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When Is Science Used in Science Policy? Examining the Importance of Scientific and Technical Information in National Research Council Reports

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Abstract

A frequent lament among researchers is that public policy makers should pay more attention to scientific and technical information (STI). If there is any single area where one might expect STI to be used in public policy making and agenda setting it is in science and technology policy. Many of the policy makers in science and technology policy are themselves scientists or researchers and presumably would prove especially receptive to STI. However, STI is only one of many types of information used in policy making and policy actors often differ in the extent to which they view STI as credible, particularly compared to other types of potentially policy-relevant information. Research on credibility (the believability of information, information types, and media) has shown variance and policy makers' "credibility maps." Thus, some policy makers have preference for formal information generally and STI specifically, but others privilege raw data, personal experience, authority, history and anecdote, analogical reasoning, or conformance to ideology, to name just a few of the information choices. Here, we build on the current researchers' previous bibliometrics-based work and use data from 41 semi-structured elite interviews with National Research Council (NRC) executives and staff and NRC committee members concerning the use of STI in reports issued by the NRC. Findings show that the use of STI in NRC reports varies according to the nature of the inquiry and the sponsor. Information used in the reports is based on not only the assessed credibility of information but also its perceived direct relevance and the availability of STI as compared to other types of information. In general, the amount of STI in the NRC reports tends to have modest effects on the likelihood that reports will be used in policy making or by the mass media. More important factors include the timing of the report with respect to political agendas, the party requesting the report, and the enacted roles of NRC staff members and committee chairs.

KEY WORDS: national governance, civil society, innovation, intellectual property

何时在科学政策中运用科学？探讨国家研究委员会报告中科技信息的重要性

研究者们经常哀叹道，公共政策制定者应该更多地关注科技信息(STI)。如果说在公共政策制定和议程设计中可能想到运用STI的任何单一领域，那就是科技政策。这一领域的许多政策参与者都接受科学培训。尽管STI只是决策过程中使用的众多信息之一，政策参与者在多大程度上认为STI是可信的，尤其是与其他类型的潜在政策相关信息相比。基于可信度理论的研究表明，决策者一般都有各自偏爱形式的信息，就STI具体而言，他们经常将个人经验、权威、历史和轶事、类比推理或与意识形态一致视为比手头决定更为重要。然而，以前的研究并没有把重点放在科学家和科学政策上。本研究中笔者引用了41位精英关于NRC报告使用STI情况接受国家研究委员会(NRC)　高管，工作人员以及委员会成员的半结构式采访数据。调查结果显示，NRC报告中的STI数量对报告被用于决策或被大众媒体使用的可能性影响不大。更重要的影响因素包括报告政治议程的时间安排、要求提交报告的党派以及NRC工作人员和委员会成员的既定角色。

关键词： 国家治理，民间社会，创新，知识产权

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¿Cuándo se usa la ciencia en la política científica? Examinar la importancia de la información científica y técnica en los informes del consejo nacional de investigación

Una queja frecuente entre los investigadores es que los responsables de las políticas públicas deberían prestar más atención a la información científica y técnica (CTI). Si hay un área única en la que uno podría esperar que la CTI se utilicen en la formulación de políticas públicas y en el establecimiento de la agenda, es en la política de ciencia y tecnología. Muchos de los actores políticos en este dominio tienen entrenamiento científico. Sin embargo, la CTI es solo uno de los muchos tipos de información utilizados en la formulación de políticas y los actores de las políticas a menudo difieren en la medida en que consideran que la CTI es creíble, en particular, en comparación con otros tipos de información potencialmente relevante para las políticas. La investigación arraigada en la teoría de la credibilidad muestra que los formuladores de políticas han variado la información formal de preferencias en general y específicamente las STI, a menudo consideran la experiencia personal, la autoridad, la historia y la anécdota, el razonamiento analógico o la conformidad con la ideología, como más importante para la decisión en cuestión. Sin embargo, estudios anteriores no se han centrado en los científicos y la política científica. Aquí utilizamos datos de 41 entrevistas semiestructuradas de élite con ejecutivos y personal del Consejo Nacional de Investigación (NRC) y miembros del comité de la NRC sobre el uso de CTI en informes emitidos por el NRC. Los hallazgos muestran que la cantidad de CTI en los informes de la NRC tiende a tener efectos modestos en la probabilidad de que los informes se utilicen en la elaboración de políticas o en los medios de comunicación. Los factores más importantes incluyen la sincronización del informe con respecto a las agendas políticas, la parte que solicita el informe y los roles promulgados de los miembros del personal de la NRC y los miembros del comité.

PALABRAS CLAVE: gobernanza nacional, sociedad civil, innovación, propiedad intelectual

Introduction

Often researchers are disappointed by the limited extent to which peer-reviewed research seems to contribute directly to high-level public policy decision making and policy advice (see Edgar, Schofield, & Campbell, 2001; Guston, 2007; Sabatier, 1978; Shipp, 2013). Researchers produce a highly specialized form of information with a unique claim to veracity, claims related to the correspondence among theory, method, and empirical results. Perhaps understandably, those who commit their lives to research tend to feel that the validity warrant for scientific results is stronger than for many other form of information. There is a continuing interest in the topic, including by the very scientists who are providing policy advice (Kelly, Oelrich, Aftergood, & Tannenbaum, 2004).

If we join Miller and Neff (2013) in defining science policy as the link between scientific research and the accomplishment of anticipated policy results, it is easy to understand why policy advice is focused on political preference, reforms, and feasibility (e.g., Ahmed, 2005; Feuer & Maranto, 2010; Frewer & Salter, 2002), much like in other policy domains. But the fact that few expect evidence-based science policy to preempt all other considerations does not blunt the expectation that at least some decisions or some parts of decisions will be informed by data-driven, empirical scientific research.

The focus of the present study is the use of formal scientific and technical information (hereafter STI), defined as the formal peer-reviewed journal literature in the science policy advisory in the form of National Research Council (NRC) reports.[1] While one could take a wide variety of perspectives on the issue of STI use at one of the nation's leading science policy-making institutions, our approach and concerns are

rooted in public policy studies. Thus, we are chiefly interested in how and the extent to which information, including but not limited to STI, is used in policy-relevant decision making, ultimately in hopes of improving understanding of policy making. Given this perspective, we give less attention to other approaches that could yield interesting insights but insights not ultimately policy-focused.

As is appropriate to this perspective, we employ a model that has been widely used in public policy, namely "credibility theory" (Bozeman, 1986; Coursey, 1992; Dunn, 1982). In a section below, we provide extensive information concerning the credibility theory but for present purposes let us suffice to say that credibility pertains to individuals' assessments of the believability of specific information content, but also information types, media, and processes. The basic relevance to our work is straightforward: we are interested in understanding how and why STI is used in science policy making and a maintained assumption of the paper is that parties to a decision vary in their credibility assessments and, in turn, this explains much (but certainly not all) concerning their information choices.

While the current authors feel that the information types and resources used in science policy making are important to policy effectiveness they take no position on the proposition that more STI should be used in science policy making (this issue is revisited in the paper's concluding section). In some cases the preferences of researchers often have little bearing on the knowledge ingredients in the policy cocktail (McLaughlin, Kathuria, Zmud, & Lynn, 1990). Even among those policy makers who feel that STI is a more valid type of information than other types, the validity of the information used may be perceived as less important than other aspects of information, aspects such as the accessibility, utility, feasibility, and persuasiveness of information (Thomas, Koomanoff, Riches, Cambel, & Madden, 1985). Hammond, Mumpower, Dennis, Fitch, and Crumpacker (1983) present some of the fundamental obstacles to the STI use in policy making, namely the situational issues in policy context, cognitive limits of policy makers, and the nature of scientific information such as its generalizability and the extent to which it is probabilistic in nature.

Regardless on one's position on the optimal role of STI in science policy making, relatively little research actually documents either the extensiveness of STI use or the dynamics by which STI is combined with our types of knowledge used in policy making. However, the scarcity of such research also depends upon the breadth of one's definition of science policy. While science policy and environmental policy usually are considered distinct, perhaps owing to different institutional histories and different relevant government agencies and statutes, environmental policy certainly is science-intensive and, moreover, those focused on environmental policy seem more attentive to the issue of the policy uses of STI (e.g., Holmes & Clark, 2008; Pielke, 2007; Scheer, 2015; Sundqvist, Bohlin, Hermansen, & Yearley, 2015). Also contributing to our knowledge of STI use in science policy making are many fine studies that focus more generally on policy making and policy processes for basic science (Barfield, 1982; Lane, Fealing, Marburger, & Shipp, 2011), medical science (Rushefsky, 1986), and environmental science (see McNie, 2007, for an overview) but at the same time provide insights into the use of STI.

The authors' own research, both in this study and a recently published companion publication (Youtie, Bozeman, Jabbehdari, & Kao, 2017) focuses directly on the topic of STI use in science policy. The earlier study, based on quantitative analysis of

bibliometric content of National Academy of Sciences reports, focused on citations of scholarly articles, patents, and other National Academy reports. The earlier results suggest that for certain types of policy domains, such as defense topics in National Academy reports, STI competes with other types of knowledge, including raw data, personal experience, authority, history and anecdote, analogical reasoning, or conformance to ideology, to name just a few of the alternatives to use of STI. This previous study, based as it is in data from the reports, cannot give any significant insight as to just why and under what circumstances reports are more intense in their use of STI nor does the bibliometric approach allow us to learn much concerning the reasons why science policy reports have impacts. Thus, gaps remain in our knowledge of the reasons for STI use, its relationship to other types of information and, especially, the factors that mitigate the use and the impacts of STI in policy making.

The use of bibliometrics and content analysis have important advantages in terms of precision, comparability among reports and their use and in providing data that can be conveniently analyzed in statistical models. However, what is gained in precision is lost in nuance and depth of findings. The aim of the current study is to supplement these earlier findings with data from semi-structured interviews. Since the interviews were conducted well after the quantitative results, they were informed by those earlier results and the interviews were, at least in part, designed explicitly to address some of the limitations and unresolved questions from Youtie et al. (2017). Here, we are interested in addressing a variety of factors that may pertain to the degree of use of STI in NRC reports and also the extent to which NRC reports are used by policy makers.

There is much literature on the use of science in policy making (Boswell, 2009; Edgar et. al., 2001; Frewer & Salter, 2002; Hammond, Harvey, & Hastie, 1992; Landry, Amara, & Lamari, 2001; Sabatier, 1978; Sabatier & Jenkins-Smith, 1988). However, since there is very little theory or systematic research on the character of knowledge in NRC reports, we rely on three sources to inform our thinking in this study. First, in the traditions of participant-observer research and embedded scholarship (Jenkins, Maxwell, & Fisher, 2012) we rely on the direct experience of two of the authors with NRC committees. The lead author has served as a member of five diverse NRC study committees, as a consultant for two other committees, as an external reviewer for several committees, and has provided commissioned background research for yet another. Reflection from experience seems a warranted approach given the paucity of directly relevant research and the fact that previous experience with NRC work was one of the primary factors giving rise to this research project, including this paper. The second basis for informing the present research is our previous related study (Youtie et al., 2017). In the prior paper we explored some of the same topics but with very different data. The third resource for our research is bodies of indirectly related research and theory, including especially work on use of STI in contexts other than policy making (e.g., innovation studies); the considerable research on knowledge utilization, most of which focuses on policy analysis and program evaluation information; and, finally, work on "credibility" of policy analysis and effects of framing on decision making. Each of these is explained below in some detail. The semi-structured interviews with NRC committee chairs and members, and NRC staff enables us to investigate not only the level of STI usage but also the particular logic and processes of

information selection entailed in these reports, especially the interplay of credibility, information availability, and utility assessment of information.

Background: The National Academy of Science as a Policy Actor

The National Academies include the National Academy of Science, the National Academy of Engineering, and the National Academy of Medicine (previously Institute of Medicine). For convenience, we hereafter refer collectively to this set of academies as the NAS. The NAS is a quasi-public body established in 1863 by the U.S. Congress (Boffey, 1975; Mullins, 1981; Seitz, 2007) and charged with providing advice concerning science and technology-intensive policy issues. One of the tangible indicators of the importance of NAS is its budget, composed chiefly of grants and contract revenues provided by Congress and federal agencies. According to the *Report of the Treasurer of the National Academic of Sciences* (National Academy of Sciences, 2016), for the calendar year ending December 31, 2015, the NAS received $279 million in receipts from a variety of study sponsors and contractors, including 74% from the federal government (Congress and federal agencies) and 26% from nonfederal sources (nonprofit institutions, state governments, and industry). The market value of its endowment portfolio was reported as $410.9 million as of December 31, 2015.

Why Study the NAS?

In many respects, the NAS seems an excellent institution for study of STI provision and use because, as a result of its origins and mission, it has a sort of "built-in" policy demand for the reports produced by the NAS committees and released through the NRC at the time we conducted this study, although since then, the NAS has done away with the use of the NRC as an explicit name for its report-producing function. In 2015, NAS produced more than 200 reports and their studies and projects cover a range of fields such as the defense, national security, and space; education and social issues; health and safety; industry, commerce, and technology; international affairs; national resources and the environment; the scientific enterprise in general; and transportation (NAS, 2016). While the NRC reports are sometimes controversial and address politicized policy issues, it is nonetheless the case that the policy positions and advice reflected in NRC reports are viewed by many as unbiased and the best available scientific advice. This is due not only to the prestige of the NAS but to the method employed in the reports, namely setting up ad hoc committees of persons, generally but not always researchers, who are widely recognized as experts on the subject at hand.

Compared to most government reports, the NRC reports are widely viewed as "scientific" in their basis and in general the committee reports strive to include relevant STI, both by the use of formal publications but also as mediated by the expertise and knowledge of persons on the committees and by the experts they call upon to testify before the committee. In short, the structure of the NAS and its committee responsibilities provide an opportunity, arguably an unparalleled opportunity, for the injection of STI into policy making and policy advice. Just as important, the combination of the institutional prestige of the NAS and the typically high level of

prominence and professional reputations of committee members ensures a level of access to a wide variety of person-to-person and informal information sources. Thus, the committee members and staff persons charged with producing the reports often have access to persons who are widely recognized as leading experts. Oftentimes, the committee members are themselves highly reputed (at least one member of each committee must be an elected fellow of the NAS) and have a level of social capital and an intensity of valuable social network ties found only rarely in public policy making of any sort. This means, then, that the use of STI as bases for reports competes with other important sources, including the committee members' experiential knowledge.

In all likelihood, the diverse NAS committees differ in the extent to which peer-reviewed, journal-based STI is important to committee findings and recommendations as compared to, say, expert testimony, personal experiences of committee members, or any of a variety of competing and often worthy sources of information. In short, the NAS committees' information choice environment is unusually rich and about as close to perfect access to information as one might encounter outside of the pure theories of information proposed by economists (Machlup, 1984).

One caveat for our study: whether warranted or not, the National Academies are viewed by some policy makers and opinion leaders as generally apolitical. Thus, comparing results on the use and impact of STI at the NAS may not be generalizable to all institutions potentially using STI in policy making.

The NAS Role in Public Policy

The NAS plays a significant and widely acknowledged role in U.S. science policy and there is general agreement, even among its critics, that the NAS is a major actor in U.S. science policy. Thus, it is a bit surprising that very little research has focused on the NAS as an institution or on its policy role. The modest literature on the NAS and NRC focuses on (1) its history (e.g., Cochrane, 1978), (2) specific policy processes and organizational aspects (Boffey, 1975; Ellefson, 2000; Parascandola, 2007; Policansky, 1999), (3) criticisms of the decision-making structure of the NAS (Boffey, 1975; Fein, 2011; Shapiro & Guston, 2007), especially the perceived limitations of the consensus report process and its utility in providing reports useful for priority setting and policy planning. With very few exceptions, the literature on the NAS is based on case studies and anecdotal information and many of the best-known studies are journalistic in nature and, indeed, written by journalists (e.g., Boffey, 1975). The NAS has not often attracted the interest of policy scholars. To our knowledge, our previous study (Youtie et al., 2017) is the only analysis of the NAS based chiefly on systematic quantitative data.

There is a more extensive literature on scientific advice in policy making, some of which touches on the role of the NAS and some of which does not (e.g., Jasanoff, 1990; Pielke, 2007). Much of this science advice literature is critical or reform minded (e.g., Frewer & Salter, 2002; Hilgartner, 2000), focusing chiefly on the utility of advice for science policy and the approaches employed. One of the reasons the NAS plays no more prominent role in literature on science advice is that the topic is more popular with European scholars (e.g., Ausubel, 1993; Irwin & Wynne, 1996;

Maasen & Weingart, 2005; Martin, 1995) than with Americans, perhaps because science advice in Europe tends to be more distributed (no European nations have an institution similar to the NAS) and in many cases science advice is more central than in the United States to science policy making and planning. Indeed, one of the characteristics of U.S. science policy is the lack of enthusiasm among politicians and policy makers for any significant long-range planning of science (Bozeman & Kim, 1981; Moser & Boykoff, 2013).

A somewhat related concept to the scientific advisory role of the NAS is that of scientific assessment. The NAS is not an assessment panel focusing on a particular policy area nor is it removed from distinctive political processes. Studies of scientific assessment, nevertheless, can be illustrative because of the evidence-based approach (Crowley & Scott, 2017; Mervis, 2017; Newman, 2017) taken by the NAS and assessment panels. In this area, the Intergovernmental Panel on Climate Change (IPCC) has been a particular subject of extensive study because of the global prominence of the organization and its mission. The Global Environmental Assessment Project, begun in 1995, has involved over 50 scholars from science and technology studies, political science, international relations, and natural science, and has amassed an impressive body of scholarly work on the IPCC (GEA, 2006). Some of this literature is summarized in Hulme and Mahony (2010) and updated in more recent publications (e.g., Mahony & Hulme, 2016). This work organizes its literature review based on questions posed by Shackley (1997) concerning the IPCC's inclusiveness, openness of its process, authority and legitimacy, and role and impact. More recent works have continued these themes. Ford and colleagues (2016) discuss the importance of including more indigenous information especially in adaptation recommendations of the IPCC. Vardy, Oppenheimer, Dubash, O'Reilly, and Jamieson (2017) question the privileged role of peer-reviewed literature over indigenous information in IPCC processes, contending that this privileged role limits the ability of reflexive learning and engagement of actors representing other policy positions such as climate denial. This link between science and policy is represented by Lidskog and Sundqvist (2015) as a conventional distinction between international relations, which accords greater legitimacy to science the more distant it is from politics, and science and technology studies, which contends that science has greater authority the more it is embedded in policy. Most of these studies draw on the seminal work of Sheila Jasanoff concerning the importance of coproduction of science and society for its legitimacy and authority (Jasanoff, 2004, 2010).

Our work contrasts with Jasanoff's excellent work in that we do not focus on macro-level issues of legitimacy and authority but, rather, the on-the-ground concern about how and why STI (and "competitor" information types) get injected in NAS reports and policy making. We do not examine the authority and legitimacy of the NAS as a body, because there is no obvious basis for questioning its authority and legitimacy given its long-standing statutory basis, its close relationship with Congress and the federal executive branch, and its prominent role among scientists. Rather our work focuses on the credibility of information used to produce NAS reports by committee members and NAS staff, and the subsequent reactions of congressional staff based on what information they deem to be credible. This perspective on credibility and knowledge use is discussed in the next section.

Theoretical Perspectives: Knowledge Content and Knowledge Use

The primary focus of this paper, use of STI content in a policy-related document produced by the NRC, seems to us well justified, especially in light of the scant research on STI use in science policy. While the research directly related to this topic is quite modest, there is a considerable literature in public policy studies and related fields on the use of knowledge in policy making. This literature gives much less attention to STI (at least as we define it here) than to program evaluation use and use of "professional social inquiry," to refer to the Lindblom and Cohen (1979) term. Here, we contend that credibility theory and the knowledge utilization literature are relevant to our question of STI use in NRC reports, and the use of NRC reports in policy making.

Credibility Theory

The theoretical lens we employ to help frame the study and suggest research questions is credibility theory. *Credibility* refers to the individual's subjective assessment of the believability of information, apart from its manifest utility. Individuals differ in the extent to which they find credible certain types of information. By credibility, we mean that the believability of facts is based on the frame of reference that the decision makers bring to the process (Bozeman, 1986; Bozeman & Landsbergen, 1989; Landsbergen, Coursey, Loveless, & Shangraw, 1997; Miller & Neff, 2013). Thus, for example, one person might have a higher value than another for information based on personal experience and be more willing to generalize from personal experience. Another might have more value for the views of experts. Yet another might have a stronger attraction to STI. However, even in the case of STI, individuals may prefer it for different reasons, including among others, a respect for its methodological warrants (e.g., experimentation), its precision, or the social context related to its acceptance (i.e., test under the fire of peer review).

Credibility and NRC Reports

The NRC reports provide the ability to accommodate a variety of credibility warrants; indeed, every NRC report can be characterized as a mix of information types. For most NRC reports STI, as we have defined it in terms of refereed journal articles, is one component. But as long known by students of policy making (e.g., Dunn, 1982, 1990; Webber, 1991), "information competes" and the closer policy gets to policy making the greater the competition (Blom & Vanhoonacker, 2014; Rigby, 2005). Thus, while most NRC committee members can be presumed to have at least some value for STI, given the nature of the institution and its specific mission, members vary in their views about STI, about the value of other sources of information, and about the value of STI in comparison to other sources of knowledge. What are some of those other sources of knowledge? Some of the types of knowledge known to be included in NRC reports include panelists' personal experience; testimony from experts and witnesses (both invited and at public hearings); views and personal experiences of members of agencies involved with or authorizing the report; data, models, and simulations perceived as relevant to the topic at hand; general history and history specific to the

problem at hand; knowledge based on reputation; and knowledge based on authority. In addition to the formal knowledge embodied in our definition of STI, there is also knowledge based in case studies and context-based reports, consulting reports, government reports, and previous NRC reports. Further, the credibility of types of information varies in known ways. For example, STI tends to have a different degree of credibility when it is one's own research or research of close acquaintances.

Most of the work on credibility of information in policy making focuses specifically on the individual decision maker. However, the cobbling together of an NRC report is better viewed as "group-based credibility assessment." While there is no literature on group-based credibility assessment, at least with respect to science policy making, there are a few studies that relate group judgment to science policy making (Hammond et al., 1983, 1992) and many others related to such possibly relevant issues as group decision-making dynamics in the workplace (e.g., Janis, 1982; Hoegl & Gemuenden, 2001; Kerr & Tindale, 2004), credibility and STI use in innovation settings (Rycroft, Regens, & Dietz, 1987), and "framing" studies directly related to public policy-relevant group decision making (e.g., Bostrom, Fischhoff, & Morgan, 1992; Doyle & Ford, 1998; Wong-Parodi & Strauss, 2014).

STI Credibility Precursor

While there is a significant body of work relevant to STI use and to credibility, there is very little work, as one might well expect, on the relation of these topics to the work of the National Academies of Science. The current authors have recently published a paper directly on this topic, almost certainly the only paper on this topic, and it is important to distinguish the current work from this previously published paper. It is also important to note that the previous paper help frames the propositions provided below.

Our previous work (Youtie et al., 2017) included bibliometric analysis and content analysis of 589 NRC reports in order to determine the extent of use of STI in the reports, with STI defined as citations to refereed scientific and technical journals. To predict STI use, our study focused on various characteristics of the reports (e.g., size, year of publication), variables pertaining to the policy content areas, attributes of committee members (e.g., sectoral affiliation of committee member from committee biographies, sectoral affiliation of reviewer from reviewer organizational information), and nature of the authorization for the studies. We also examined not only the use of STI but the extent to which the reports were used by Congress (most studies were authorized by Congress or executive agencies) in subsequent policy making, where use was operationalized as conveyance through hearings or testimony or briefings on the one hand and whether the report was cited in Congressional documents on the other. In short, all methods were unobtrusive and data-driven, in sharp contrast to the present study, which is based chiefly on interviews.

The chief findings of the Youtie et al. (2017) study show that most NRC reports use a considerable amount of STI but that the extent of STI use does not predict the use by Congress, excepting a small negative relationship between the amount of STI in the report and the likelihood of Congressional use. The study concluded that STI was often less important to use than a variety of other possible factors, ones that could not

be studied in any detail with an approach relying exclusively on unobtrusive measures and bibliometric analysis. Our empirical findings showed great variance in STI use in NRC reports and, interestingly, there was no significant relationship between STI use and likelihood of reports being transmitted to Congress or used by Congress in policy making.

This current study, which employs interviews (in contrast to the bibliometric approach of Youtie et al. [2017]) to delve into detail about factors pertaining to the development and use of STI, seeks to shed some light on the factors that could not easily be addressed in the earlier study. Thus, the hypotheses provided below are to some extent suggested by the previous study but extend the earlier study's concerns.

Research Propositions

We propose that STI will be widely used in NRC reports given that it is a formal part of the NRC study process. However, we also expect that other factors will be important such as the credibility that committee members place on STI and the utility and availability of other types of information. Use of STI is likely to vary by policy area, with some policy areas having less publicly available scientific information (Shea, 2004) or requiring more timely information than the typical journal article publication process allows (Luwel & Moed, 1998).

In the interests of space, the propositions we provide here include only the amount of accompanying information required to explain them succinctly (but we provide more detail in the report of the findings).

- *Proposition 1: NRC panels vary in their use of STI in reports and one determinant of variation is the institution requesting the report.*

As a result of our previous quantitative research (Youtie et al., 2017), we know that there is variance in NRC reports' use of STI, but the previous study could not provide sufficient depth to shed light on all the reasons for variation in STI use. We also know from experience and casual observation that the agencies requesting reports vary a good deal with respect to their requirements and expectations as well as their ability to consume STI. In some cases, such as federal laboratories or the Environmental Protection Agency, the requesting agencies have a substantial number of staff that have advanced scientific training. Thus, we expect that for those agencies there will be a tendency to include more STI, all else equal, because they have a greater ability to absorb it and interpret it. For other agencies, such as the Internal Revenue Service or the Federal Aeronautics Administration, the number and percentages of scientific employees are less and, thus, we expect that the intensive use of STI might be perceived as either less appropriate, in less demand, or less effective.

- *Proposition 2: The political visibility, political contentiousness, and potential breadth of impact of the panel topic will affect STI content.*

We anticipate that committees that have higher political visibility and potential for conflict will tend to use STI because the focus will be more diffuse and because more

value-laden information will be important. However, we are not entirely confident about this proposition's reach. In some known cases, highly contentious panels may use STI as a "knowledge weapon" to bring attention to the point of view expressed in the panel report.

- *Proposition 3: The organization of the report writing affects STI content. With respect to work organization, we expect (a) the distribution of writing tasks influences STI usage, with the amount and pieces of STI in use being negotiated during the writing process; (b) the STI content of reports will be to some extent driven by the external reviewers, who in some instances are advocates for "more science" in the report.*

More than most, this proposition flows directly from the authors' experience as members and consultants for NRC committees. In their experience, when the responsibility for report writing was decentralized and specialized, more STI was used in the report. When groups did the writing, especially heterogeneous groups, less STI appeared in the report. We do not know, of course, whether the authors' personal experience is representative.

Direct experience also suggests to us that report reviewers can play a role in increasing STI use. In the majority of instances, report reviewers are persons with advanced scientific training, typically researchers who are accustomed to conducting peer reviews of papers submitted for publication. We expect they will use many of the same norms in reviewing reports, including being drawn to data and literature, as they have used in journal-related peer review. If the STI literature is scant, reviewers likely will ask why or suggest additional literature.

- *Proposition 4: Testimony, public hearings, and expert witnesses affect STI use in reports; the valuing of these respective sources depends upon panelists' views about the credibility of various knowledge types.*

We expect that testimony, public hearings, and expert witnesses will negatively affect the amount of STI used, chiefly because each of these provides an alternative to STI, a variety of "competitor knowledge" that may be used in the report. However, when those serving as expert witnesses are scientists then the amount of STI included may be increased.

Regarding panelists' views concerning the credibility of information sources, we note that while panelists who are practicing scientists or engineers may resemble one another in their views of the credibility of information, even among them there will be variation in the extent to which STI will be viewed as more credible than other types of information. In the first place, scientists will have had a peek behind the wizard's curtain and will understand the contentiousness of science. Second, they may have a tendency to trust their own experiential knowledge and expertise even more than they trust the formal STI. In the case of non-scientist members, we expect the variation in credibility assessments will be even greater. Some non-scientists will be intimidated or unquestioning about STI, some will simply view it as inaccessible and others will tend to think other types of information are more important, typically more personalistic information provided in testimony of witnesses or in history-based anecdotes.

- *Proposition 5: The level of STI usage in the report has no significant influence on the impact of the report.*

In our previous bibliometrics-based study (Youtie et al., 2017) we learned that the STI-intensity of NRC reports has little effect or even a modestly negative effect on the use of the report by Congress. Thus, even using the very different research approach of semi-structured interviews we anticipate a similar result. However, we revisit this hypothesis not only to determine if different methods yield the same result, but also because our earlier approach to determining use (described above) necessarily provided a fairly circumscribed construct for use and generally equated use to impact. The interviews allow us to probe more deeply into both use and impact.

Study Procedures

The interviews for this study were conducted in 2015 to 2016 by the authors and two research assistants. Interviewees included 29 committee chairs, and 10 NRC staff members and 2 members of Congressional staff (information about interviewees and an interview key is provided in the Appendix).

Due to the need to maintain anonymity we cannot divulge the names of the interviews but we can provide the reasons we chose these individuals and we can also identify some of the limitations of our procedures. First, we were chiefly interested in interviewing NAS staff who work directly with the study committees and, preferably, ones who are full-time staff rather than contractors. We sought to represent the breadth of NAS programs: Defense, National Security, and Space; Education and Social Issues; Industry, Commerce, and Technology; Natural Resources and Environment; and the Scientific Enterprise (for example, studies of universities). We did not include the Transportation Research Board owing the fact that their procedures are quite different than other program units, as are their reports (see Youtie et al. [2017] for a more detailed explanation).

The number of full-time staff working directly with committees is actually quite small (it is not easy to develop an exact estimate but the number is surely less than 20). When considering our desire to interview staff associated with a variety of program units, full-time and more experienced staff and, of course, staff wishing to be interviewed, the choices were few. We used two NAS employees with whom we were well acquainted from past professional experience to advise us concerning the program affiliations of staff, their level of experience, and full-time status. Our advisers identified 11 staff members who agreed to speak with us. Each met our criteria of full-time employees with extensive experience working with NAS committees. In turn, our interviewees suggested that we might wish to interview Congressional staff persons who were quite familiar with NAS work and suggested two such individuals. The Congressional staff working regularly with NAS is an even smaller number than NAS full-time program staff. Both Congressional staff members, each associated with a science-intensive Congressional Committee, agreed to be interviewed.

The choice of NAS study committee members to be interviewed provided many more degrees of freedom. Here, our rationale was that we should, again, choose

committees and, thus, committee members, from a diversity of the NAS program units. We focused only on committee chairs reasoning that they would have a broader view of the committee's work and also its subsequent impacts. While committee chairs at NAS vary a good deal, in most instances their work is vital and they generally work hand-in-glove with NAS staff to a degree not common with other study committee members, many of whom choose to play specialized roles. We also decided to include only committees that had concluded their work but that were functioning within the past three years. In doing so we hoped to lessen problems of recall. We drew up two lists of 50 committee chairs that met these criteria from different parts of the distribution of committee reports in terms of their use of STI based on data obtained through the earlier bibliometric study (Youtie et al., 2017): within one standard deviation of the mean use of STI which was 129 references, only one-to-five STI references, and no STI references. Twenty-nine of these agreed to be interviewed. We were unable to find up-to-date contact information for many members of the lists (because they had retired, changed jobs, or were deceased). The few who explicitly refused to participate cited concerns about the need for secrecy in their committee work.

All the NRC staff and Congressional staff interviews were conducted face-to-face. Most of the committee chair interviews were conducted by telephone, with one conducted in person, one by Skype, and two via multiple email exchanges. Interviews were conducted by six researchers including three authors of this paper. While a thematic protocol[2] was developed at the beginning of the study, the interviews varied a good deal according to the interviewee's role. We provided assurances of anonymity so it is not possible to provide either the names of the interviewees or of the committees on which they served. We do use and show code numbers representing the committees in question (the committees on which the interviewees either served as members or as staff). For some of the propositions we have considerable relevant interview data and for some relatively little; this disparity does not reflect the relative importance of the propositions but rather the natural variance one finds in the extent to which particular research topics receive attention.

Findings

We present the findings[3] for each of the respective propositions provided above, with information from the interviews presented in the Appendix. The quotes below are presented with their interviewee number; interviews C1 to C4 are NRC staff, C5 and C6 are Congressional staff, C7 to C35 are NRC committee chairs and remainder are directors of boards. *We note that due to space constraints we have provided below only a small minority of the interview quotes.* Those interested in more details can contact the corresponding author who will provide a table associating the propositions to the more extended quotes, coded by interviewee number, as here.

Proposition 1: NRC panels vary in their use of STI in reports and one determinant of variation is the institution requesting the report.

The interviews bear out that the extent of STI use in reports varies considerably among the panels, corroborating our results from the related quantitative study (Youtie et al., 2017). The STI use and reason of usage largely depends on the nature

of the committee charge and the substantive area, task and question of the report, as the following quote illustrate.

- C2, "Depends on the area. In defense, some of that is classified. In the nuclear realm, a lot of that is gray area literature. Someone from DOE thanked us for using some think tank report. But once we used it here, it was ok. A lot of it depends on problem area. In life sciences, a lot of what we do relies on journal articles and formal literature. … All of those will draw on peer reviewed literature."

Some respondents answer that the STI is the fundamental knowledge type in the reports, although the level and usage have variation.

- C3, "All reports have science but the depth varies. … We try to use science to ground the report. It isn't going to be a deep dive but it wasn't going to be extremely deep. It is often to give the study its grounding so we can go ahead and write the report the way it needs to be written. … Because we are in the policy arena we have to think more strategically. A discipline-focused area will be deeper in terms of the science…"

The purposes of STI usage also vary. The respondents describe the role of STI as follows.

- C22, "… [H]aving solid scientific support is extraordinarily important. We wanted a strongly scientific based study, free from bias, a report with independent scientific advice."
- C32, "STI is used to support what the committee was saying. In fact, the committee did not find literature disagreeing with its conclusions. The literature was supportive of everything. Only in one case did the committee cite two sides of a dispute."

One respondent argues the purpose of the report itself is about the use of STI.

- C9, "The goal of the report was to make the science relevant to policy makers. … The goal was to facilitate practice of intelligence."

The level of STI usage varies among the sections within the report.

- C10, [The report is] "bifurcated—early part of the report focused on history, heavy in STI, later part more forward looking for field, used more committee members' personal experiences and personal views. Drew on history a bit for early part and to buttress history but more of a secondary concern."

Many respondents felt that STI was the dominant or at least a very important type of information in their respective committees' reports. For example:

- C8, "It is very important. It wasn't the only ingredient, but it was the most important."

- C9, "It was central to the report. … It was all about grounding advice in research."

Other informants, a minority, responded that STI use was not significant in their reports. Sometimes reports use less STI because of the nature of the report's inquiry. Some reports, particularly in the education and social issues area, involve social inquiry into conditions of need and social welfare, with scientific issues being of only secondary importance. In other cases, such as the defense and national security area, there simply is very little extant STI. In some panels, the committee charge requires original study and data collection or site visits, because of the nature of the task and particularly the absence of relevant STI as the committee is investigating new areas and topics. For example:

- C12, "[We used] very little STI … we used preceding reports, army reports, that were not peer reviewed. We [got] input from previous army panels."
- C19, [STI was] "not big for this report—this one was very focused on fact finding and documenting, site visiting."

The nature of the STI makes a difference. One respondent describes an issue of the nature of STI, in a manner that pertains to Hammond et al.'s (1983) typology of the three fundamental obstacle of STI usage in policy making.

- C36, "The classic issue with science is that it can take time to write a paper, get it through review; even in the best of circumstances, it can be a year, two years. They couldn't wait that long so what they did was get the best information possible about the immediate events and talk about those events in terms of case studies and use references as they were available, but indicating again in the report that there hasn't been a peer review of this and earthquakes are happening as our pens are running across this page."

Another respondent describes how raw data can be used in the committee.

- C37, "We're very careful. One of the trickier areas is handling sort of raw data. That's something we're very careful about. There are actually special internal procedures that have been set up. There are cases where there isn't any published work and you're being asked a question that depends upon data that's out there. This doesn't tend to be stuff my work does. But I've seen the process. There's a process to make sure you've got people with the right expertise on the committee and the right reviewers to make sure you have analysis done in a competent way."

The same respondent provided an especially interesting perspective concerning the extent to which STI plays a relatively small role in settling disputes.

- C37, "It's funny because I wouldn't think of it and STI and non-STI framing. Sometimes you resolve things by having the discussions and one group or the other group sits in that discussion. Sometimes you resolve these things by changing the type of disagreement to one where you actually sort of agree to

each other's perspectives. Sometimes you hash it out and you find a resolution. But sometimes you say ok we're going to agree to disagree, but we agree to each other's characterizations of the situation and present both arguments."

The second aspect of Proposition 1 relates to the role of institutional request and its effects on STI use in reports. In some cases, the requesting institution may set very specific aims for the committee and report. Depending in part on the institution requesting the study, the committee may be implicitly or explicitly mandated to look at STI, or other types of information may be required. For example:

- C7, "The nature of the committee's charge mandates that they mostly look at STI."
- C28, "This question depends heavily on who pays for the report. Because there is close to $1 million involved, the NRC wants to be able to defend what they are doing. This report, in particular, had some impact. … They [the sponsor] wanted 'new ideas from new people.'"

In short, the results show that the use of STI in reports is largely influenced by the fields of inquiry and nature of the problem addressed by the committee and these factors interact with the institution requesting the support.

Proposition 2: The political visibility, political contentiousness, and potential breadth of the panel topic will affect STI content.

The relationship here is not straightforward. In some cases, high-profile topics will use very little STI because it is viewed as less accessible or, in many cases, as less relevant. One important finding is that the lack of technical expertise of members of Congress is not weighed heavily. The respondent C38 described that some members of Congress ask the staffs about the technical aspects of reports.

- C38, [*Probe: Do they ask about STI in reports?*] "Sometimes. Some members are very interested. … There's 19 doctors who do understand what a protein is, 9 psychologists, 12 nurses, 20 engineers. There are a lot who understand. …"

The respondent C38 further described the examples of members of Congress who are very interested in STI in the reports, including some who have PhDs in science and who read *Science* and *Nature* every week. However, the following respondent indicates the opposite case.

- C40, *Probe: Did Congress members question the science at all or did they try to couch or contextualize questions as 'This is the bad outcome that science leads to.' It seems that there was already bias there.*] "There was certainly bias. [The respondent identifies a particular Congressional committee chair] believed in case studies basically. That's his grandchild. The case studies of all the kinds of internet that his daughter glommed onto. So he thought he was using evidence. He thought he was using STI. I want to believe that in his heart he felt he was using STI. He just couldn't understand why that wasn't data."

Thus, the response of Congress and other audiences may also vary considerably. On the relationship between the potential impacts and the STI usage, an NAS committee chair describes it as follows.

- C8, [*Probe: How did the possible uses of the report shape the type of information and the information content the committee included in the report?*] "The committee kept a specific audience in mind, which affected how the information was presented but not so much the specific content. They wanted the report to be accessible to policy makers and congressional staffers, so they made sure it wasn't too technical and it was written in a clear and concise manner. They did consider how the use of certain types of information might influence the perceived value. The report seems to have been viewed as a very successful report from NRC bureaucracy's perspective… but many committee members were disappointed in the outcome. They felt that, though it was well done, it was too bland, and general(.)"
- C38, [*Probe: Do you find that when you're working on bipartisan issues that there are differences in how both sides want to use STI?*] "Oh yes. Well, it depends on which part on what side. Neither side is not guilty of using science in the way they want. Most people want NRC reports to back their plan. So I'm very careful to go to both sides including the people who will be disappointed with our findings. Sometimes our findings are very injurious to people's agendas."

Although some reports may deal with politically visible and controversial issues, the scientific rigor tends to be at the center of inquiry, rather than the political issues, at least that is the view of some respondents:

- C19, "Well I mean you try to be persuasive but rigorous. This is not a lay public document and none of the reports are, so we don't try to dumb it down for Congress. We assume staffers will get into these issues and pick up the message. The culture is to write these rigorously for a scientific audience so that the people get these scientific recommendations. That's the reason why briefings are held … to translate science to the press."

One respondent talked about his experience in the two congressionally mandated studies.

- C36, "I was [the study director] for two recent [studies]. Both of these studies were congressionally mandated. So it was anticipated that there would be congressional briefing, not necessarily testimony because one does not necessarily follow the other; it depends on the circumstance. As study director, I don't know we deviated in any way from what we normally do from studies, which is to try to make them as scientifically sound as possible. The basis for us is always what does the science, engineering and technology say. So we didn't add special attention because it was congressionally mandated. We treated as we would any study where we want the science to take us where it went."

This respondent thinks that the Congressional mandate did make them think about the briefing but they used the same scientific basis as reports not Congressionally mandated.

According to the same respondent, STI centrality relates to the timeliness and the expected life span of the report:

- C36, [*Probe expressing tradeoff of timeliness and scientific rigor and thoroughness*] "I think they were extremely careful because [of] wanting your report to have relevance and also wanting to make sure you weren't saying something that would be disproved three weeks after the report was released because new info come to light. … I think the care with which they approached it was born out given where we sit today with the report. The report is still being used and it's four years old. It's still being used and referenced."

In controversial areas such as climate change, the quality of evidence and STI are viewed as especially important:

- C39, [*Probe: In your experience in preparing reports that will be used in climate change Congressional testimony, how much does STI relate to use in testimony?]* "It's largely based on STI. Our approach in writing reports is that there needs to be a strong basis for any statement is made. If a report has a recommendation, I think of it as a pyramid. The commentary recommendations are at the tip of the pyramid which needs to be supported by a lot of information behind them. In our review process, there's a lot that goes into saying 'is that an opinion? If so, how is it supported?' [W]ith climate in particular, because there's so much attention to that work, that there's more scrutiny…"

Political visibility of study topics often receives at least some consideration:

- C38, *[Probe: Does the fact that there will be Congressional testimony affect the use of STI?* "It depends. Some of the reports are requested by Congress. With those, you'll be sure there will be testimony. It doesn't affect use of STI."

Overall, we can conclude that the influence of political visibility and beliefs about the likely impact of the reports may affect the presentation of STI but it does not necessarily affect the amount of STI provided.

Proposition 3: The organization of the report writing affects STI content. With respect to work organization, we hypothesize (a) the distribution of writing tasks influence the STI usage, with the amount and pieces of STI in use being negotiated through the writing process; (b) the STI content of reports will be to some extent driven by the external reviewers, who in some instances are advocates for "more science" in the report.

In some cases, NAS staff are intimately involved in information gathering and writing process. At least in some cases, as C1 notes, staff involvement may be increased because committee members are deemed too zealous.

- C1, "If you get somebody who is that committed you almost don't want them to write. Sometimes you have to hold the chair back. Sometimes you ask them to draft certain sections. When it happens, you often have to hire a writer at

the end to have a coherent voice at the end … we tend to get very qualified people."

The STI usage may depend on the individual panel members' preferences when the writing tasks are distributed to individuals with responsibility to decide what information is needed in each chapter.

- C33, "Authors of individual chapters decide what references are used. In the discussion, other panel members usually add more references which they thought important. The process is very similar to the academic [writing process]."

Respondents describe the STI use and group dynamics as follows.

- C34, "(STI was) one of the many types of information. STI came in later in the process. Initially, the members draw on their knowledge and personal experience, as well as those coming in to give presentations, to formulate opinions and points of views. Then in later stages, to document them, the committee went to STI, to check if the views are consistent with literature, and find any sources to back up the points."
- C30, "… If they [the committee] included everything they wanted, the report would have been five times longer. They tried to select examples that make the technical point and the societal point. They wanted to give justice to the technology and those that live/work in the industry. This is where the skills of the committee members became really important."

These qualitative results suggest that committee members have some leeway to determine the extent of STI that appears in the chapters to which they have been assigned. However, this latitude is limited by NRC staff review and the practical length of the report. We did not find mention made of the role of external reviewers in increasing or reducing the use of STI in reports, although this lack of reference to external reviewers may well be a function of the particular interview subjects in our sample rather than a substantive finding.

Proposition 4: Testimony, public hearings and expert witnesses affect STI use in reports; the valuing of these respective sources depends upon panelists' views about the credibility of various knowledge types.

Not all committees include testimony or public hearings and, when they do, their effects vary more than one might expect. Some of those appearing as witnesses are themselves scientists and commenting on "the science," drawing from their knowledge of scientific issues and, especially, their own work. A key factor in the use of public hearings and experts is the nature of the committee's charge and the characteristics needed for the report. The interview results suggest that the testimony, public hearing, and expert witnesses involve both those with experts of the studied topic, stakeholders, and sometimes the public in general.

- C11, [*Probe: Personal experience?*] "A lot of personal experience but being very familiar with the scientific literature. We also had open sessions where the public and non-committee members could speak and they did. I hate those things. But you have to give everybody a chance." [*Probe: was the open session material used in the report?*]" "In my opinion, no. They were just giving personal opinion as opposed to experience and scientific knowledge, opinion and knowledge are two different things."
- C4, [*Probe: is there a lot of use of testimony?*] "It varies. We give more emphasis to experts. Testimony that is controversial, they have to satisfy our commitment to openness. When we hold workshops that are part of a large study we have experts. … This doesn't rise of the level of evidence in a journal, but still…"

The committees vary in the extent to which they use the collected information. As one interviewee notes:

- C7, "My committee is unique because we took public testimony twice, allowing more than 200 people to speak for two to three minutes each. We listened to testimony not to agree or disagree, but to determine whether there was a scientific basis to the points being raised. We listened to testimony from experts, and many committee members had expertise in working with public as regulators. All of these types of information played a factor."

Others providing testimony representing interest groups and providing policy statements, statements may or may not include any scientific content.

- C14, "Yes we had whole hearings, several in which various interest groups were invited to participate. Some of those presentations were by vested interest [groups] who make certain claims… [T]hat's a preference that was clearly not based on… scientific data, but it was a policy statement. [*Probe: How important were they in the report?*] Not very—because the [anonymous] committee's judgment was that the states had not taken any action and were not likely to without federal incentives."

These comments indicate that committee members do take in testimony from witnesses and experts to uphold the open nature of the proceedings. As the proposition suggests, the effect of experts' statements on the NRC report are gauged against their scientific veracity, with policy statements and interest group claims receiving less weight than knowledge sources which committee members deemed more scientifically credible.

Proposition 5: The level of STI usage in the report has no significant influence on the impact of the report.

From our earlier study (Youtie et al., 2017) we know that the level of STI usage does not generally have great influence on the impact of the report. However, the earlier work could not easily get at contingencies, the factors that determine the relationship of amount of STI to the use of reports. Thus, the findings here give some

elaboration of the earlier findings and, at the same time, some insight into contingencies. One interviewee feels that STI is crucial for impact, but provided a nuanced view of the contingencies:

- C2, [*Probe: What is a strong report.*] "The best possible evidence. Another would be being very clear about what you don't know and where the uncertainties lie. And depending the uncertainties, is there a path to resolve those. Another is you have the chance to actually continue to do dissemination of results after it is done. It is not always easy to persuade funding agencies that the project is over after the report is published. Sometimes the report is for a particular agency. You've got a good intellectually diverse committee and could come to consensus carries real weight."

Although some reports may deal with more controversial issues, impacts may depend on a range of factors, especially timing:

- C41, "… This report has had a tremendous impact. It … had several congressional hearings and it's still getting written up in the newspaper frequently. The Supreme Court cited it. This was a great example of policy making success. It hasn't changed too much policy, but it stirred things up. It didn't rely critically on STI. … Somebody in the senate asked for this report, which nobody in government had wanted to touch this subject. … There's very little science and basic standards like quality control—certainly not in uniform. When I say not much STI, the committee did look at a lot of the research publications…, but most of them were very low quality because you can tell that, but how do you document that. So, we didn't say a lot about that. … This book [report] is much more of a narrative about problems."
- C16, [*Probe: Did you consider how the use of certain types of information might influence the perceived value or use of the report?*] "Thought about that a lot—for better or for worse the Hill was interested in this whole thing, received it very positively, and it actually made a difference in terms of the things that various agencies actually did—even last year had a request from some staffer on the Hill about the state of progress on some aspect of the report."

Although the committee may try to prepare a stronger, more credible report with scientific rigor and integrity, the STI usage in the report itself may not influence the impacts and dissemination of the report. Different people, both within the study committees and among potential users, have different views of credibility. Moreover, a variety of situation-specific factors may affect the requirement for more or less STI, including not only timing, but the technical content of the topic and the state-of-the-art in research related to the question at hand.

Discussion

The use of STI in NRC reports certainly is not one-dimensional. STI can play many roles, including, among others, deep background for the panel's deliberations, evidence presented and used directly in the report, or evidence presented only as

references and not otherwise used. Adding to complexity, scientific information can be included in many different ways, not only through citation of journal articles but also in expert witnesses' remarks and in committee members' framing of the study, but without specific citation. Related, at least some of the gray literature used in reports includes, in turn, STI for its basis. In short, determining STI use is not at all straightforward and, thus, more intensive case studies or interviewing can sometimes provide insights not gleaned from counts and bibliometric methods.

One of our chief interests was determining the perceived credibility of STI as compared to "competing" sources of information. In addition to the scientific merits of information, the respondents tend to consider the utility and direct relevance of the information to the study problem. In some cases, this requires weighing the greater rigor of the information published in a journal article against the lesser rigor but greater relevance of other sorts of knowledge such as, for example, personal experience or case study knowledge. Most committee members do not view STI as the only credible information type. This is particularly true of policy areas such as defense and national security where there is less availability of published journal articles.

The finding that parties to NAS reports vary considerably in their "credibility maps" and that they do not in some cases find STI more compelling than other information types is quite consistent with findings from both credibility theory and from studies of non-scientists and non-professionals involved in decision makers (e.g., Coursey, 1992; Mandell, 1989). One might expect that scientists, given the nature of their work, would have a much greater preference for STI, but the preference for STI is a function not of their training and socialization but other factors, especially the nature of the task entailed in the reports. Overall, the interview results show that the level of STI usage varies among committees, and a number of factors affect STI use, including the nature of the committee's task; policy area; timeliness issues; and the credibility, relevance, and availability of the information. Other factors such as the requesting institutions, political visibility, use of clear-cut criteria and reputations for the STI selection, and distribution of writing tasks may have less influence on the STI content and usage. The committees generally pursue scientific rigor and are eager to include STI when appropriate, within the practical limits of report length as circumscribed by NRC staff, but the volume of STI content does not have major impacts on reception of the report and its use.

While Hammond and colleagues (1983) suggest that there are many obstacles to use of the STI in the policy process, the respondents in our study tend to phrase their information usage as more about the usefulness, advantage, and justification. They are pragmatic and very much focused on the task at hand, especially the ability to complete their work with some recognition of the time horizon of policy issues.

Despite some scientists' concerns about insufficient use of STI in the policy process, most of those we interviewed were not strong advocates for using even more STI than is now employed in NRC reports and almost all of them recognize the need to blend STI with other types of knowledge. Most viewed their task as less about infusing as much STI as possible and more about ensuring the utility, availability, and credibility of the information included, whether STI or not.

In short, as committee members and staff choose from an expansive information environment, there is a sort of competition of knowledge types, with STI sometimes

being especially relevant and other knowledge types being more important in other instances. Nor is information choice always based solely on rational determinations of credibility, rigor, or relevance. Group dynamics always play a role, the composition of committees is important, and sometimes pure idiosyncrasy plays a major role, including such factors as who volunteers to write what section of the report. Perhaps the best way to think about STI use in NRC reports, and perhaps science policy more generally, is in terms of a constrained optimization problem, whereby STI competes against other types of knowledge and the pastiche that ultimately results is determined not only by systematic reflection about information use but also by a wide variety of largely unpredictable social factors. One respondent summed up this complexity very nicely:

- C37, "I don't know that we make as formal a distinction between STI and non-STI, but I think we're very cognizant of what kinds of evidence we're bringing to bear. I think we would clearly understand the difference between peer reviewed paper, expert testimony, [and the other information] we get. … It's all mixed up. The testimony you get is often backed up by or draws on the peer review research that the person is providing the testimony gives. So it's not easy to distinguish."

Importantly, the credibility structure (Bozeman & Landsbergen, 1989) seems to vary considerably among NRC reports, because individual members vary in the information preferences and selection heuristics. Our interviews suggest that the credibility structure involves negotiation among multiple parties with different ideas about credibility and utility of information.

Much of what we have said here may not be very surprising for students of knowledge utilization who study domains other than science policy (e.g., Green, Ottoson, García, Hiatt, & Roditis, 2014; Rich, 1997; Weiss, 1979). Nevertheless, what we can conclude about how the use of STI in science policy differs from the use of research (Lindblom & Cohen, 1979) in other contexts. To be sure, many of the same factors are at work, including competition among types of knowledge, differences in views about credibility, perceived relevance, and timeliness. Perhaps the most important differences relate to the *expectation* that STI will prove available and relevant. The knowledge utilization and evaluation research literatures show a consensus that science-based knowledge is of no greater importance than other types of knowledge reflecting other considerations, especially political feasibility (Lester, 1993; Purtle, Dodson, & Brownson, 2016; Sabatier, 1978). Most of those we interviewed shared that consensus. We note, however, that researchers who participate in science policy making and especially in NRC committees may differ from the many researchers who have no such experience.

Another difference between STI as defined here and other forms of research-based knowledge is that STI is more likely to seek generalization and is less sensitive to situational needs. Much social science research and nearly all research in policy analysis and evaluation attend closely to context because researchers generally aim to have targeted utilization by policy makers, not primarily by other researchers. Thus, while it seems that the use of scientific knowledge in science policy just makes sense in terms of the match between the knowledge content and policy domain, the fit between policy demand and STI is, understandably, not often that close. Scientists seek

generalization and empirically based theory more often than situationally focused knowledge for policy problems. Participants in NRC studies, and perhaps other science policy-making arenas, seem very much in touch with the fact that there is a role for STI but in most cases there is little reason to privilege STI over other forms of knowledge that contribute, sometimes more directly, to policy problems.

Finally, let us note that the paper has important limitations, ones that we hope will be addressed in future research. In the first place, the paper relies entirely on interview data and with a relatively small number of interviewees. While interview data often are quite useful for developing nuance and richness of response, the limitations of interview data are well known–not easily coded, not easily replicated, not easily quantified in a useful manner, subject to multiple interpretations (for an overview of limitations see Lamont & Swidler, 2014). We would like to think that our earlier bibliometric-based research (Youtie et al., 2017) compensates in part for the methodological and data limitations in this study, but we understand that the weaknesses of the current approach are not entirely abrogated by the application of a different method.

A second limitation of the study is that if focuses on STI use in only one of several types of science policy making and only one institution in one nation. Even though we feel it is an important type of science policy making, the generalizability is questionable.

A third limitation is that we are have no direct data about social processes but are relying on second-hand accounts. At a minimum, we would like to have witnessed actual committee hearings and analyzed social processes and interactions in these. Resources did not permit us to do so.

From limitations flow problems but also ideas. We hope that future studies will be able to provide systematic comparisons among science policy institutions and activities, preferably in multiple national and cultural settings. We would also like to see a more expansive conceptualization of STI use than we have employed in our studies, a conception that goes beyond use of journal articles. We understand that STI can come from different places and at different angles and it may well be the case that we have underestimated the infusion of STI in policy making owing to our specific focus.

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Notes

1 For decades, the National Academies of Science and the National Research Council have been the names used for these two closely related institutions, with the NRC being viewed as the research study arm of the NAS. Recently the name NRC has been abandoned and all is under the National Academies name. Since the distinction remained during the period of our interviews and since NRC is a term used by our interviewees, we retain this distinction.

2 In the interest of space, the protocol is not included here but is available from the corresponding author upon request.

3 The six interviewers involved in the study varied in their use of direct quotes (e.g., "we used a lot of STI") as opposed to characterization (e.g., "she said the committed used a lot of STI"). Since most used direct quotes and first person, the remaining interviews, ones employing third person, have been converted to first person. This was done for purposes of consistency and readability. We were conservative in doing so, adding no embellishments to the basic points. Since the vast majority of interview notes are direct quotations or paraphrases, we have changed the style of the notes that are characterizations.

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Appendix. List of interviewees and code numbers

Code Number	Policy Area	Position
C1		NRC staff
C2		NRC staff
C3		NRC staff
C4		NRC staff
C5		Congressional staff
C6		Congressional staff
C7	Natural Resources and Environment	Committee Chair
C8	Education and Social Issues	Committee Chair
C9	Education and Social Issues	Committee Chair
C10	The Scientific Enterprise	Committee Chair
C11	Natural Resources and Environment	Committee Chair
C12	Defense, National Security, and Space	Committee Chair
C13	The Scientific Enterprise	Committee Chair
C14	Natural Resources and Environment	Committee Chair
C15	Industry, Commerce, and Technology	Committee Chair
C16	Natural Resources and Environment	Committee Chair
C17	The Scientific Enterprise	Committee Chair
C18	Education and Social Issues	Committee Chair
C19	Industry, Commerce, and Technology	Committee Chair
C20	Education and Social Issues	Committee Chair
C21	Education and Social Issues	Committee Chair
C22	The Scientific Enterprise	Committee Chair
C23	Education and Social Issues	Committee Chair
C24	Defense, National Security, and Space	Committee Chair
C25	Natural Resources and Environment	Committee Vice Chair
C26	Defense, National Security, and Space	Committee Chair
C27	Education and Social Issues	Committee Chair
C28	Education and Social Issues	Committee Chair
C29	Defense, National Security, and Space	Committee Chair
C30	Natural Resources and Environment	Committee Chair
C31	The Scientific Enterprise	Committee Chair
C32	Defense, National Security, and Space	Committee Chair
C33	Natural Resources and Environment	Committee Chair
C34	Natural Resources and Environment	Committee Chair
C35	Defense, National Security, and Space	Committee Chair
C36		Director of an NAS Board
C37		Director of an NAS Board
C38		Executive Director [Anonymous staff group]
C39		Member NAS Board
C40		Member NAS Board
C41		Director NAS Board