greater detail on the intellectual merit, in terms of the specific items asked about in reviews, and some elaboration of BIC (National Science Board, 2006).

What are the broader impacts of the proposed activity?

- ○ How well does the activity advance discovery and understanding while promoting teaching, training, and learning?
- ○ How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)?
- ○ To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks and partnerships?
- ○ Will the results be disseminated broadly to enhance scientific and technological understanding?
- ○ What may be the benefits of the proposed activity to society?

The broader impacts are no clearer than above, with the result that a wide array of content is presented in proposals as broader impacts.[1]

Many researchers have failed to embrace the BIC (for a review of such criticisms see Holbrook, 2005; Frodeman and Holbrook, 2007). Most criticisms focus on either the limited conceptualization of the BIC or its apparent embedded assumptions, including a linear model of research. Some focus on the desirability of latching quality and social impact together (Tretkoff, 2007), especially in fields that are for the most part curiosity driven.

Despite criticism, the idea of assessing science and engineering research according to not only technical merit but also social impact has many supporters. Nevertheless, advocating social impact assessment (Von Schomberg, 2013; Owen et al., 2013) is not the same thing as advocating the NSF's BIC policy (e.g. Sarewitz, 2011). For example Bozeman and Boardman (2009) criticize BIC despite being quite sympathetic to its goals. They contend that the BIC assumption that the conventional peer review process can be used to wring more social value from research is misguided because "conventional peer review, based as it is on scientific and technical expertise and excluding non-experts, is not up to the task of making adequate judgments about social impact." There is no reason to believe that a chemist or an electrical engineer, or any of the technical experts normally employed in NSF peer review, will have any greater insight into social impacts assessment or forecasting that will ordinary lay citizens. Consequently, the outputs and outcomes resulting from efforts to address the BIC can be diffuse and variable.

3. Comparing the four program initiatives

As discussed above, our comparison of the four program initiatives is based on an analytical framework we feel useful for understanding the characteristics of science and technology programs and, ultimately, how those characteristics shape socio-economic outcomes. We use this framework not only to structure our discussion of the respective program initiatives but also in a later section we use in our discussion of gaps in current approaches to evaluating science and technology policies and program impacts.

First, let us say a few words about the development of the framework presented below in Table 1. The major source of inspiration was the general public policy literature and our framework has much in common with earlier ones. Comparative frameworks are common in the general policy literature (for an overview see Bemelmans-Videc et al., 2011), as well as in many specific policy domains such as, for example, health policy (Mays et al., 2010), higher education (Perna et al., 2008), and environmental policy (Lester, 1986). However, comparative policy frameworks are much less common in the science and technology policy literature. The dearth of comparative frameworks for science and technology policy is due in part to the strong reliance on traditional economic approaches, including microeconomic models consonant with standard benefit cost approaches. When one is interested almost exclusively in economic impacts of programs such models are quite appropriate but when one adds to the equation social impacts then such models, while remaining helpful, cannot address some important social

[1] Both authors have served on NSF grants review panels and as ad hoc reviewers and, between them, have reviewed literally hundreds of proposals. From this experience we conclude that many researchers (less than a majority) seem not to know what to do with these criteria and for the most part just restate elements in the technical part of the project, saying that their information will be disseminated to users who can benefit. Among those with responses that are not confused or perfunctory (the large majority in our experience) most seem to fall into one of a few categories: enhancing access or representativeness of minorities or women; outreach to the general public and to students, especially high school students; working with business to put knowledge or technology to use; developing collaborations with other fields and other institutions and, generally, building networks. In our view, a significant percentage, perhaps 10% or so, provide extremely innovative approaches or ideas about promoting social benefit. In sum, it is difficult to generalize about the broader impacts responses, except to say there is high variance on almost all relevant accounts.

Table 1
Framework for Comparing NSF Programs.

	ESPSCoR	I-Corps	CNS-ASU	Broader Impacts
Modality	- Funding redistribution - Developing S & T human capital	- Training - Economic development	- Research and research dissemination	- Mandated grants criteria
Enabling Policy Vehicle	- Congress, legislation	- Congress, legislation	- Congress, legislation - Center grants review (cooperative agreement)	- National Science Board recommendation adopted
Benefit Guarantor	- Congress - NSF program managers	- NSF program managers	- NSF program managers - University researchers	- NSF program managers - Peer Reviewers
Benefit Distribution and Appropriability	Broad benefits: - Initially 10 states' universities and economies - Currently 37 states' universities and economies - Medium appropriability	Narrow benefits: - Particular trainees and their business - Selected regions' economies - High appropriability	Public domain benefits: - CNS-ASU research in public domain with "public goods" benefits - Low appropriability	Broad benefits, diverse beneficiaries: - Specific groups affected by specific research grant awards - Appropriability dependent upon specific groups targeted
Beneficiary Specificity	High	High	Low	Medium
Social-Economic Range	Social (S & T Human Capital) and Economic	Predominately Economic	Predominantly Social	Mixed, dependent upon specific groups targeted
Timing of Benefit Stream	Short term (awards), Long term (S & THC)	Short term (effects on individuals and firms), Possible long term (trickle down economic benefits)	Unpredictable (dependent and research diffusion and utilization)	Unpredictable (dependent upon specific groups targeted)

impacts and their determinants. Our interests includes impacts not only related to economic outcomes, but also social outcomes and, as we shall see subsequently, outcomes that at least take into account the relation of politics to outcomes. Thus, the general approaches used in policy and political science typological efforts obtain here (for discussion of general approaches and development criteria see Howlett et al., 1995; Dunn, 2015). Typically, the policy models literature focuses on characterizing policy origins and policy formulation, policy processes, attributes of policy content, and stages of policy (see for example Ripley et al., 1973; Howlett, 2009; Hill and Varone, 2014). Our approach is quite similar to traditional typological models inasmuch as we focus on the interactions of institutions and the instruments of policy (Heclo, 2011).

Though our analytical framework is derived chiefly from the institutionally-focused general literature on public policy, examining policy instruments, attributes and the institutional actors developing them, we also draw from our own experience in research, evaluation and application (e.g. Youtie and Shapira, 1999; Youtie et al., 2006; Corley et al., 2006). The authors have conducted at least two dozen systematic evaluations of science and technology policy and program impacts for a wide variety of sponsors (e.g. the US NSF, National Institutes of Health, Department of Energy, Department of Commerce, state governments, OECD, the United Nations, and (non-US) nations' science and technology policy apparatus). Almost all of this work has been conducted in teams and in every instance the specific evaluations include team member debriefings about what aspects of the evaluations needed improving. Thus, though not perhaps a formal method in evaluation, this sort of career long, team-based adaptive learning is at least as important to the logic of the paper as is the general public policy modeling literature. Naturally, tracing specific propositions to specific experiences is not feasible, especially since for us, as with almost all evaluation professionals, practitioner experience is very much embedded in theoretical knowledge. It is easier to trace the assumptions and case findings to the policy literatures, at least in some instances, and we do so in the discussion of the cases.

The result of this amalgamation of indirectly related literature, traditional approaches, and experiential knowledge is presented in the framework presented in Table 1. While the framework is for consideration of NSF programs, we feel it has relevance to other science and technology policy programs as well as many programs not related to science and technology policy.

Modalities. We use the term "modalities" to refer to the program mechanisms by which a program seeks to achieve its objectives. The modalities of the four NSF program initiatives are quite different. The ESPSCoR approach relies chiefly on funding distribution, initially addressing a geographic inequity, and the use of funds to develop scientific and technical human capital (S & THC) in places where there was a perceived shortfall. As noted above, the EPSCoR program evolved from a redistributive to a distribute policy instrument. The very different I-Corps approach, much more traditional, focuses on economic development, only incidentally presuming possible trickle down effects of social benefit. Here the social technology is training. The Center for Nanotechnology in Society focuses specifically on development of research and, especially, its application for presumed socially beneficial purposes, especially public involvement and participation. Thus, the program modality is research, its diffusion and its application. In the case of the NSF BIC initiative, the modality is essentially regulatory specification, requiring as a condition of eligibility that grant proposers address specifically broader socio-economic impacts.

Enabling policy vehicle. The institutional driving force behind the respective program initiatives is of more than incidental interest to evaluators of social impacts. The enabling institution and the particular characteristics of the enabling policy vehicle suggest possible clients for evaluation, and client characteristics make all the difference in terms of the likely viability of any particular approach. In three of the four cases, the US Congress played a major role. Only in the BIC case did NSF play a major role in developing the policy (at the behest of the National Science Board, which often works hand-in-glove with NSF officials). The US Congress is notorious for *not* being an avid client for evidence-based policy evaluations of any sort (witness the closure of the Office of Technology Assessment and the limited analytical role of the Congressional Research Service), not least because so many policies stand chiefly and sometimes solely on their political rationale rather than any evidentiary basis. By contrast, in cases where the agency has some clear autonomy or even maneuverability, NSF's ability to develop as a "sincere client" (Bozeman and Landsbergen, 1987) for evaluation is much facilitated. This is not to say that all Congressional-originated initiatives are the same. A critical variable is whether members of Congress and their staff continue to take a strong interest, as opposed to establishing and then leaving design and follow-up to the agencies in charge of implementation. Thus, Congress continues to have interest and oversight with EPSCoR (where distribution of tax dollars is at stake), and to a lesser extent with the lesser-funded I-Corps, but seems to have little knowledge or interest in the Center for Nanotechnology in Society other than the fact of its establishment.

Benefit guarantor. Related to the enabling policy vehicle, the benefit guarantor is the institution or organization charged with ensuring that the benefits intended in the policy initiative are actually realized. In the case of the EPSCoR program it seems fair to say that Congress has a significant guarantor role because they actually specify the eligible population and criteria. NSF program managers and peer reviewers play an important role in choosing among proposals and recommending awards. The latter is "business as usual" but the role of the Congress as a de factor guarantor is unusual and largely confined to distributive policy programs. In the case of the I-Corps program, it could be construed as a distributive policy program and thus Congress has questioned whether NSF should be in the business of promoting the creation of companies and "picking winners-and-losers" (i.e., getting involved in industrial policy), which strays from the agency's primary basic science mission. In general, however, the historical involvement of Congress has been much less, presumably because of the lower economic and political stakes involved. Thus, the primary guarantors of the program are more traditional for NSF, program managers and peer reviewers. In the case of the CNS-ASU, the guarantor processes are not much different than any other NSF centers based on cooperative agreement grants vehicles. The fact that potential social benefits pertain does not affect the guarantor mechanisms. The BIC policy uses similar mechanisms as do other research project awards, through NSF reporting, although reporting measures tend to be more applicable to the intellectual merit criteria (i.e., published papers or patent applications) than to the BIC.

Benefit distribution and appropriability. Benefit distribution and appropriability interact. What we mean by benefit distribution is quite simply: "What is the breadth of the benefitted population?" What we mean by appropriability is much like the use of the term in economics—the degree to which an individual or, typically, a firm has the ability fully to capture value created from work products, typically knowledge and innovation (Winter (2006) provides a review of the *economic* appropriability literature). Typically, economics-focused innovation researchers concern themselves with the ability of firms to exclude others from benefitting as free riders from the knowledge and technology developed and produced by the firm and also on the attendant strategies they employ, including patents, trade secrets and control of standards. But in the case of social benefits from science and engineering research, the objectives typically are quite different. Indeed, for many social benefits programs the idea is to spread the benefits as much as is feasible and with as few barriers to entry as possible (Bozeman, 2001; Bozeman and Sarewitz, 2005, 2011).

It is important to note that benefit distribution is a long standing criterion among both policy makers and policy theorists, harkening back at least to Lowi's (1964) classic distinction (see also Heckathorn and Maser for an extended application of the Lowi typology and distributional policy). However, benefit distribution is not always a criterion in public policy programs and is rarely so, at least explicitly, in US science and technology focused public programs. However, it is sometimes an important consideration in the evaluation of these programs, in part because science policy agency and program managers have more detailed programmatic objectives than are found in the statutorily based missions of their agencies. Moreover, we focus here on one program that does have explicit benefit distribution requirements in the initial authorizing mission statement for the program (EPSCoR)[2] and other than often has benefit distribution elements included by grants recipients (BIC). Finally we note that benefit distribution is not only useful as a prospective means of characterizing science and technology programs' designs but also in some cases as an evaluation criterion, at least in those cases where benefit distribution is acknowledged as a program objective.

As seen in the Table, our view is that two of the programs, EPSCoR and the BIC, have considerable breadth in the population of beneficiaries, whereas the I-Corps program has a fairly narrow set of direct beneficiaries (though perhaps a much broader set of "spillover" beneficiaries). As is the case for most research-focused programs, the CNS-ASU benefits are quite diffuse and indirect, as is normally the case for public domain research. With respect to appropriability, the I-Corps program is a fairly typical economic development program and like most government-sponsored efforts in this realm the benefits are intended to be appropriable to some degree, otherwise firms and individuals would likely have little interest in participating. The CNS-ASU output, like most knowledge products not embodied in technology, is not easily appropriated but is widely accessible. With the BIC initiative the appropriability depends on the specific outputs from specific awards.

Beneficiary specificity. The ability to specify benefits is certainly one of the more precise and familiar evaluation approaches. But when the beneficiaries are not easily specified many such approaches are rendered feckless. Thus, evaluating the impacts of I-Corps seems not much different than many previous evaluations of publicly-sponsored economic development programs including, for example, NIST's Advanced Technology Program (Ruegg and Feller, 2003; Link and Scott, 2004, 2012; Ruegg and Jordan, 2007), manufacturing extension programs (Shapira and Youtie, 1998a,b; Shapira, 2001), or federal laboratory cooperative research and development programs (Bozeman and Papadakis, 1995; Leyden and Link, 1999; Saavedra and Bozeman, 2004).

The lack of beneficiary specificity in large-scale social programs, including those for science and technology impacts, can present a major challenge for evaluators. If it is not possible to put a reasonable boundary on the beneficiary population then many rigorous evaluation techniques simply are not eligible for use. For example, some of the most rigorous evaluations of social programs have been enabled by the fact that the beneficiary population can be precisely specified (e.g. a classroom, an entitlement group), enabling analysis of counterfactual evidence relative to a comparison group of populations not in receipt of these benefits. But in the case of most social impacts of science and engineering research the beneficiary population is unclear, not unlike the case with the users of scientific knowledge. In the case of scientific knowledge use there is often an ability to rely on outputs such as citations but there is not equivalent currency for most types of social outcomes targeted at an amorphous beneficiary population.

The case of the CNS-ASU presents the most amorphous beneficiary population- generally the user community for their research as well as the "general public." By contrast, both I-Corps and the EPSCoR programs present relatively few challenges in specifying the beneficiary population, at least among the immediate and direct beneficiaries.

Social-economic range. The four programs vary with respect to their focus on economic or social benefits. The I-Corps program is quite similar to programs sponsored by other federal and state agencies, programs seeking to enhance economic development. Like such programs as manufacturing assistance, incubators and technology commercialization, the focus is almost exclusively on economic benefit, often under the (questionable) assumption that economic benefits lead

[2] EPSCOR's mission is consistent with the NSF original mission but also has explicit language encouraging attention to benefit distribution. According the National Science Foundation Act "*…it shall be an objective of the Foundation to strengthen science and engineering research potential and education at all levels throughout the United States and avoid undue concentration of such research and education, respectively…*" (National Science Foundation (NSF) Act of 1950 *(Pub. L. 507–81st Congress)*. With respect to EPSCoR, the Memorandum from NSF Director Richard Atkinson (1978) to the National Science Board, the enabling authority of the program: "to stimulate competitively meritorious research in regions that are not able to compete successfully." Atkinson noted that "significant national, as well as local, benefits would be derived from each states' participation in the national scientific enterprise." In short, this is a classic distributional basis for a program.

inexorably to desirable social outcomes. The direct social benefit from the EPSCoR program comes in the form of enhancing the S & T Human Capital of particular researchers, usually academic scientists and engineers. While ESPSCoR has clear economic objectives, the fact that one of the main outcomes is providing training and productivity to enhance the competitiveness of states does not work well when the actual outcome is more value on the labor market and the use of grants to propel recipients to jobs at "better" universities. CNS-ASU focuses very little on direct economic development outcomes and, instead, seeks to improve social well-being with the development and application of research. Finally, the BIC initiative focuses on both social and economic benefits but in unpredictable ways inasmuch as the beneficiaries are dependent on the specific grant activities and targets of proposers.

Notably, and characteristically, none of the program initiatives focuses exclusively and directly on providing social benefits. This is not unexpected given the primary mission of the NSF, supporting basic research and enhancing scientific quality. Moreover, most U.S. science policy focuses on a national defense paradigm, an economic development paradigm, or, less common, a cooperative technology paradigm (Crow and Bozeman, 1998). It seems fair to say that none of the primary US agencies charged with supporting scientific research (i.e. NSF, National Institutes of Health, Department of Defense, or Department of Energy) has a straightforward social impact mission.[3]

The issue of what we refer to as social economic range is highly relevant to evaluation issues and methods. Specifically, to the extent that the focus is on economic output, any of a wide variety of familiar and often efficacious evaluation technologies can be brought to bear. By contrast, the state-of-the-art for social impact assessments of research remains quite primitive with few choices and limited theory-guidance. One possible and most unfortunate consequence is a sort of methodological drunkard's search: focusing on the economic aspects and not the social aspects simply because that is where the light shines.

Timing of benefit stream. The problem of the timing of benefits and costs is quite familiar to evaluators, especially those steeped in cost-benefit approaches. Indeed, a major methodological contribution of cost-benefit analysis is to identify a discount rate based on the timing for the accrual of benefits and costs. Scientific knowledge is notorious for occurring in long-term and often highly unpredictable benefit streams due in part to downstream steps taken by private firms. True, one might argue that for the vast majority of knowledge outputs one can rather quickly determine if there is any benefit. Consequently, many of these evaluations find very skewed outcomes, with no impacts resulting from the typical intervention and significant impacts in only a few high performing cases. For the vast majority of studies providing negligible benefit the question of timing is moot. But for the small percentage of high impact knowledge products determining the use and benefit trajectories is often exceedingly difficult, with a "churn" model of use generally more apt than a linear one (Bozeman and Rogers, 2002).

The four NSF programs vary substantially in the timing of their respective benefit streams, especially with regard to predictability of that timing. Most output from the CNS-ASU is quite similar in benefit stream to most scientific research- unpredictable and highly dependent on utilization patterns. The benefit stream from the BIC initiative is unpredictable for a very different reason, the dependence on the specific outputs from specific awards. But the I-Corps program has a traceable if not predictable benefit steam and, when providing benefits, they tend to be short- or intermediate-term. With respect to the direct S & T human capital benefit streams from EPSCoR, the benefits can be traced with some validity inasmuch as they are reflected in career trajectories (see for example Bozeman et al., 2001; Ponomariov and Boardman, 2010). But when the focus is on S & T human capital embodied in firms or organizations, the benefit streams are not as easy to predict, especially secondary or spillover economic and social benefits.

4. Assessing social impacts of science and engineering research: implications from the case comparison

Thus far we have provided case illustrations of four NSF programs (or to be precise, three programs and one administrative policy initiative) and we have provided a systematic comparison of them, employing criteria drawn from the general policy literature, traditional approaches, and experiential knowledge relevant to devising approaches to assessing social benefit. The comparison suggests that gaps in the ability to assess social benefits from these four programs stem in part from methodological and substantive challenges for assessing social impacts observed by applying the framework to the four case studies, including modality diversity, broad enabling vehicles, lack of guarantors with interest in social benefit appraisal, diffuse distribution and appropriability of potential benefits, vague beneficiary boundaries, over-attention to economic impacts and limited focus on social aspects, and long-term and often unpredictable benefit streams. In this concluding section we ask: What is the nature of these gaps? That is, what are the most pressing methodological and theoretical issues that need addressing for greater progress in assessing social impacts?

Each of the gaps we identify below pertains in part to one or more of the eight elements identified in Table 1, Framework for Comparing NSF Programs. Some of the elements in the framework are more relevant than others to issues of evaluation improvement. This is in part because some of the elements (e.g. modality) are related more to attributes of the program than to traditional evaluation criteria. However, even in the case of the design attributes, it is still important to understand the interrelation between core elements of program design and specific needs for evaluation. Thus, for example, when the program benefit guarantor is Congress, the evaluation needs might be much different than when the benefit guarantor is NSF program managers. The respective guarantors likely require different sorts of information and in some cases different ideas of program effectiveness. Thus, our framework is best viewed as factors affecting the design of evaluations rather than as specific evaluation criteria.

Gap One: Social, Economic and Socio-Economic. Our first proposed gaps relates to several of the factors in our framework but particularly to *socio-economic range.* That aspect of the framework underscores that social and economic benefits relate to one another in diverse ways, with economic impacts sometimes giving rise directly to social impacts, sometimes social impacts having significant economic impact implications and, at least in some cases, the implications of one for the other are relatively modest. Moreover, our four cases illustrate well the convergence of social and economic goals and values. None of the cases is "purely" social or economic, rather they represent a mix of social and economic, in some cases emphasizing one more than the other.

The approaches developed for assessing social impact, including not least our own approaches (e.g. Bozeman, 2003; Bozeman and Sarewitz, 2011), do not easily accommodate this blending.[4] Actually the econometric approaches fare a bit better in being adapted to public values. True, econometric approaches sometimes bend to the breaking point assumptions about the possibilities for monetizing values, but at least methods exist and are used. By contrast, although social impact may occur without a prior economic impact or may be accompanied by other impacts such as a mediating political impact, most social impact approaches give little or no heed to the fact that economic benefit may be a precondition or precursor to social impact. It is easy enough to

[3] Most research aimed specifically at improving social conditions and quality of life is sponsored by "mission agencies." However, even most of the mission agencies rationalize their research funding in terms of economic benefit provided. Finally, the research budgets of the agencies focused squarely on such social issues as welfare, education, and crime prevention are a small fraction of the budgets allocated to more fundamental scientific research.

[4] There are felicitous exceptions (e.g. Georghiou et al., 2002).

argue that economic measures are in some cases only a pale reflection of the outcomes truly valued by humans (e.g. Bozeman, 2001, 2007). However, our models of social benefit tell us again and again that socio- and economic- are not easy to disentangle. Qualitative methods might be useful to disentangle these relationships between economic and social factors, but difficult to yield generalizations. To this end, quantitative work has been pioneered to track, for example, content in legislation, both economic and social, and compare it to funding announcements in the nanotechnology domain (see for example, Slade, 2011). Perhaps more work is required to measure socio-economic benefits, work informed by serious theory and hypotheses about the causal paths by which societies go from funding investments to publicly valued outcomes. Any approach to measuring socio-economic benefits of science and technology based programs would do well to understand first the intended specificity of benefits and the intended timing of the benefit stream (two of the program features we present here) inasmuch as such understanding is useful and may even be a precondition to effective evaluation.

Gap 2: Meta-methodological Guidance. Our framework from Table 1 emphasizes the importance of the program *modalities,* the instruments used for achieving outcomes (e.g. training programs, research dissemination, mandates). The modalities of programs seeking to enhance social impacts from science and technology are many and diverse. It comes as no surprise, then, that different methods are needed for assessing different program modalities. We are not arguing here that there is a methods gap (perhaps there is, but that is for another paper), but rather that it would be extremely helpful to develop an impact assessment codex, a set of well-reasoned guidelines about when to employ what approach to assessing social impacts from science and engineering research. To some extent, this approach is reflected in Ruegg and Jordan (2007), Walker et al. (2008), and Youtie et al. (1999).

To be sure, this recommendation comes with a major caveat. While researchers choose assessment approaches according to the nature of the problem, an even greater determinant is the particular mix of methods and techniques in their analytical tool-kit. It would make about as much sense to say to historians that “you cannot understand this without time series statistical modeling” as it would to say to economists “if you are not conversant with the nuances of history leading to the problem you have framed, you cannot learn.” The prescription for cutting through this obstacle is, of course, an easy one- multidisciplinary teams. Indeed, this is an approach used by many (e.g. Molas-Gallart et al., 2002; Bozeman and Sarewitz, 2011; Gaunand et al., 2015). Still, the lack of a meta-methods theory, where meta-methods refers to a systematic technique for combining the results of methods (i.e., qualitative and quantitative) used by various evaluation disciplines, for helping interdisciplinary teams decide on an analytical focus is to some extent an impediment, especially if one heeds our call for socio-economic rather than social or economic assessment.

One interesting question is whether evaluations should take the modality of the program as a given or whether one aspect of the evaluation should be the assessment of the modality itself. Thus, in evaluating a program based on mandated rules or regulations, should the evaluator consider suggesting that another modality, say, information sharing, may prove more effective? We suggest that such an approach is warranted but only if the evaluator provides supporting evidence, such as from quantitative data comparing modalities (e.g. as from a field-based quasi-experiment) or from systematic, theoretically informed case studies.

Gap 3: Stop speaking nonsense to power. Both the *benefit guarantor* and the *enabling policy vehicle* should be taken into account in evaluating outcomes but, for a variety of reasons, these are considered haphazardly or not at all. For example, in most cases, the larger the stakes in science policy, the less the role for evidence-based assessment among benefit guarantors such as Congress. Whereas program managers and funding agency officials typically develop policies and programs that serve relatively specific and usually non-competing objectives, the US Congress, as is the case for most nations' legislative bodies, routinely considers programs in terms of not only competing programs but also values only directly related to specific program values, values such as the desire to be re-elected, the desire to consider the dictates of political party leaders, and the desire to respond to the urging of interest groups. In short, the evaluation practice evaluation picture is very different from some evaluation clients than for others.

If there is little alignment between the “credibility warrants” (e.g. internal validity, generalizability, transparency) of those performing the evaluation and the clients for the evaluation, then evaluations usually contribute little. In some cases, evaluation evidence competes with a variety of additional concerns. Thus, for example, one might expect that rigorous, methodologically sophisticated evaluations of EPSCoR have little effect on Congressional opinions about EPSCoR. There is a long literature (e.g. Weiss, 1998) suggesting that rigorous evaluations have important impacts only when the client is interested in the type of information that professional evaluators can provide (as opposed to the type of information clients obtain from public opinion, or political calculations or from reflections about their own personal self-interest or core values). As we note elsewhere (Youtie et al., in press), research based information competes with a wide variety of other information, even when the questions at issue have strong scientific content.

Evaluators who fail to consider competing interests and competing information do so at their peril. Different *benefit guarantors* (in terms of our framework) have varied, but in some respects predictable, information requirements. Bonvillian (2014) and Shapira and Youtie (2010), for example, observe that the highly regarded evaluation toolkit developed for the Advanced Technology Program (Ruegg and Feller, 2003) was not able to salvage the program against its Congressional detractors. While it is true that evidence could perhaps be used to reinforce positions already set in concrete, helping program advocates or detractors coat their arguments with a veneer of scientific research, the greater truth is the political truth. When it comes to allocating benefits that relate to the clear and immediate electoral self-interests of members of Congress (or state legislators, or Governors, or US Presidents) the role of policy analysis is at best circumscribed and at worst irrelevant. Weiss (1998) contends that the better users of evaluation are not Congress, but rather the clients and administrators of the program. In the US and perhaps in most industrialized democracies there are two chief clients for research, each powerful, each with very different rules and sources of power: the professional bureaucracy (including benefit guarantors such as NSF program managers) and the mass media. We distinguish the mass media because, while not a formal benefit guarantor, it has considerable influence on policy agenda setting (Dearing and Rogers, 1996). While mass media coverage can in many instances accomplish outcomes that would never be possible through the normal course of knowledge production and utilization, the mass media utilization function is not often congruent with the strengths of impact assessment, most of which rely on theory, methods and data warrants. Weingart notes, the mass media do not gravitate to research according to its validity (not surprisingly journalists would have difficulty ascertaining validity) but according to reputation of institutions and individuals, the “Cassandra syndrome” (catastrophes draw attention), and the dire, novel or counterintuitive nature of findings.

In most cases evaluation has the most likelihood of leading to program improvement when the *enabling policy vehicle* is from an agency rather than from a legislative body and, even more important, when the *benefit guarantor* is a program manager or an external advisor (e.g. peer reviewers). In most respects the professional bureaucracy is an especially apt client for evaluations. In many cases persons working in science-intensive agencies focus on accomplishments of particular programs and want to know what works (i.e. has impact) and what does not. Usually program managers and similar professionals have a narrower set of competing values, a higher degree of *beneficiary specificity* and, thus, are prepared to suspend judgment until evidence is at hand.

Gap 4: Help improve top down BIC-like approaches. The NSF Broader Impacts Criterion case is quite distinctive and provides some important lessons for improving evaluation. As noted in Table 1 Framework, the BIC has a different *modality* (mandated criteria) from any of the other cases, a different *benefit guarantor* (chiefly delegated to peer reviewers), and considerable divergence with respect to both its *benefit distribution* and its *beneficiary specificity*. Thus, is has little in common with most science and technology policy program initiatives.

The distinctiveness notwithstanding, the NSF is hardly the only major funding agency interested in some sort of broader impacts criteria in the allocation of research funds. In the US, the NIH has made some strides in considering socio-economic impacts (see for example, Roback et al., 2011). In Europe, the EU and many European nations have taken an even more activist approach, sometimes encouraging not only consideration of socio-economic impacts but also issues pertaining to distributional equity in the benefits and costs of research outcomes. These examples are particularly noteworthy in the agricultural research area (BMZ and GIZ, 2015; Embrapa, 2015).

In the US there has been much discussion of BIC and some scholarly deliberation. With very few exceptions the scholarly deliberations have been conceptual and philosophical. While such efforts are certainly welcome, what is missing in BIC and most such designs is any significant input from persons with any professional or research interest in empirical evaluation of science and technology policy generally and social impacts particularly. In most instances, in our view, the BIC criteria employed leave much to be desired in terms of clarity, measurability and intersubjective validity. The same types of efforts that have been brought to public agencies' assessments of the socio-economic impacts of research can be brought to the design of BIC-like initiatives. To be sure, criteria are not the same as outcomes or impacts. Nonetheless, technical design considerations are certainly relevant for assessing social impact and for a variety of reasons largely missing. One seeking to evaluate the BIC, at least in its current program structure, is evaluating a will-of-the-wisp. Perhaps the chief lesson is that when there is limited and variable *beneficiary specificity* and great variability with regard to both *social-economic range* and the *timing of benefit streams* that systematic evaluation is unlikely to make much headway. The evaluation literature (Trevisan, 2007) talks about program's "evaluability." Perhaps one implication of this evaluation gap, when considered with our framework, is that the BIC program structures does not auger well for its evaluability.

Gap 5: Convergence of social benefit assessment and bibliometrics. The element or our framework we refer to as *social-economic range* reminds us that social and economic impacts can interact in a great many ways and also that, at least in the case of science and technology policy, many programs focus as well on issues that are to some extent internal to science (e.g. expanding S & T human capital, increasing scientific productivity and knowledge, both for application and its own sake.) Given this range of impacts and the diversity of *modalities* seeking to achieve them, it seems to us unfortunate that evaluation traditions and methods often are poorly integrated.

To a large extent, the science studies/research evaluation world compartmentalizes bibliometrics as a set of approaches useful for understanding scientific quality and productivity though there have been important applications for understanding networks and the relation of productivity to scientific careers and mobility. What is largely missing is the use of bibliometrics to track social value.

Most bibliometric approaches begin by examining publication and citation data and then, through various technical legerdemain, provide increasingly impressive explanations of the behavior and accomplishments of researchers. But what does this approach have to do with socio-economic benefit? First, most theories of impact have use as a precondition. When claims are made for the impacts of research, use is a good place to start. For example, in a study conducted by the authors (Youtie et al., 2006), the object was to test the "bench to bedside" theory of practice used by a unit of the NIH. The working theory was that the basic research they sponsored would be used by medical researchers and, in turn, the clinicians would use the findings of the medical researchers, and, in turn, patients would benefit. Our research determined that the utilization theory simply did not work; not only were none of the clinicians aware of the funded basic research outcomes but only a very small percentage of the medical researchers were aware of these outcomes. True, this was a use of bibliometrics to test the counter-factual, but seems useful in design pertaining to public benefit. From that same project a colleague examined data on the effects of developing scientific capacity and scientific and technical human capital and, again using bibliometric techniques, found strong positive impacts (Gaughan, 2009). We feel there are many ways in which bibliometrics can be used to either measure social impact or to test delivery models underpinning programs for social impact.

5. Improving the framework, closing the gaps

As shown above, the various elements of our Framework for Comparing NSF Programs seems to have some utility not only for providing a taxonomic understanding of differences among policies and programs, but also gives some cues about improving evaluation of science and technology programs' impacts. A core assumption of our paper is that evaluations will generally prove more successful if one begins with a systematic understanding of program structures and design and tailors evaluation approaches accordingly. The "I have a hammer and everything is a nail" approach to evaluation is never a great idea but in the case of science and technology programs the approach is especially hazardous. Moreover, improving evaluation depends not only on advances in methods and technique but also understanding program structures. Thus, if it is possible to refine and improve upon the elements in our Framework, those improvements will likely also contain the seeds for improving assessments of research policies.

We have identified just a few of the gaps we feel should be addressed if we are to improve the ability to assess the broader socio-economic benefits of research. One final point. We have tried to focus here on gaps that are largely specific to research policy rather than policy evaluation more generally. However, it is also good to recall that there is a decade's long development of technical and methodological work in evaluating social programs. We can benefit from this work. Not all elements of the social outcomes of research are unique to this domain. If we do not remain vigilant in avoiding reinvention of the wheel then our analytical wheels may keep spinning with little forward progress.

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