New Methods in Creating Transdisciplinary Science Policy Research Agendas: The Case of Legislative Science Advice

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Abstract

In transdisciplinary fields such as science policy, research agendas do not evolve organically from within disciplines, but instead require stakeholders to engage in active co-creation. "Big questions" exercises fulfill this need, but simultaneously introduce new challenges in their subjectivity and potential bias. By applying Q methodology to an exercise in developing an international collaborative research agenda for legislative science advice (LSA), we demonstrate a technique to illustrate stakeholder perspectives. While the LSA international respondents—academics, practitioners, and policymakers—demonstrated no difference in their research priorities across advisory system roles, the analysis by developing and developed nation status revealed both common interests in institutional- and systems-level research and distinct preferences. Stakeholders in developing nations prioritized the design of advisory systems, especially in low- and middle-income countries, while those in developed countries emphasized policymaker evidence use. These differences illustrate unique regional research needs that should be met through an international agenda for LSA.

1. Introduction

Identifying and prioritizing societally relevant research poses one of the great challenges for science policy (Funtowicz & Ravetz 1993; Gibbons et al. 1994). Policy-relevant research originates in real-world problems, in which the solutions seldom fall under the remit of a single disciplinary community. When mismatches between the supply and demand for policy-relevant science occur, the breakdown often lies in the development of research agendas (Holmes & Clark 2008; Sarewitz & Pielke 2007; Van Enst et al. 2014) and their failure to represent the perspectives of pertinent academic and professional communities. As a result, research may be inappropriate, not meet users' needs, or result in their disenfranchisement (Sarewitz & Pielke 2007 p. 12). Addressing these challenges requires bringing stakeholders into deliberative processes to set research agendas, such as through the ideal of a democratic and "well-ordered science" of benefit to the collective good (Kitcher 2011).

A growing literature describes collaborative efforts to identify and prioritize scientific questions of policy importance by diverse communities of stakeholders (Rudd 2011; Sutherland et al. 2011). In this article, we use one such case example—the development of an international agenda to further the study and practice of legislative science advice (LSA)—to illustrate one of the fundamental challenges of transdisciplinary research, namely accounting for differences in the perspectives and priorities of stakeholders. Studies have consistently shown that the results of expert consultation processes are highly dependent on the selection of participants (Webler et al. 1991) and that communities on both sides of the science-policy divide often experience challenges in linking science to decision-making (McNie 2007).

The term LSA (Kenny et al. 2017)—or alternately, parliamentary science advice (Tyler 2013)—refers to the "broad systems that provide scientific and technological information to legislatures, including—but not restricted to—legislative research services, committee support systems, technology assessment bodies, lobbyists, and advocacy coalitions" (Akerlof et al. 2019 p. 2). As such, it represents a subfield within the discourse of "government science advice" (Gluckman 2016).

By employing an analytical method to illustrate the effects of stakeholder subjectivity on the prioritization of potential research questions on LSA, we describe the influence of stakeholder perspectives on agenda-setting and evaluate their implications for the emerging field. This technique (Q Methodology), while well-known as a social science technique for evaluating differences in stakeholder perspectives in a wide array of contexts—from health (Brown 1996; Valenta & Wigger 1997) to the environment (Cuppen 2012; Webler et al. 2009; Webler & Tuler 2001)—we believe has never been employed for the purpose of identifying research agendas. As such, it presents a new opportunity for methodological innovation and transdisciplinary field development in science policy.

2. Developing a research agenda for legislative science advice

Providing science advice to political leaders is as old a practice as science itself (Hannam 2011). The modern tripartite of legislative, executive, and judicial branches of government described in the 1748 *Spirit of the Laws* (Montesquieu 2011) has created the need for advisory capacities that align with the decision-making contexts and routines of each type of institution. Legislatures differ from the executive branch in their form and function. In comparison to executive agencies—which implement a nation's laws, provide fiscal management, and develop policy—legislatures make a country's laws, debate the issues of the day, and scrutinize the executive. Executives typically have a few political appointees and a large civil service, whereas legislatures have a large number of elected politicians (including sometimes appointed politicians, such as in the UK's House of Lords) with a much smaller number of career staff. Currently, a small percentage (~10%) of countries worldwide possess dedicated legislative science and technology advisory bodies (LSTABs) that provide scientific information to elected officials (Kenny et al. 2017; Tyler & Akerlof 2019). Some countries have maintained robust advisory units for decades (e.g., the UK Parliamentary Office of Science and Technology and the French Parliamentary Office for the Evaluation of Scientific and Technological Options), other nations are in the process of developing them (e.g., Spain), and yet others have had them but lost them due to political shifts (e.g., the United States and Denmark).

LSA is being provided in an increasingly complex and global context. The exponential rise in scientific information (Bornmann & Mutz 2015) and new technologies—what some term the "Fourth Industrial Revolution" (Schwab 2017)—pose challenges to the administrative structures, in some cases centuries old, upon which legislatures rely (Isman et al. 2019). Bornmann and Mutz estimate that the volume of scientific literature is doubling every 24 years. Meanwhile, information technologies such as social media and video-sharing platforms are changing the nature of governance and democracy (Miller 2019; Trottier & Fuchs 2014). These trends illustrate the imperative for understanding, and improving upon, the practices of LSTABs and wider science and technology advisory systems.

Research on LSTABs and providing scientific advice to legislatures to date has been primarily focused on institutions in Western democracies (Hennen & Nierling 2014, 2015a, 2015b), many of which pre-date these substantive developments in information and communication, with few studies in other parts of the globe (Sanni et al. 2016). In order to establish a contemporary agenda for research on LSA relevant to diverse stakeholders in both developing and developed nations, the research team conducted a series of exercises to collect and evaluate research questions from academics, practitioners, and policymakers worldwide. We reported the set of collaboratively generated research questions and findings about priority areas in Akerlof et al. 2019. In this study, we use the data to assess differences between stakeholders, present a novel method for illustrating them, and interpret their meaning for the direction of a LSA research agenda.

3. Developing transdisciplinary research priorities

In the practice of normal or "Mode 1" science (Gibbons et al. 1994; Kuhn 1970), research problems and methods are defined internally by disciplinary communities and emerge from the foundation of their shared body of knowledge. Working within these paradigms to identify key research questions allows collective puzzle-solving among members of the discipline with the goal of advancing the scope and precision with which phenomena can be described. Conversely, addressing real-world problems of societal relevance requires a different modality of scientific research, referred to as post-normal or "Mode 2" science, which breaks the bounds of normal science by straddling diverse academic and professional communities that lack commonly held philosophies, bodies of knowledge, or methodologies (Funtowicz & Ravetz 1993; Gibbons et al. 1994).

In "Mode 2"—characterized by transdisciplinarity (Gibbons et al. 1994)—science is opened up to a wider peer community. Because of the complexity of stakeholder interactions and new sites of production, "Mode 2" science is defined by different methods of communication. A burgeoning literature on co-production and usability of science broadly addresses the interactions between stakeholders as a kind of knowledge that is generated and used in a variety of ways by individuals and institutions (Bremer & Meisch 2017; Gibbons et al. 1994; Kirchhoff et al. 2013; Lemos et al. 2012). At the same time, a much narrower literature has emerged to describe one potential dimension of those interactions: the process of identifying shared research priorities among stakeholder groups.

The development of this practice originated with Sutherland in the fields of ecology and conservation (Rudd 2011; Sutherland et al. 2006). An expanding number of these exercises—which typically consist of some form of research question collection and selection (Sutherland et al. 2011)—have been conducted in the environmental domain (Brink et al. 2018; Moreira et al. 2019; Musvoto et al. 2015; Nagulendran et al. 2016; Parsons et al. 2014; Sugiyama et al. 2017). However, they have been executed in other areas as well, such as poverty reduction (Sutherland et al. 2013). Rudd (2011) categorizes the influence of these "big questions" exercises as conceptual (changing the way people think), instrumental (programmatic or policy design, and funding), and symbolic (supporting existing positions). While he acknowledges some skepticism from within the scientific community about their utility, Rudd claims that these exercises have the potential to influence science-to-policy processes and advocates for their use more broadly. Indeed, Sutherland and colleagues (2011) state that the article from one of their exercises was one of the most downloaded papers ever from any British Ecological Society journal, attracted substantial media publicity, and influenced the UK Marine Science Strategy (p. 246).

The methodology for these "big questions" exercises raises two fundamental questions, however, that are common to all participatory processes: 1) how stakeholders are chosen, and 2) how their perspectives are communicated and contribute to the final recommendations or decisions (Fung 2006). The practice of transdisciplinarity—by cutting across any number of disciplinary and practice boundaries—makes defining who should participate in these exercises, and the relative proportions of group representation, inherently difficult. As a result, the sufficiency with which the identification and recruitment of relevant participants has been conducted is hard to evaluate, or whether some group perspectives disproportionally bias the results due to the structure of the exercise. During exercises, participants typically contribute the research questions that serve as the basis for identifying the "big questions" (Sutherland et al. 2011). They then synthesize the questions: editing them, reducing duplicates, and voting until there is a final list.

A recent innovation is the addition of participant rankings to the exercise methodology (Rudd & Fleishman 2014). Research question ranking facilitates the assessment of differences between stakeholder groups in their preferences, even if we cannot statistically parameterize the bias resulting from who participates and how. Examples of "big questions" exercises in which participants ranked the research questions include: 1) the identification of conservation priorities in Peninsular Malaysia with representatives from government, NGOs, the private sector, and academia (Nagulendran et al. 2016); and 2) the collection of key research questions from scientists and decision-makers in regards to U.S. resource management policy (Rudd & Fleishman 2014). Nagulendran and colleagues asked respondents to rank by priority the top five issues within seven conservation themes from a list of 35 questions and found general agreement among the four stakeholder groups. Rudd and Fleischman asked scientists and policymakers to rank 40 questions as "the most or least likely to increase the effectiveness of policies related to the management of natural resources in the United States" (p. 220) and found differences between the stakeholders, but not along clear science and policy community dimensions. Hence, the dimensions on which stakeholders may differ in their research preferences are not always clear. A study that compared research question submissions, instead of preference rankings, found differences between six different types of stakeholders—respondents from research institutions, governmental agencies, NGOs, land managers, environmental consultancies, and business corporations--and their regional geographical representation in the prioritization of questions on biodiversity conservation for the Mediterranean (Moreira et al. 2019).

Because of the subjectivity with which experts are likely to view the importance of different types of research inquiries, we chose to use Q methodology due to its ability to highlight commonalities and differences between individual perceptions (Stephenson, 1965), which are likely to be lost in other forms of expert consultation (Webler et al., 1991). The technique employs inverted factor analysis, in which the respondents form the variables. This technique allows researchers to assess how different groups vary in their perspectives along any one dimension through identification of common factors, distinguishing statements related to these factors, areas of most agreement/disagreement, and consensus statements that do not distinguish between any set of factors.

We hypothesized—as did the aforementioned studies—that there would be differences in stakeholder preferences for a research agenda on LSA based on their varied experiences. Because of disparities in the prevalence of LSTABs in developed versus developing nations, we anticipated perspectives to reflect the stage of development of governance systems in addition to the individual roles that stakeholders play within legislative science advisory systems.

> **H_1:** There are differences in research question prioritization between respondents from developing and developed nations. **RQ_1:** How can these differences in prioritization between countries of different development status be characterized?

H_2: There are differences between respondents with different roles in the science advisory system. **RQ_2:** How can these differences in prioritization between science advisory roles be characterized?

4. Methods

Q methodology is a form of discourse analysis in which carefully chosen participants order a sample of statements to reflect their thinking about a topic (Stephenson 1965). Inverted factor analysis is used to reveal patterns among the individuals' ordering of the statements, in which the results represent shared narratives about the topic in question. The study consisted of three stages that were conducted between September 2018 and January 2019: research question collection, vetting, and ranking. The methodology is also described in Akerlof et al., 2019.

An online survey was first used to collect research questions on LSA from academics, science advisers, and policymakers worldwide (Sept.-Nov. 2018). Next, during a workshop at the International Network for Government Science Advice Conference on Nov. 8, 2018, in Tokyo, Japan, participants scrutinized the set of research questions. We coded all research questions into discrete categories, representing advisory system dynamics (evidence use, communication, system design, evidence development, ethics) and actors (policymakers, institutions, scientists, public, brokers). In the language of Q methodology, this set of questions formed our "concourse," the universe from which we developed statements to include in our Q sample (see Supplementary Information, SI Table 1). Finally, using an online survey platform, a subset of the original survey participants ranked the statements according to which information they would be most interested in learning (Dec. 2018-Jan. 2019, see SI Boxes 1-3). The ranking data from the third stage forms the basis for the analyses described in this study. The research protocol for the study was approved by Decision Research's Institutional Review Board [FWA #00010288, 277 Science Advice].

Table 1. The experts who performed the ranking were asked to characterize their work as producing, providing, or using scientific information, or a combination of their roles.

Respondent Science Advisory System Roles	**Developing (%)**	**Developed (%)**	**Total (%)**
Producer of scientific information	15	27	21
Provider of scientific information to government	42	23	33
User of scientific information within government	3	13	8
Producer and provider	12	7	10
Provider and user	6	10	8
Producer, provider, and user	21	20	21
** Missing data on expertise, n = 1*	*n* = 33	*n* = 30	*n* = 63

4.1 Expert participants

We asked international experts in the production, provision, and use of science advice—particularly in legislatures—to participate in the ranking exercise. We sought to capture diversity in both national representation and the roles that experts play: the two dimensions in which we hypothesized that we would see differences in research prioritization. The full set of study participants—who submitted research questions in Stage 1—were identified in three ways: (1) through an academic literature review and lists of organizational membership; (2) through a referral by another study participant; and (3) from study advertisements by science advice-related organizations to their members. These organizations included: the International Network for Government Science Advice (INGSA); European Parliamentary Technology Assessment (EPTA) member and associate nations; a European project on parliaments and civil society in technology assessment (PACITA); the International Science, Technology and Innovation Centre for South-South Cooperation under the Auspices of UNESCO (ISTIC); the European

Commission's Joint Research Centre (JRC) Community of Practitioners-Evidence for Policy; Results for All (a global organization addressing evidence-based policy); and the American Association for the Advancement of Science's science diplomacy network.

Full characteristics of the 183 experts who submitted research questions and those who participated in the workshop are described in Akerlof et al., 2019. Ninety people who submitted research questions were asked to participate in the online ranking of what information they would be most interested in learning about LSA. Participant selections were made based on geographic diversity and LSA expertise. Sixty-four individuals from 30 countries responded. All but one had experience specifically with legislatures. Thirty-three were from—or in one case studied—developing nations (52%), and 31 were from developed countries (48%) (United Nations Statistics Division 2019). The experts' roles in science advisory processes were highly varied (Table 1). While most served in a distinct role, whether as producers of scientific information (21%), providers (33%), or users (8%), more than a third said that their work crossed these boundaries (38%).

4.2 Study protocol

The initial set of 50 research questions on LSA—collected and vetted in Stages 1 and 2—is listed in the supplementary materials (SI Table 1). In order to simplify the demanding cognitive task of ranking the items, we asked the experts to evaluate the importance of the information that would be gained from research, instead of the importance of the question itself. Evaluating the question requires a larger set of judgements than assessing the information it seeks to identify, such as whether the question could be answered, or the difficulty in doing so. Hence, for the purposes of the ranking, we developed a set of parallel statements for each of the research questions. (The feasibility and generalizability of obtaining the information was assessed in separate survey questions for the top ranked statements.) By way of example, the research question "How do culture, and political and economic context, affect the development of LSA institutions?" became the following statement: "How culture, and political and economic context, affect the development of LSA institutions."

Following Q methodology, respondents sorted the 50 statements (Table 2) into nine categories, ranging from "extremely uninterested" to "extremely interested" using an online survey platform (Qualtrics). They could place only a certain number of statements in each category, resembling a forced-normal distribution. Participants were instructed to rank the statements relative to each other, even if the labels on the categories did not necessarily match their sentiment. (See the distribution, instructions to respondents, and the online interface in SI Boxes 1-4.) At the end of the survey, the respondents were asked to identify the extent of their career spent as producers, providers, or users of scientific information (Table 1).

Table 2. Fifty statements were ranked by the international experts.[a]

1	POL	The characteristics of the producers of scientific information most preferred by legislators and their staff
2	INST	How institutions that deliver LSA can be characterized
3	INST	How culture, and political and economic context, affect the development of LSA institutions
4	COMM	Whether iterative engagement between researchers, legislators, and staff improves E-USE
5	E-DEV	How social relevance is weighed in the production of academic research
6	BRKR	What role intermediaries and research brokers play in getting scientific information before legislators and their staff
7	COMM	Which communication tools facilitate working with legislative decision-makers on scientific topics
8	E-USE	How the formal and informal practices of legislatures influence the consideration and use of scientific information
9	INST	How legislative research departments synthesize and translate scientific information for legislators
10	DESIGN	How the requirements and needs of a science advice system for policymaking differ across countries

11	DESIGN	How the design of new structures, processes, and systems can increase legislative capacity for science use
12	E-USE	What metrics can be used to assess the use of scientific information across different legislative contexts
13	INST	What institutional approaches for LSA are instructive for other countries
14	E-DEV	How policymakers and researchers work together in defining problems and processes for generating evidence
15	E-USE	Under which conditions the use of scientific information changes the framing of policy debates
16	POL	How the Internet and social media affect the information-seeking behavior of legislators and staff
17	POL	Whether training for legislators and/or staff can increase their use of scientific information
18	BRKR	What forms of evaluation can be used to measure the effect of "brokering" scientific information
19	SCI	Which behaviors of scientists and other advisers increase the likelihood of E-USE
20	COMM	The frequency of communication between legislative staff and scientists from inside and outside government
21	DESIGN	What examples exist of improvements to legislative science advisory systems in heavily resource-constrained countries
22	COMM	How scientific information is embedded in policy debate rhetoric
23	POL	Under what conditions legislators and staff seek out scientific information or use what is presented to them
24	POL	What value legislators and staff place on scientific evidence, as opposed to other types
25	INST	How the staffing, budgetary, and political capacity of committees affects their ability to use scientific information in legislatures
26	SCI	How scientists and issue advocates try to manage the quality of scientific information and expertise used in legislatures
27	E-USE	Whether legislative use of scientific evidence improves the implementation and outcome of social programs and policies
28	SCI	What individual and institutional factors motivate scientists to share their research with legislators and their staff
29	COMM	How different communication channels—hearings, face-to-face meetings, email, social media, etc.— affect informational trust and use
30	PUB	How the impact of current citizen initiatives in LSA can be measured
31	ETHICS	What ethical principles for providing LSA can be derived
32	POL	How legislators and their staff assess the credibility of scientific information
33	SCI	What information, skills, and training are needed for scientists to work with legislators and their staff
34	INST	How the impact of legislative science advisory offices on legislative processes can be measured using indicators
35	PUB	The extent to which the public is aware of, and places value in, the scientific information being used in legislatures
36	INST	How internal and external organizations assess and meet the needs of legislatures for in-depth analysis
37	POL	How legislator and staff preferences for scientific evidence compare between countries
38	PUB	How public participation affects legislative processes in which scientific information may be considered

39	POL	The factors that legislators weigh in deciding whether to accept or reject a scientific recommendation
40	ETHICS	How values can be made transparent in providing science advice
41	DESIGN	What lessons can be learned about how to manage scientific advice to legislatures from a systems approach
42	E-DEV	How the scientific topics most relevant to the public and policymakers can be determined to inform research
43	E-USE	Identification of the ways in which scientific information is "used" in legislatures
44	INST	How different institutional approaches to LSA influence its nature, quality and relevance
45	E-USE	What types of scientific information are used in legislatures
46	COMM	How political polarization affects information flows to legislators and their staff
47	E-USE	What incentives motivate or compel legislatures to use scientific information
48	DESIGN	How racial and gender biases affect researchers' and practitioners' activities and influence policy advisory systems
49	COMM	How risk and uncertainty can be communicated comprehensibly to legislators and staff
50	DESIGN	In societies without established science advice systems, how scientific information is used—if at all—by legislatures

[a] *Each statement was classified into one of ten different categories of LSA system dynamics and actors. System dynamics: Communication, COMM; evidence use, E-USE; evidence development, E-DEV; system design, DESIGN; ethics, ETHICS. System actors: Policymakers, POL; scientists, SCI; brokers, BRKR; institutions, INST; the public, PUB.*

4.3 Factor analyses

To test our hypothesis that research priorities for LSA would differ between developing and developed countries, we analyzed our Q sort data for each subset of Q participants independently. We first divided the data into two sets according to whether respondents were from developed or developing nations (United Nations Statistics Division 2019). We ran the Q analyses using qmethod in R (Zabala 2014, 2019) using varimax rotation. We examined a number of solutions, including 3, 4, 5, 6, 7, and 8 factor solutions. All resulted in Q participants not loading on at least one factor and others being confounded on multiple factors. Deeper investigation into the distinction of meaning the factors revealed there was very little to be gained from a solution with more than three factors. The three-factor solution (Table 3) reveals interesting insights in the data and adding a fourth factor did not significantly add meaning to the three-factor narrative (see factor matrices and arrays, SI Tables 2-14).

Table 3. *Factor solutions for separate and combined analyses of developed and developing nation respondents*

Factor		*n*	Eigen values	% explained variance	Respondent advisory system roles by factor						
					Producer-Provider-User	*Producer*	*Producer-Provider*	*Provider*	*Provider-User*	*User*	*N/A*
Developed (*n*=31)	DD1	9	3.87	12.47	1	1	3	1	2	1	0
	DD2	11	3.63	11.69	2	4	0	3	0	2	0
	DD3	9	3.01	9.7	3	3	0	2	0	0	1
Developing (*n*=33)	DG1	8	2.96	8.97	1	2	1	3	1	0	0
	DG2	9	2.91	8.82	3	2	1	3	0	0	0
	DG3	5	2.54	7.69	1	0	0	3	1	0	0
Combined (*n*=64)	ALL1	15	5.91	9.24	2	5	1	4	1	2	0
	ALL2	12	4.05	6.33	3	1	1	5	0	2	0
	ALL3	9	3.93	6.13	3	2	1	1	1	0	1
	ALL4	12	3.88	6.06	1	3	1	5	1	1	0

Table 4. *Two-way repeated measures ANOVA*

Predictor	df_{Num}	df_{Den}	*Epsilon*	*F*	*p*	η^2_g
Development	1.00	51.00		7.36	.009	.02
System role	5.00	51.00		0.91	.484	.01
Development x System role	5.00	51.00		1.24	.303	.02
Factor	2.95	150.42	0.98	2.09	.105	.03
Development x Factor	2.95	150.42	0.98	1.89	.134	.03
System role x Factor	14.75	150.42	0.98	0.70	.779	.06
Development x System role x Factor	14.75	150.42	0.98	0.81	.659	.06

Note. df_{Num} *indicates degrees of freedom numerator.* df_{Den} *indicates degrees of freedom denominator. Epsilon indicates Greenhouse-Geisser multiplier for degrees of freedom, p-values and degrees of freedom in the table incorporate this correction.* η^2_g *indicates generalized eta-squared.*

Our factor solution did at times demonstrate instances of positive and negative loading on factors by those individuals significantly associated with the perspective ($p<0.01$), which indicates the inability of the models to capture the full variance demonstrated in these viewpoints. However, these cases were not frequent enough to justify splitting the factor into two competing narratives. We consider that a three-factor solution tells the most meaningful story in this dataset.

In order to identify whether there were significant differences between the perspectives of experts from developed and developing nations, we then ran a factor analysis on the entire data set (Table 3). In this case, we identified four factors, though we faced a similar context with some respondents not loading on any factors, or respondents who loaded both positively and negatively.

In the following review of the findings we compare the aggregate rankings for the perspectives across the categories of LSA actors and dynamics: policymakers, institutions, scientists, brokers, the public, communication, evidence use, evidence development, system design ethics. We then assess how each group ranked specific statements in order to describe their perspective in detail. In referencing the statements, we cite the statement number and then ranking, ranging from -4, the lowest possible, to 4, the highest. Hence the notation (34: 4) refers to the 34th statement, ranked 4, the highest possible on the scale.

5. Results: Research prioritization by experts in developed nations

We conducted an inverted factor analysis with the research rankings of 31 respondents from developed nations and extracted three factors (DD1, DD2, DD3) that each explained between 9 to 12 percent of the variance, totaling 33.86% (Table 3; Figure 1). Two of the experts did not load onto any of the factors.

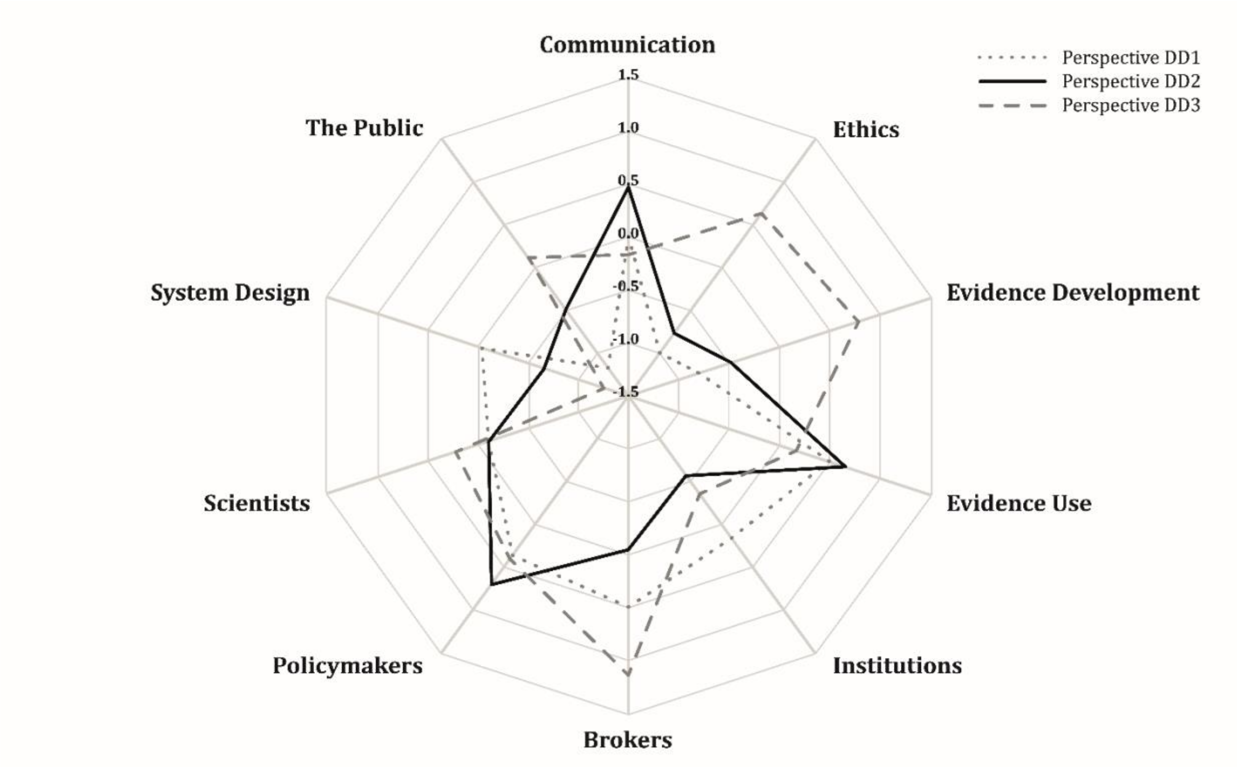

Figure 1. *The interests of the three developed nation (DD) perspectives across advisory system dynamics and actors vary. Higher average loading values for each category of statements—those falling toward the outer circumference of the radar—represent those areas most favored by the experts. All three perspectives place higher priority on policymakers and evidence use.*

5.1 Consensus priorities

Developed nation participants were in agreement in their prioritization of five statements (4, 6, 28, 29, 37). They prioritized two more highly: (1) what role intermediaries and research brokers play in getting scientific information before legislators and their staff (6: 3, 3, 2); and (2) how different communication channels—hearings, face-to-face meetings, email, social media, etc.— affect informational trust and use (29: 3, 2, 2). They also were in agreement in ranking as of lesser priority how legislator and staff preferences for scientific evidence compare between countries (37: -2, -2, -3).

When assessing mean category rankings for LSA actors and dynamics—e.g. averages of rankings for statements coded as about policymakers, communication, ethics, etc.—all three developed nation perspectives show broad interest in evidence use and policymakers, and a relative lack of concern for system design (Figure 1). We next explore how they ranked specific statements—which were highest, lowest, and higher or lower relative to other perspectives (see SI Tables 7-9).

5.2 Applied Institutionalist (Institutions and Policymakers) [Perspective DD1]

This developed nation perspective prioritizes research on institutions and policymakers that has a clear focus on application. Research on institutions and communication of a more theoretical or explanatory nature is of less interest to these experts. This factor (DD1) has an eigenvalue of 3.87 (which means that it explains the same variance as 3.87 variables) and explains 12.47% of the variance (Table 3). Nine participants are significantly associated with this perspective (p<.05). This perspective has the lowest ratio of scientific producers (e.g. researchers or scientists) to other roles or role-combinations with only one scientist among the nine experts (Table 3). Most of these participants have played varied roles in the production, provision, and use of science, whether as producer and provider (3), provider and user (2), or producer, provider, and user (1). Only three out of the nine with this viewpoint spent their careers solely as producers of science (1), providers (1), or users (1).

5.2.1 Institutions. The focus of this perspective on the usability of research is highly apparent in three of the most heavily prioritized potential research areas on institutions: 1) how different institutional approaches to LSA influence its nature, quality and relevance (44: 4); 2) how the impact of legislative science advisory offices on legislative processes can be measured using indicators (34: 4); and 3) what institutional approaches for LSA are instructive for other countries (13: 3). Questions with less obvious application ranked at the bottom: (1) how institutions that deliver LSA can be characterized (2: -4); and (2) how culture, and political and economic context, affect the development of LSA institutions (3: -3).

5.2.2 Policymakers. This perspective placed two research areas about policymakers as top priority. But even when this perspective rated policymaker research areas as lower than other perspectives, the lowest on a scale from -4 to 4 was -1 (16, 24). Again, the most highly prioritized research areas were directly relevant to the practice of LSA: under what conditions legislators and staff seek out scientific information or use what is presented to them (23: 4); and how legislators and their staff assess the credibility of scientific information (32: 4).

5.3 Promoter of Policymaker Evidence Use [Perspective DD2]

This perspective places primary emphasis on policymakers with a secondary emphasis on evidence use. It is less interested in research on institutions with a very applied focus. Research on the use of indicators for evaluation, and instructional approaches for other countries—both highly ranked by experts in the perspective DD1 above— are at the bottom set of priorities for these experts (34: -4; 13: -4). The factor for this perspective (DD2) has an eigenvalue of 3.63 and explains 11.69% of the variance (Table 3). Eleven participants are significantly associated with this perspective. This perspective has the largest proportion of self-identified scientific researchers (4/11), and few experts who identify as having careers that span science production, provision, and use. Of the 11 participants who demonstrate this perspective, nine define themselves as either producers of science (4), providers (3), or users (2). The other two have served in all three producer, provider, and user roles.

5.3.1. Policymakers. While three of the top-ranked research areas for this perspective are about policymakers, a communication topic relevant to legislators also ranks at the top of the list: how political polarization affects information flows to legislators and their staff (46: 4). The experts with this viewpoint prioritize the same top two research areas about policymakers as those with the previous perspective: 1) how legislators and their staff assess the credibility of scientific information (32: 4); and 2) under what conditions legislators and staff seek out scientific information or use what is presented to them (23: 4). But they also want to know what value legislators and staff place on scientific evidence, as opposed to other types (24: 4), which was not highly ranked in the previous perspective (-1). This emphasis on evidence use appears in their second-tier research priorities as well.

While not as high a priority as within other perspectives, evaluation of which factors influence policymakers are within the top 25 ranked statements. These include the characteristics of the producers of scientific information most preferred by legislators and their staff (1:1) and the factors that legislators weigh in deciding whether to accept or reject a scientific recommendation (39:1). Whether training of legislators and staff increases use of science was rated an area of less interest (17: -2).

5.3.2 Evidence use. The experts in this perspective are not uninterested per se about legislatures as institutions, but their interest is derived from their organizational roles in relation to evidence-based decision-making. Secondary-level research of interest in this respect includes: (1) how the formal and informal practices of legislatures influence the consideration and use of scientific information (8: 3); and (2) what incentives motivate or compel legislatures to use scientific information (47: 3).

5.4 Impact-driven Systems Thinker [Perspective DD3]

Experts in this perspective highly rank a number of different LSA actors and dynamics as important subject matter for research. While previous perspectives have ranked scientists, evidence development, and the ethics of science advice as middling to lower concerns, for these experts they rise to the top. The factor for this perspective (DG3) has an eigenvalue of 3.01 and explains 9.70% of the variance (Table 3). Nine participants are significantly associated with this factor. Like the previous perspective, there is a relatively large number of scientific researchers who fall into the group. Three of the participants are producers while two are providers. Another three have served in all three producer, provider, and user roles. (One of the participants did not self-identify with any of the categories.)

There is no single topic area that dominates this perspective. The combination of policymakers, brokers, scientists, and institutions—along with ethics, communication, evidence use, and evidence development—reveals a prioritization of research areas across the entire spectrum of the LSA system. Measurement and evaluation of outcomes appears as a focus of three of the most high priority items: 1) how the impact of legislative science advisory offices on legislative processes can be measured using indicators (34: 4); 2) what forms of evaluation can be used to measure the effect of "brokering" scientific information (18: 4); and 3) whether legislative use of scientific evidence improves the implementation and outcome of social programs and policies (27: 4). But, notably, these experts are not interested in cross-national comparisons of these legislative systems (10: -4), or how evidence use functions in countries without them (50: -4).

The previous two perspectives have focused on policy decision-makers and their institutional context. The experts with this particular perspective do not ignore those elements of the system, as can be seen above, but they also pay attention to the role that scientists play, including how policymakers and researchers work together in defining problems and processes for generating evidence (14: 3), which behaviors of scientists and other advisers increase the likelihood of evidence use (19: 4), how values can be made transparent in providing science advice (40: 3), and the characteristics of the producers of scientific information most preferred by legislators and their staff (1: 3).

6. Results: Research prioritization by experts in developing nations

We next conducted an inverted factor analysis with the research rankings of 33 respondents from developing nations and extracted three factors, each characterizing a perspective (DG1, DG2, DG3). Each factor explained between 7 to 8 percent of the variance, totaling 25.48%. Only 22 of the 33 experts loaded onto one of the factors (Table 3; Figure 2).

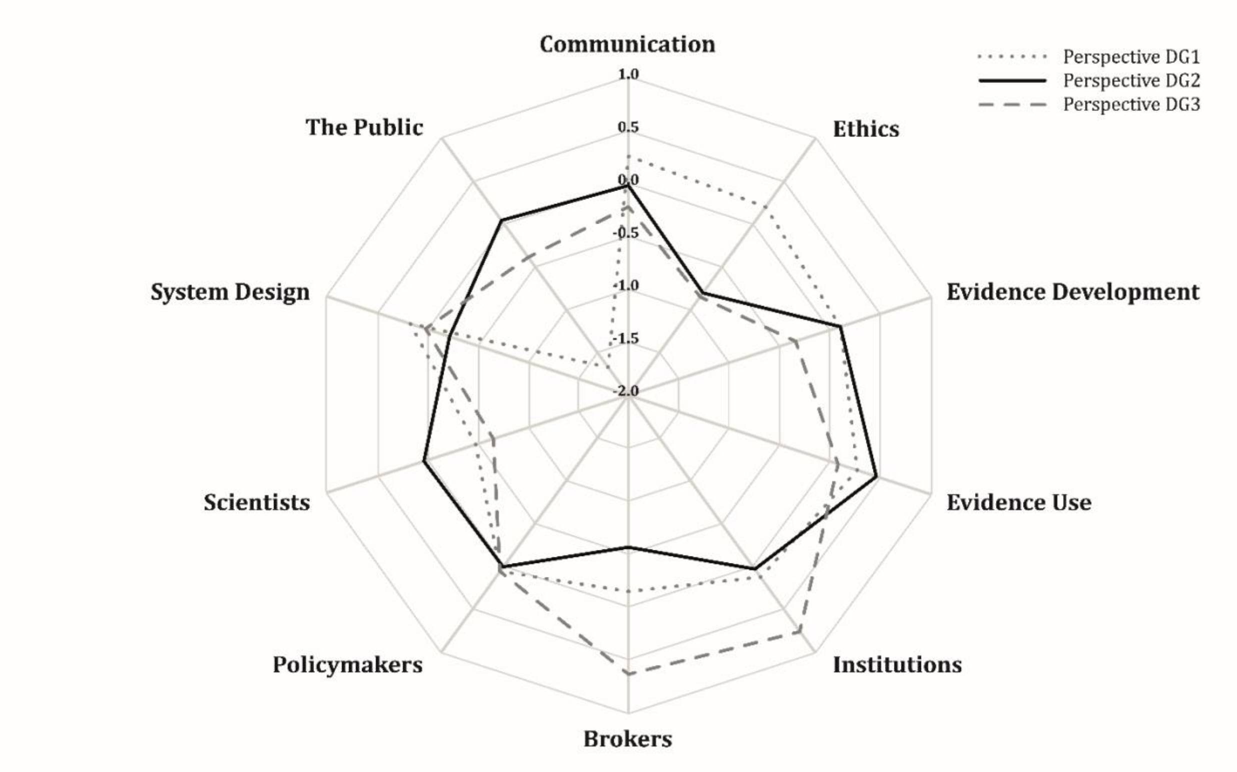

Figure 2. *The three developing nation (DG) perspectives place higher priority on evidence use and institutions.*

6.1 Consensus priorities among developing nation respondents

There was consensus among developing nation respondents on the prioritization of five of the 50 statements (14, 33, 41, 46, 49). Those most highly ranked included those categorized as evidence development and communication: 1) how policymakers and researchers work together in defining problems and processes for generating evidence (14: 3, 3, 2); 2) how political polarization affects information flows to legislators and their staff (46: 3, 3, 2); and 3) how risk and uncertainty can be communicated comprehensibly to legislators and staff (49: 2, 2, 2). In contrast, the consensus statements on scientists and system design were ranked in the middle (33: 0, 0, 1) (41: -1, 0, -1).

When assessing average category rankings, all three developing nation perspectives show interest in evidence use and institutions, but are divided in levels of prioritization across all other categories (Figure 2). We next explore how these perspectives ranked specific statements—which were highest, lowest, and higher or lower relative to other perspectives (see SI Tables 11-13).

6.2 Advisory Systems Designer [Perspective DG1]

These experts prioritize research on how LSA system design differs internationally and what ways resource-constrained countries have made improvements. They would also like to know how evidence use contributes to policy debates, implementation, and outcomes. None of the perspectives show strong interest in public participation in LSA as a research topic, but respondents with this viewpoint are the least enthusiastic. Three of the research areas on public participation ranked at the bottom (38, 30, 35).

The factor for this perspective (DG1) has an eigenvalue of 2.96 and explains 8.97% of the variance (Table 3). Eight participants are significantly associated with this factor. The respondent backgrounds for each of the three developing nation perspectives are highly variable. In this perspective, five of the participants had spent their careers in just one role, whether as producers (2) or providers (3). Another three had spanned these roles: producer and provider (1), provider and user (1), and producer, provider, and user (1).

6.2.1 System design. These experts are the most likely to prioritize the comparative study of legislative science systems with an eye especially toward low- and middle-income countries (LMICs). They are broadly interested in contrasts between different systems, including policymaker preferences for evidence. They want to know both how the requirements and needs of a science advice system for policymaking (10: 4) and how legislator and staff preferences for scientific evidence (37: 4) differ across countries. And they would like to explore specifically what works in LMICs, e.g. what examples exist of improvements to legislative science advisory systems in heavily resource-constrained countries (21: 3).

6.2.2 Evidence use. The normative question of whether evidence use is a good thing—e.g. whether it improves social programs—is of importance to these experts, as are research areas that can provide information on the factors related to the effectiveness of science advice. Among the most highly prioritized research areas are: (1) whether legislative use of scientific evidence improves the implementation and outcome of social programs and policies (27: 4); (2) under which conditions the use of scientific information changes the framing of policy debates (15: 4); and which communication tools facilitate working with legislative decision-makers on scientific topics (7: 3).

Metrics for assessing evidence use were not of interest to this group, however. Developing metrics that can be used to assess the use of scientific information across different legislative contexts was ranked fairly low (12: -2), as was how to incentivize legislatures to use scientific information (47: -2).

6.3 Impact-driven Systems Thinker [Perspective DG2]

Evidence use is a consistent theme across all perspectives, both for developed and developing nation experts. This perspective rates statements on evidence use-related research as slightly higher than the other two perspectives (Figure 2) and places more attention on its relationship to LSA system actors, whether policymakers, scientists, or institutions. The factor for this perspective

(DG2) has an eigenvalue of 2.91 and explains 8.82% of the variance (Table 3). Nine participants are significantly associated with this factor. Five are producers (2) or providers (3). Another four have crossed roles, either as a producer and provider (1), or as a producer, provider, and user (3).

6.3.1 Evidence use. As in the previous perspective, these experts rate research on whether legislative use of scientific evidence improves the implementation and outcome of social programs and policies as of greatest interest (27: 4). They, too, would like to know what factors relate to science use, such as how the formal and informal practices of legislatures influence the consideration and use of scientific information (8: 3). But unlike the previous perspective, they prioritize establishing metrics for evidence use, placing it among the top half of the statements they ranked (12: 2).

This group is less likely to value research on evidence use that just quantifies the status quo with no obvious application. They rated these research areas either in the middle or toward the bottom: 1) identification of the ways in which scientific information is used in legislatures (43: -2); 2) what types of scientific information are used in legislatures (45: 0). One of their highly prioritized topics was how the design of new structures, processes, and systems can increase legislative capacity for science use (11: 4). Correspondingly, they have comparatively little interest in how legislatures with no established science advice systems function (50: -4).

6.3.2 Actors. All six perspectives among developed and developing nation experts demonstrate relatively low interest in research on the role of scientists in LSA. This perspective places the highest value on it within developing nation respondents. They would like to know how scientists and issue advocates try to manage the quality of scientific information and expertise used in legislatures (26: 4). But they are similarly interested in policymakers as well. How legislators and their staff assess the credibility of scientific information is one of their top priorities (32: 4). Finally, at the institutional level, they are interested in how culture, and political and economic context, affect the development of LSA institutions (3: 3).

6.4 Impact-driven Institutionalist [Perspective DG3]

Experts in this perspective are particularly focused on the ways in which institutions create capacity for LSA and how to characterize and measure their effectiveness. While this perspective is more interested in the brokering of scientific information than the other two (18: 3), the experts in this group overall do not prioritize communication as highly (22: -4; 4: -4). The factor for this perspective (DG3) has an eigenvalue of 2.54 and explains 7.69% of the study variance (Table 3). Five participants are significantly associated with this factor. Three of the five have been providers of science. One of them has been a provider and user, and other as a producer, provider, and user.

6.4.1 Institutions. Those who hold this perspective are interested in the dynamics of legislatures and the people and organizations within them. They want to know how policymakers find and use scientific information within these institutions: under what conditions legislators and staff seek out scientific information or use what is presented to them (23: 4); how legislative research departments synthesize and translate scientific information for legislators (9: 3); and identify the ways in which scientific information is used in legislatures (43: 4). However, committee structures are of low interest to this group (25: -4).

These experts focus on research that characterizes institutional activities in typologies and quantifies them. They prioritize how institutions that deliver LSA can be characterized (2: 4); how internal and external organizations assess and meet the needs of legislatures for in-depth analysis (36: 3); and how the impact of legislative science advisory offices on legislative processes can be measured using indicators (34: 4). But they are also interested in differences across legislatures, e.g. how different institutional approaches to LSA influence its nature, quality and relevance (44: 3).

7. Combined analysis

Having described the different perspectives of LSA experts in developed and developing nations, we next combined the datasets to test whether there are any statistically significant differences, either by roles within the advisory system or according to national development status. We ran the inverted factor analysis on all 64 respondents and extracted four factors (Table 3). Each factor explained between 6 and 9 percent of the variance, totaling 27.76%. Using two-way repeated measures ANOVA in R (ezANOVA) (Lawrence 2016), we found significant differences according to respondent national development status ($F(1, 51)=7.36$, $p=.009$), but not by role ($F(5, 51)=0.91$, p=.484) or any of the interactions between the variables (Table 4). Further, the effect size for the effect of development is small ($\eta_{2g} = .02$).

The only significant difference in perspectives by national development status appears in the first factor (ALL1; Figure 3). This perspective highly ranks research that addresses communication with policymakers and the effects of institutional approaches, with less focus on the design and functioning of broad LSA systems, incorporating brokers, the public, and the production of scientific knowledge (see Supplementary Information, SI Table 14). Among the statements most highly rated in this perspective and more strongly associated with developed nation respondents: how risk and uncertainty can be communicated comprehensibly to legislators and staff (49: 4); how legislators and their staff assess the credibility of scientific information

(32: 4); how different institutional approaches to LSA influence its nature, quality and relevance (44: 4); and under which conditions the use of scientific information changes the framing of policy debates 15: 4).

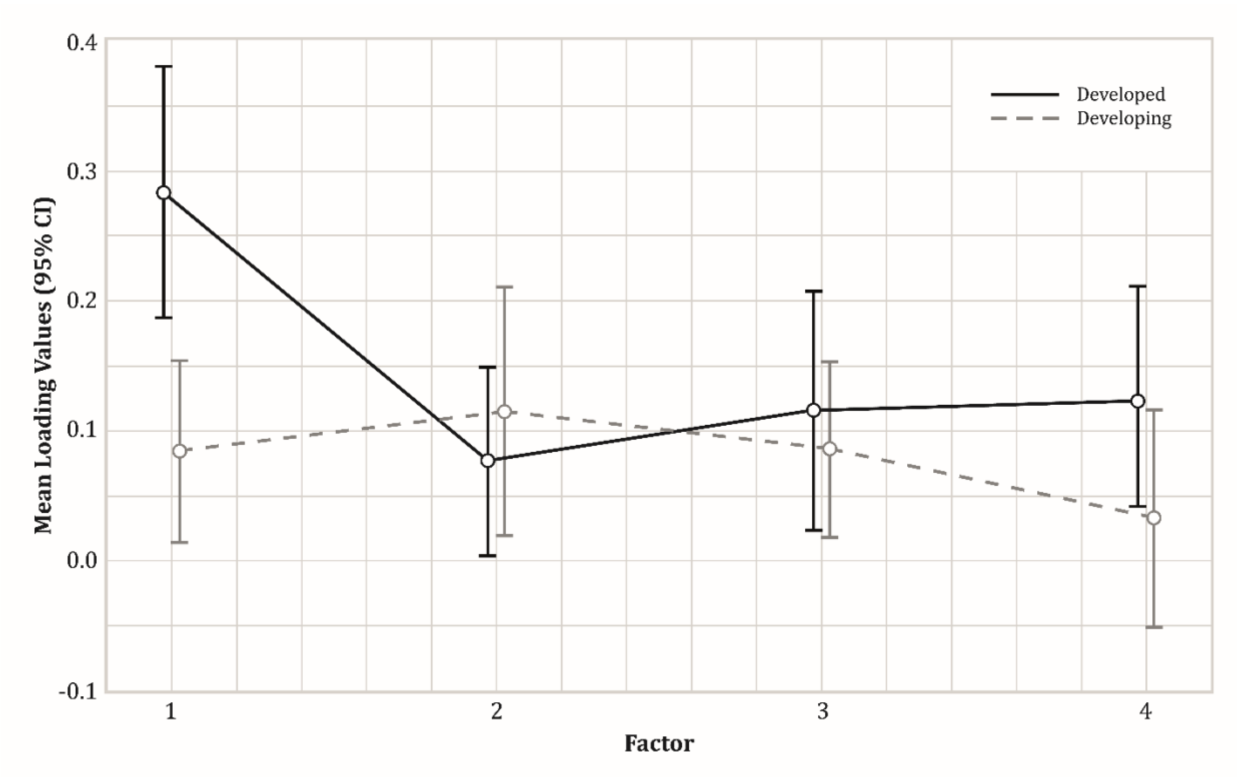

Figure 3. *There are significant differences in the means of the perspectives across developed and developing nation respondents. While the sample cannot be said to be representative, the differences provide preliminary indications of differences between these groups.*

8. Discussion

We had hypothesized that both national development status (**H_1**) and expert roles (**H_2**) would influence the research priorities of the academics, policymakers, and practitioners who work within legislative science advisory systems. While we did identify what appear to be differences between experts from developed and developing nations, both in the nature and the explanatory level of their perspectives, we did not find differences due to advisory system roles within the sample. Instead, we found that firm boundaries for the participants in these systems have all but collapsed, with many crossing regularly across them and others not identifying with any particular community. Likely as a result of the fluidity of these identifications, we found no difference in our study participant research priorities by role, even though other studies have (Moreira et al. 2019; Rudd & Fleishman 2014).

The largest differences between the research interests of developed and developing nation respondents lie in their prioritization of studying the LSA system design, especially in LMICs (represented by the DG1 "Advisory Systems Designer" perspective), versus a focus, particularly by scientists, on understanding policymaker evidence use (exemplified by DD2 "Promoter of Policymaker Evidence Use"). The research areas that developed nation respondents were most likely to concur were high priority were those of evidence brokering and communication: (1) what role intermediaries and research brokers play in getting scientific information before legislators and their staff (6: 3, 3, 2); and (2) how different communication channels—hearings, face-to-face meetings, email, social media, etc.— affect informational trust and use (29: 3, 2, 2). In contrast, developing nation respondents were more likely to agree on the importance of understanding the broader relationship between evidence development and use, and the effects of large systemic factors such as: (1) how policymakers and researchers work together in defining problems and processes for generating evidence (14: 3, 3, 2); (2) how political polarization affects information flows to legislators and their staff (46: 3, 3, 2).

Another difference between the two groups (DD/DG) is in the explanatory ability of the models. The lower ability of the models to explain the variance in the rankings of the developing nation respondent group may indicate less consensus about the role of science advisory systems in these countries and what research needs exist. Whereas, in contexts with a significant history of LSA, priorities are likely to arise from long-term engagement with different system variants.

Having noted these differences, we also see a great number of similarities between the perspectives. For example, there are analogous versions of an "Institutionalist" (DD1, DG3) and a "Systems Thinker" (DD3, DG2) in both sets of respondents. While these perspectives are not identical in each of the groups, they have resemblances in the themes that are emphasized. For example, all four of these perspectives have an applied focus and an interest in evaluation. The Institutionalist in both developed and developing nation respondents thinks of the problem as institutional development, while the Systems Thinker prioritizes a wider array of actors within the advisory system, including the role played by scientists.

8.1 Implications for the development of an international research agenda for LSA

In developing a research agenda for LSA, this study suggests that the current vogue in Western developed countries to focus on "communication with policymakers" (Cairney & Kwiatkowski 2017) may not be as strongly of interest to developing nations, which instead prefer approaches to LSA research that describe the development of systems and are comparative in nature. Yet, we see a number of commonalities as well in thinking about the different levels of the problem, whether institutions or systems. These suggest that there are needs for both more targeted approaches in understanding the relative requirements of different nations for LSA research, but also that many—if not most—of the questions will be of interest internationally.

The finding that there is less consensus among the perspectives of respondents in developing nations also suggests the need to have further conversations in these regions about their goals for setting up LSA systems that reflect their particular institutional characteristics and cultural heritages. Sensitivity to stakeholder perspectives must be taken into consideration in these discussions.

8.2 Use of Q methodology in setting research priorities

Q methodology holds the potential for bringing a richer more qualitative understanding of the inherently subjective perspectives that stakeholders bring to their prioritization of research questions. The introduction of using rankings in “big questions” transdisciplinary exercises allows comparisons between stakeholders to evaluate where differences lie. Q methodology provides an additional level of qualitative analysis to aid in interpreting these results in a way that can be implemented by those making programmatic and funding decisions. It provides for a fuller illustration of these perspectives by looking holistically across the entire ranking preferences. As such, it should be considered as a vital tool in setting science policy research agendas.

9. Conclusion

Rapid—indeed exponential—changes in science and technology worldwide mandate the need for new mechanisms and advisory systems that will allow democratically elected representatives to make decisions on behalf of their constituents. Without these tools, governance institutions will likely falter, if not crumble, in face of the barrage of new information and societal change. Building an evidence base for LSA worldwide offers the potential to forestall this potential future, but first it requires stakeholder participation that itself honors the nature of democratic participation by valuing the perspectives of stakeholders. Q methodology offers one route to do so.

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