Global perspectives on scientists' roles in legislative policymaking

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Keywords: Legislative science advice, science policy, scientists, roles, developed nations, developing nations

Declarations

Funding: This material is based upon work supported by the National Science Foundation under Grant No. XX.

Conflicts of interest: The authors have no conflicts of interest to declare.

Data and code availability: Data and code are available in the osf.io repository, https://osf.io/phj85/?view_only=0a94d4796e004ffe8e17d928923cf9fb

Introduction

There are many ways that scientists can play a role in policy processes. These range from making policy decisions themselves as elected or appointed officials, to solely reporting scientific results within academic publications that others convey to decision-makers, and everything in between. The question of how scientists can—and indeed should—engage with policymakers has attracted significant popular and scholarly attention as both a pragmatic question and a topic of philosophical and theoretical debate since at least the 1950s (Douglas, 2009). With the exponential growth in scientific information and technological change (Bornmann & Mutz, 2015; Moore, 1965), and the rise of "wicked problems" that cannot be solved through the process of normal scientific discovery (Rittel & Webber, 1973), perspectives on the appropriate role of the science advisor reflect an evolving understanding of the social contract between science and policy (Jasanoff, 2012).

Indeed, the ways in which scientists produce knowledge are increasingly becoming transformed (Gibbons et al., 1994) as researchers respond to calls for societally relevant science (Bornmann, 2012). These new models of knowledge production shed light on the diversity of interactions by which scientific knowledge impacts society, apart from basic research that culminates in disciplinary publications (Muhonen et al., 2020; Schneider et al., 2019). At the same time, these new approaches potentially redraw boundaries between science and policy that have evolved historically to protect both the authority of scientific knowledge and democratic governance (Gieryn 1999; Guston 2001; Jasanoff 1987).

Contemporary legislatures require scientific and technological (S&T) information to be able to perform their representative functions in democratic governance of policy development and oversight of the executive (Morgan & Peha, 2003). But scientific knowledge use in legislatures is complicated by the diversity of political viewpoints held by politicians and the range of policy options that they consider viable (Tyler, 2013). Further, the institutionalization of S&T advice within legislatures through mechanisms like technology assessment offices has a relatively short history and is not well-developed even within many Western developed nations, not to mention in other parts of the globe (Grunwald, 2018).

Emerging democracies and countries in the developing world have been overwhelmingly ignored in comparative legislative studies led by scholars in the Global North (Barkan, 2009). While efforts to advance legislative science advice (LSA) capacity in developing countries encounter some of the same difficulties as in developed nations like accessibility of information and the speed with which legislators need to act (Sanni et al., 2016), they also confront unique challenges. For example, many African nations face weak parliaments compared to the executive, constitutional legacies from colonialism, the difficulties of transition to a knowledge society with higher levels of education, and the need for financial support for parliamentary capacity development (Barkan, 2009; INASP, 2016).

As legislatures across the globe consider how to strengthen their science advisory systems and adjust to the changing S&T landscape (Santillán-García et al., 2020), the ways in which scientists, policymakers, and those who study these systems view the appropriate role of the science advisor becomes increasingly important, bringing into focus their understanding—and

assumptions—regarding the nature of these functions. This study provides an empirical assessment of expert preferences for the role of scientists in advising legislatures, testing the effects of different types of expertise and national development on role preferences with implications for the design of legislative science advisory systems internationally.

In this article, we assess global expert perspectives for how scientists should participate in the policy processes of legislatures due to the importance of these representative institutions to democratic governance. We explore whether these experts' preferences for scientists' roles are associated with their own roles in regards to policy processes as science advice researchers, providers of scientific information to government, and users of scientific information within government, and whether their views are related to their nation's level of development. In a worldwide survey of legislative science advice experts, we asked them to select which policy roles they consider appropriate for scientists and describe their rationale. We found broad agreement that scientists should work closely with policymakers and others to integrate scientific results in policy decisions. Experts describe the purpose of the involvement of scientists in legislative policy processes in very instrumental terms: primarily to improve decision-making and communication of science. While there are no differences in preferences according to experts' own roles in policy processes, there are some differences between developed and developing nations. Experts from developing nations are more accepting of scientists' advocacy and less supportive of their solely publishing in academic journals.

"Appropriate" roles of scientists in policy

Questions about how scientists navigate objectivity and value judgments become visible when researchers step outside of the academy to participate in political processes, or even advocate for specific outcomes. The term "advocacy" has many different interpretations (Runkle & Frankel, 2012). We employ the definition of Nelson and Vucetich (2009): "it [advocacy] entails more than merely conducting research and communicating results through primarily scientific venues—even if the nature of the research is inspired by or relevant to a policy matter … advocacy entails promoting, developing, or assessing policy positions" (p. 1091). The authors summarize the arguments for and against advocacy: Is science objective or value-laden? Is advocacy detrimental to the authority of science or do scientists have a moral obligation to participate in advocacy as citizens?

These longstanding philosophical debates undergird the typologies of roles that scholars have developed to categorize how scientists can engage in policy. Of the typologies, Pielke's (2007) is arguably the most well-known. He posits that there are five ideal-type ways in which scientists can engage with policymakers. The "pure scientist" solely produces knowledge and does not engage with policy (and according to Pielke rarely exists; most researchers obtain external funding tied to policy-relevant societal goals). The "science arbiter" uses their scientific expertise to answer questions of relevance to decision-makers about the policy options before them. The "issue advocate" employs their research to support a particular political agenda or policy goal, restricting policy options, while remaining transparent about how these positions are informed by their personal values in addition to their science; in contrast, the "stealth advocate" similarly limits the range of options for policymakers but claims to do so solely under the guise

of science. Finally, the "honest broker" attempts to assist policymakers by broadening the array of policy options before them based on scientific information. This typology informs advice to researchers on how they can participate in policy processes by organizations such as the American Association for the Advancement of Science (personal communication), the world's largest general scientific society (AAAS, 2020).

Other scholars have conceptualized scientists' roles in policy as falling along a continuum of increasing participation in shaping policy decisions, or advocacy. Donner described the two ends of the spectrum as "science," characterized by objective judgments, and "advocacy," consisting of normative judgments influenced by individuals' worldviews under conditions of higher scientific uncertainty, but also greater professional risk (2014). Donner hypothesized that as climate scientists moved toward higher levels of advocacy, they would risk losing their credibility. Though relatively few empirical studies exist, preferences for the role of scientists in providing advice to decision-makers has been tested with samples of the public, scientists, and decision-makers in developed countries (Kotcher et al., 2017; Lach et al., 2003; Spruijt et al., 2013, 2016, 2019). Kotcher and colleagues tested Donner's proposition that advocacy would negatively affect credibility in an online experiment with members of the public, who were shown Facebook statements from an interview by a fictitious climate scientist or meteorologist, each crafted to reflect a position along Donner's spectrum (Kotcher et al., 2017). Instead, the respondents rated the scientist as equally credible across all message conditions, with the exception of a condition in which the scientist supported nuclear power policies.

In this study we employ a five-point scale similar to Donner's that was developed by Steel and colleagues to evaluate differences in how natural resource managers, scientists, and the public view scientists' appropriate roles in policy decisions (Steel et al., 2001, p. 141) (Box 1). In 1999, the researchers conducted surveys with members of the public from Washington, Oregon, and British Columbia and asked them to select one or more of the scientists' roles in policy as appropriate. They hypothesized that geographic location, sociodemographic characteristics, and value orientations would influence public preferences. Overall, scientists' integration of scientific results in policy decisions was the most commonly selected role, followed by interpretation of the results, but they also found significant differences in the types of respondents who supported each role across each of the hypothesized categories, such as their political orientation. In a follow-up study, the researchers evaluated the same set of roles with scientists, natural resource managers, interest groups, and members of the public in the Pacific Northwest (Lach et al., 2003). The groups generally agreed on the need for integration and interpretation of information by scientists, though scientists were somewhat more supportive of interpretation than integration.

Box 1. Potential roles for scientists in policy

1) Scientists should only report scientific results and leave others to make policy decisions.
2) Scientists should report and then interpret the results for others who are involved in policy decisions.
3) Scientists should work closely with policymakers and others to integrate scientific results in policy decisions.
4) Scientists should actively advocate for specific policies they prefer.
5) Scientists should be responsible for making decisions about policy.

**Adapted from Steel et al., 2001, p. 141*

According to Pielke, any of the four roles—outside of "stealth advocate"—promote the welfare and functioning of democracies; scientists must choose for themselves how they want to engage (2007). As such, their preferences likely reflect individual and collective norms like those explored by Steel and colleagues. Spruijt and colleagues conducted a review to assess the literature on these factors from across differing academic perspectives, finding clusters of citations from post-normal science, science and technology studies, science policy studies, politics of expertise, and risk governance (Spruijt et al., 2014). They identified six different potential influences: issue complexity/uncertainty, area of expertise, values, organizational affiliation, context, and changing expert beliefs.

These previous studies have focused on Western developed nations in understanding cultural preferences for the roles of scientists in policy. We contribute to the expansion of this work both by widening our scope to encompass global experts and by focusing on legislatures as critical institutions for democratic governance:

> $RQ_{1a,b}$: What do global experts say are the most appropriate roles for scientists in informing legislative policy processes, and why?

Based on the findings from the studies previously described about the importance of experts' professional context on their views of the appropriate roles of scientists in policy—but a lack of

evidence for how preferences might vary between those of science advice researchers, providers of scientific information to government, and users of scientific information within government—we further explore:

> RQ_2: Do experts' perceived appropriate roles for scientists in advising legislatures, and associated rationales, relate to their functions within the advisory system as science advice researchers, providers of scientific information to government, and users of scientific information within government?

Previous research in a region of two Western developed nations (U.S. and Canada) found that scientists, managers, and other stakeholders supported scientists' integration and interpretation of information for policymakers (Lach et al., 2003), as opposed to more politicized roles as advocates and decisionmakers. Because of the importance of legislative science advice to governance capacity globally, including in developing nations, we explore whether national development status might also relate to preferences for the roles of scientists in advising legislatures, for example due to shorter histories for boundaries—and boundary conflict—between the communities to evolve. While admittedly a somewhat crude measure, we employ the United Nations designation for developed versus developing nations (United Nations Statistics Division, 2019) in posing our third research question.

> RQ_3: Is national development status related to expert perspectives on appropriate roles for scientists, and associated rationales, in providing advice to legislatures?

Methods

The research methodology is described in full in [REMOVED FOR REVIEW]. We identified experts in science and technology advice, and particularly LSA, in three ways: (1) through an academic literature review and lists of organizational membership; (2) through a referral by another participant in the study (snowball sampling); and (3) from requests to join the study after seeing information advertised by science advice-related organizations. We recruited representatives and members of the following groups: 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. The research protocol for the study was approved by [REMOVED FOR REVIEW].

Expert participants

From September to November 2018, 183 respondents participated in the online survey on research needs for legislative science advice. Approximately half of the respondents were from nations categorized by the United Nations as developing ($n = 91$) and half from those considered developed ($n = 92$) (United Nations Statistics Division, 2019). While all had expertise in science and technology advice for policy, almost three-quarters (74%) said they also had specific experience with legislatures. Close to half provided science advice to government (44.3%). The

rest said they conducted research on governmental science advice (24.6%), used scientific information within government (10.4%), or straddled one or more of these groups (19.7%). Expertise data is missing for two of the respondents.

Survey measures and analyses

Using an adaptation of the Steel et al. (2001) typology, we asked the following question of survey participants: "Scientists can play different roles in informing legislative decision-making. Which of the five roles below do you think are most helpful in informing legislative policy processes?" The experts could select one or more responses (Box 1). In a follow-up question, we re-stated the respondent's selections and asked them to explain their preferences: "You selected the following role(s) for scientists as most helpful in informing legislative policy processes [ ]. Why?" Most survey participants responded to both questions (respectively, n=168, n=158). All survey questions were posed in English. Some of the open-ended responses were written in other languages, which were then translated prior to coding.

We modeled whether an expert checks "yes" that they view a policy role described in the typology as appropriate. The analyses were conducted with mixed effects binomial logistic regression with repeated measures and binomial logistic regression in IBM SPSS 27. The variable constructs from the open-ended questions were coded by three graduate students using a codebook developed both from previous literature and a close reading of the texts. Coders obtained a Krippendorff's α of 0.8 or greater across all variables, measured using a program for intercoder reliability analysis developed by Hayes and Krippendorff (2007) (see SI Table 1). To

ensure consistent interpretability across studies, reliabilities of $\alpha \geq 0.800$ have been recommended (Krippendorff, 2004).

[TABLE 1]

[TABLE 2]

Results

Preferred roles for scientists in advising legislatures and rationale ($RQ_{1a,b}$)

The majority of participating global experts (79.2%) said that scientists should work closely with policymakers and others to integrate scientific results in policy decisions—the option in the middle of the scale between solely reporting scientific information to policymakers and taking a more active role in advocacy and policymaking (Table 1). The role of integrating science with policy was the most frequently designated as helpful to legislative decision-making by experts from across differing science advisory system roles and both developing and developed nations. Few said that scientists should just report their data (12.0%)—or alternately—advocate (18.6%) or make decisions about policy (11.5%). About half (53.0%) reported that scientists should report and interpret the results for others who are involved in policy decisions, a somewhat less active role than integrating results in policy.

In order to understand why the experts chose specific roles, we both inductively and deductively coded the open-ended responses according to content of the textual data and a review of philosophical debates over the scientific norm of disinterestedness (Merton, 1973), and the role of advocacy (Nelson & Vucetich, 2009) and values in science (Douglas, 2009) (see SI Table 1). The global experts named various communication goals, better policy decisions, and serving society as their rationale for selecting certain types of roles as more helpful for legislative

decision-making. The most common reasons given for scientists' participation in one of these advisory roles were to improve decision-making (40.5%) and the need for communication, whether through (two-way) dialogues (34.2%) or (one-way) explanations (18.4%) (Table 2). The experts also identified limitations in the potential nature of the relationships between scientists and decision-makers due to inherent qualities of science and policy processes and the people within them: scientists do not understand policymaking (4.4%), advocacy politicizes science (5.7%), science is only one factor in decision-making (7.6%), and scientists are not free of values and ideological beliefs (3.2%). A small number (7.0%) further reported that the context determines what are likely to be helpful roles for scientists.

Differences in expert preferences/rationales for scientist roles by advisory system function and national development (RQ_2, RQ_3)

A mixed effects binomial logistic regression model with repeated measures for each of the five roles that scientists can play in policy was run to determine the effect of national development, experts' function within science advisory systems, and each of the typology options on whether the expert "checked yes," selecting a roles as helpful in informing legislative decision-making. The model with two-way interactions is reported here; the three-way interaction was not significant ($F(12,865)=0.310$, $p>.05$) (SI Tables 2-3)). The model correctly identified responses in 84.3% of cases ($F(27, 877)=8.586$, $p<.001$).

We found significant main effects for the type of policy roles and an interaction between development and policy roles; there were no significant main effects or interactions for an experts' system role (Table 3, see coefficients in SI Table 4). The odds of experts selecting

integrating results as a helpful role for scientists was 37.57 times than that of just *reporting results* (Table 4, exp(B)= 37.57, $p < .0001$). But as the levels for scientist participation in policy increased, the odds of experts selecting *advocate for specific policies* and *make decisions about policy* as a helpful role for scientists was statistically the same as just reporting results.

There was no main effect of an experts' national development status, but significant interactions between development and the potential roles that scientists can play in advising legislatures. Developing nation experts were 3.66 times as likely to say that advocacy was a helpful role for scientists in informing legislative policy processes than those in developed countries and only 0.23 times as likely to say the same for reporting results (Figure 1, Table 4; exp(B)=3.66, $t(877)=2.60$, $p<0.05$; exp(B)=0.23, $t(877)=-2.48$, $p<.05$).

Figure 1. Estimated marginal means for selection of scientist roles in policy by national development (a) and type of expert (b), adjusting for the other variables in the model.

[FIGURE 1]

[TABLE 3]

[TABLE 4]

We conducted a Fisher's exact test (2-sided) to identify statistically significant differences in the frequencies of the rationales given by respondents to explain their preferences with comparisons across developing vs. developed contexts and expert roles in the science advisory system (Table 2). Developed nation experts were more likely than those in developing countries to say that helpful roles for scientists in advising legislatures were dependent on context (14.3% vs. 0.0%) and that scientific information is only one factor in decision-making (14.3% vs. 1.2%). Experts

with different roles in the science advisory system placed different emphasis on the need to reduce misinformation, one-way communication, and the context-dependent nature of scientists' roles in policy. Of the expert groups, those who straddled the categories of user/producer/or science advice researcher often responded differently than the other groups, for example, they were the only group to mention misinformation as a communication goal (6.5%).

Discussion

In sum, a majority of global legislative experts (79.2%) said that scientists should work closely with policymakers and others to integrate scientific results in policy decisions (Table 1). The next most preferred role was that of reporting and interpreting results (53.0%). The reasons the respondents gave for scientists' engagement were to improve decision-making (40.5%) and communication of science, whether through (two-way) dialogues (34.2%) or (one-way) explanations (18.4%). By way of comparison, few said that scientists should advocate for specific policies (18.6%), make policy decisions themselves (11.5%), or just report their findings and leave policy to others (12.0%). These findings suggest that while there is little support for scientists to abdicate the job of connecting science to policy to others, concerns remain over the implications of scientists who appear to promote specific policies with decision-makers. Generally, these experts viewed scientists' involvement in policy as societally beneficial: negative outcomes from scientists' participation in policy, or their limitations in doing so, were cited each by fewer than 10% of experts (politicization of science, 5.7%; science is only one factor in decision-making, 7.6%; scientists do not understand policymaking, 4.4%; scientists have values/beliefs, 3.2%).

We found significant differences between developed and developing nation experts in their respective preferences for scientists' roles in legislative policy processes. Developing nations have generally broader interpretations of appropriate roles for scientists in policy and are more accepting of advocacy roles than experts in developed countries (Table 4, Figure 1). Conversely, developed nation experts were more likely to support scientists playing more demarcated roles in which scientists should report scientific results and leave others to make policy decisions. Developed nation experts were also more likely to cite limitations in scientists' involvement—that scientific information is only one factor in decision-making (14.3% vs. 1.2%)—and that roles should reflect the policy and issue context (14.3% vs. 0.0%). There were not significant differences according to the professional role that experts themselves play within advisory systems.

Integration as Mode 2 or civic science

The finding that large majorities of science advice experts in both developed (78.3%) and developing (80.2%) countries say that scientists should work closely with policymakers and others to integrate scientific results in policy decisions mirrors the results of Lach and colleagues' survey of scientists, natural resource managers, interest group members, and the public in the Pacific Northwest (Lach et al., 2003). The authors point to support for "integration" of science with policy as evidence of the rise of a civic science model, as described by Lee (1994): "Civic science is a political activity; its spirit and value depend on the players, who make up, modify, implement, and perhaps subvert the rules. The tenor of this chapter is therefore moral: how to recognize the dilemmas in pursuing science in a political setting, and what values to protect in the compromises that we cannot evade" (p. 161). Our finding that international

science advice experts overwhelmingly see integration as a helpful role for scientists in working with legislatures suggests, too, that Mode 2 science—as described by Gibbons (1994) and under which Lee's civic science would fall—is perceived as appropriate even in highly political settings in which policy issues are often contentious and value-driven.

Theoretical rationales for the roles of scientists

The rationales provided by the experts for why they preferred certain roles for scientist engagement in policy were generally instrumental, e.g. in support of better decision-making (40.5%). The online survey methodology—instead of interviews—likely reduced the length and complexity of expert responses, but a number of the points raised in the philosophical and theoretical literature about the uneasy juncture between science and policy were cited by respondents as well: 1) difference between policy vs. science knowledge (lack of scientist understanding of policy); 2) risk of politicization of science; 3) scientific information is only one consideration in decision-making; 4) science and scientists are not value-free; and 5) decisions about roles should be made based on the issue context. As noted in the literature review, these arguments stem from literatures in Western developed countries, so it perhaps is not unexpected that when there were statistically significant differences, experts from developed countries were more likely to cite them (science is just one factor in decision-making; roles should be context-dependent).

Advocacy and science in democratic governance

Democratic governance on S&T issues concerns issues of representation, participation, and deliberation (Jasanoff, 2005). Developed nation governments—like that of the United States—

rely on the legitimacy of "objective" scientific authority in setting aside democratic control and accountability. As Jasanoff notes: "Of course, to perform these legitimating functions, science itself has to stand apart from the contaminating touch of politics*"* (p. 288). In contrast, advocacy roles place scientists squarely within the political sphere. Both developed and developing country respondents were most likely to say that scientists should work closely with policymakers and others to integrate scientific results in policy decisions (Figure 1). The similarities in preferences between developing and developed nation experts may speak to the internationalization of norms of science advice through epistemic communities (Haas, 1992) and perhaps also to the selection of experts through organizations with at least regional if not global scope. But developing nation experts were also more accepting of an advocacy role for scientists: 27.5% vs. 9.8%. This finding may speak to fewer perceived tensions between democratic representation and expert advice (Guston 1993) as these nations simultaneously seek to strengthen the capacity of their legislatures and scientific enterprises (Barkan, 2009; INASP, 2016).

Implications for global development of capacity in legislative science advice

These findings raise both pragmatic and philosophical questions. The Mode 2 relationship between scientists and society that experts say is most helpful in legislatures—"work closely with policymakers and others to integrate scientific results in policy decisions"—requires institutional contexts both within legislatures and academia that support these practices. Further, it requires scientists across diverse fields to re-envision how their scientific knowledge is formed (Bednarek et al., 2018; Gibbons et al., 1994). Arguably, neither institutional support nor implementation of Mode 2 science practices have become mainstream (Guimarães et al., 2019).

To fully realize the potential for these relationships, pragmatically the science and policy communities would need to change many of their practices.

Philosophically, some may argue that these changes may also produce unintended consequences, or at least certainly not be advisable in all cases. Scientists can both increase the divide between issue coalitions on controversial policy issues and act as intermediaries between groups (Ingold & Gschwend, 2014; Jenkins-Smith et al., 2014; Sarewitz, 2004). Depending on the issue context, the extent to which scientists become even more embedded within political coalitions in the development of knowledge may pose risks to its authority while at the same time increasing policy conflict. Ironically, too, while the typologies of scientists' roles in policy allude to individuals taking on these roles, authors like Pielke argue that it is wiser for scientists to participate through formal advisory bodies: "Individual researchers and studies are essential to the process of science, but science best guides and informs policy when it has been assessed by scientific advisory bodies to characterize the current state of knowledge on a particular topic or to present possible policy options – including perspectives on uncertainties, disagreements, areas of ignorance" (*Scientific Integrity in Federal Agencies*, 2019, p. 1). Lastly, to the extent that scientists do not appear representative of the broader national populations—by the nature of their education, politics, geography, and other socio-demographics—models of scientist participation in policy that seem to privilege the values and beliefs of an elite expert class may also encounter resistance, especially during periods of greater social inequality and the rise of populist movements (Norris & Inglehart, 2019; Zucman, 2019).

Further research

Countries differ in how they address use of S&T information in policy (Jasanoff, 2005). We would anticipate that this is true across the globe, yet there is little empirical evidence for how science advisory systems function in the developing world (Biermann, 2002). This research begins to help address that gap. Further research should assess these national differences in developing nations as well through a combination of case studies, interviews, and surveys. Because of the global scope of this survey, the questions were posed in English. Alternatively, national interview and survey studies could be conducted in each country's respective languages, which would likely increase the richness of respondents' explanations for role preferences. Future studies would benefit from the addition of another dimension to typologies: the participation of individual scientists in policy as opposed to that of scientists in advisory bodies. The costs and benefits, both for individuals and in terms of policy implications, are likely to be perceived quite differently.

Conclusion

This study captures the wind of change: global experts say that scientists should take highly involved roles in policy within legislatures, echoing the calls for Mode 2 science (Gibbons, 1994). Most respondents indicated, though in varying degrees, that scientists should take the role of reporting and interpreting results (53.0%), and that the purpose of their involvement in policy should be to improve decision-making (40.5%), or to communicate science through dialogues (34.2%) or explanations (18.4%). The similarity of expert preferences points to the extent to which science advice discourses have globalized, even though once restricted to Western developed literatures. The challenge, however, will be in implementing these types of relationships, no less in developed than developing nations. While taking into account the

potentially broader spread of acceptable roles for science and formulating systems accordingly, particularly the finding that developing nations support scientists taking an advocacy role in policy more than in developed nations, the science and policy communities must bear in mind the challenges and opportunities that those wider roles afford. If these shifts reflect persistent preferences for the shape of legislative science advisory systems, the creation and maintenance of relatively small technology assessment bodies within legislatures—such as in Europe (Kenny et al., 2017)— will likely have limited capacity to facilitate the transition, presenting the opportunity for a deeper reimagining of LSA systems for current and future global challenges.

References

AAAS. (2020). *American Association for the Advancement of Science [home page]*. https://www.aaas.org/

Barkan, J. D. (2009). *Legislative power in emerging African democracies*. Lynne Rienner Publishers.

Bednarek, A. T., Wyborn, C., Cvitanovic, C., Meyer, R., Colvin, R. M., Addison, P. F. E., Close, S. L., Curran, K., Farooque, M., Goldman, E., Hart, D., Mannix, H., McGreavy, B., Parris, A., Posner, S., Robinson, C., Ryan, M., & Leith, P. (2018). Boundary spanning at the science–policy interface: The practitioners' perspectives. *Sustainability Science*, *13*(4), 1175–1183. https://doi.org/10.1007/s11625-018-0550-9

Biermann, F. (2002). Institutions for scientific advice: Global environmental assessments and their influence in developing countries. *Global Governance: A Review of Multilateralism and International Organizations*, *8*(2), 195–219.

Bornmann, L. (2012). Measuring the societal impact of research. *EMBO Reports*, *13*(8), 673–676. https://doi.org/10.1038/embor.2012.99

Bornmann, L., & Mutz, R. (2015). Growth rates of modern science: A bibliometric analysis based on the number of publications and cited references. *Journal of the Association for Information Science and Technology*, *66*(11), 2215–2222. https://doi.org/10.1002/asi.23329

Donner, S. D. (2014). Finding your place on the science – advocacy continuum: An editorial essay. *Climatic Change*, *124*(1), 1–8. https://doi.org/10.1007/s10584-014-1108-1

Douglas, H. E. (2009). *Science, policy, and the value-free ideal*. University of Pittsburgh Press.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. Sage Publications.

Gieryn, T. (1999). *Cultural boundaries of science: Credibility on the line*. University of Chicago Press.

Grunwald, A. (2018). *Technology Assessment in Practice and Theory*. Routledge.

Guimarães, M. H., Pohl, C., Bina, O., & Varanda, M. (2019). Who is doing inter- and transdisciplinary research, and why? An empirical study of motivations, attitudes, skills, and behaviours. *Futures*, *112*, 102441. https://doi.org/10.1016/j.futures.2019.102441

Guston, D. (1993). The essential tension in science and democracy. *Social Epistemology*, *7*(1), 3–23. https://doi.org/10.1080/02691729308578676

Guston, D. (2000). *Between politics and science: Assuring the integrity and productivity of research*. Cambridge University Press.

Guston, D. H. (1999). Stabilizing the boundary between US politics and science: The role of the Office of Technology Transfer as a boundary organization. *Social Studies of Science*, *29*(1), 87–111. https://doi.org/10.1177/030631299029001004

Guston, D. H. (2001). Boundary organizations in environmental policy and science: An introduction. *Science, Technology, & Human Values*, *26*(4), 399–408. https://doi.org/10.1177/016224390102600401

Haas, P. M. (1992). Introduction: Epistemic communities and international policy coordination. *International Organization*, *46*(1), 1–35.

Hayes, A. F., & Krippendorff, K. (2007). Answering the call for a standard reliability measure for coding data. *Communication Methods and Measures*, *1*, 77–89.

INASP. (2016). *Approaches to developing capacity for the use of evidence in policy making*. INASP. https://www.inasp.info/sites/default/files/2018-04/VY%20impact%20report.pdf

Ingold, K., & Gschwend, M. (2014). Science in policy-making: Neutral experts or strategic policy-makers? *West European Politics*, *37*(5), 993–1018. https://doi.org/10.1080/01402382.2014.920983

Jasanoff, S. (1987). Contested boundaries in policy-relevant science. *Social Studies of Science*, *17*(2), 195–230.

Jasanoff, S. (2005). *Designs on nature: Science and democracy in Europe and the United States*. Princeton University Press.

Jasanoff, S. (2012). *Science and public reason*. Routledge.

Jenkins-Smith, H. C., Nohrstedt, D., Weible, C. M., & Sabatier, P. A. (2014). The Advocacy Coalition Framework: Foundations, evolution, and ongoing research. In P. A. Sabatier & C. M. Weible (Eds.), *Theories of the policy process* (pp. 183–224). Avalon Publishing.

Kenny, C., Washbourne, C.-L., Tyler, C., & Blackstock, J. J. (2017). Legislative science advice in Europe: The case for international comparative research. *Palgrave Communications*, *3*.

Kotcher, J. E., Myers, T. A., Vraga, E. K., Stenhouse, N., & Maibach, E. W. (2017). Does engagement in advocacy hurt the credibility of scientists? Results from a randomized national survey experiment. *Environmental Communication*, *11*(3), 415–429. https://doi.org/10.1080/17524032.2016.1275736

Krippendorff, K. (2004). *Content Analysis: An Introduction to Its Methodology* (2nd ed). Sage.

Lach, D., List, P., Steel, B., & Shindler, B. (2003). Advocacy and credibility of ecological scientists in resource decisionmaking: A regional study. *BioScience*, *53*(2), 170–178. https://doi.org/10.1641/0006-3568(2003)053[0170:AACOES]2.0.CO;2

Lee, K. N. (1994). *Compass and gyroscope: Integrating science and politics for the environment*. Island Press.

Merton, R. K. (1973). *The sociology of science: Theoretical and empirical investigations*. University of Chicago Press.

Moffitt, B. (2016). *The global rise of populism: Performance, political style, and representation*. Stanford University Press.

Moore, G. E. (1965, April). Cramming more components onto integrated circuits. *Electronics*, *38*(8), 114–117.

Morgan, M. G., & Peha, J. M. (Eds.). (2003). *Science and technology advice for Congress*. Resources for the Future.

Muhonen, R., Benneworth, P., & Olmos-Peñuela, J. (2020). From productive interactions to impact pathways: Understanding the key dimensions in developing SSH research societal impact. *Research Evaluation*, *29*(1), 34–47. https://doi.org/10.1093/reseval/rvz003

Nelson, M. P., & Vucetich, J. A. (2009). On advocacy by environmental scientists: What, whether, why, and how. *Conservation Biology*, *23*(5), 1090–1101. https://doi.org/10.1111/j.1523-1739.2009.01250.x

Norris, P., & Inglehart, R. (2019). *Cultural backlash: Trump, Brexit, and authoritarian populism*. Cambridge University Press.

Pielke, R. A. (2007). *The honest broker: Making sense of science in policy and politics*. Cambridge University Press.

Scientific integrity in federal agencies, U.S. House of Representatives, 116th U.S. Congress (2019) (testimony of Roger A. Pielke). https://science.house.gov/imo/media/doc/Pielke%20Testimony1.pdf

Price, D. K. (1965). *The scientific estate*. Harvard University Press.

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155–169.

Runkle, D., & Frankel, M. S. (2012). *Advocacy in science*. *Summary of a workshop convened by the American Association for the Advancement of Science, Washington DC, October 17–18, 2011*. American Association for the Advancement of Science. https://www.aaas.org/sites/default/files/s3fs-public/reports/Advocacy_Workshop_Report_FINAL.pdf

Sanni, M., Oluwatope, O., Adeyeye, A., & Egbetokun, A. (2016). Evaluation of the quality of science, technology and innovation advice available to lawmakers in Nigeria. *Palgrave Communications*, *2*, 16095. https://doi.org/10.1057/palcomms.2016.95

Santillán-García, A., Oliver, E., Grigorian Shamagian, L., Climent, A. M., & Melchor, L. (2020). #CienciaenelParlamento: La necesidad de una oficina parlamentaria de asesoramiento científico y tecnológico. *Gaceta Sanitaria*. https://doi.org/10.1016/j.gaceta.2019.08.004

Sarewitz, D. (2004). How science makes environmental controversies worse. *Environmental Science & Policy*, *7*(5), 385–403. https://doi.org/10.1016/j.envsci.2004.06.001

Sartori, G. (1987). *The theory of democracy revisited: Part One: The contemporary debate*, *Vol*. *1* (1st edition). CQ Press.

Schneider, F., Giger, M., Harari, N., Moser, S., Oberlack, C., Providoli, I., Schmid, L., Tribaldos, T., & Zimmermann, A. (2019). Transdisciplinary co-production of knowledge and sustainability transformations: Three generic mechanisms of impact generation. *Environmental Science & Policy*, *102*, 26–35. https://doi.org/10.1016/j.envsci.2019.08.017

Spruijt, P., Knol, A. B., Petersen, A. C., & Lebret, E. (2016). Differences in views of experts about their role in particulate matter policy advice: Empirical evidence from an international expert consultation. *Environmental Science & Policy*, *59*, 44–52. https://doi.org/10.1016/j.envsci.2016.02.003

Spruijt, P., Knol, A. B., Petersen, A. C., & Lebret, E. (2019). Expert views on their role as policy advisor: Pilot study for the cases of electromagnetic fields, particulate matter, and antimicrobial resistance. *Risk Analysis*, *39*(5), 968–974. https://doi.org/10.1111/risa.13224

Spruijt, P., Knol, A. B., Torenvlied, R., & Lebret, E. (2013). Different roles and viewpoints of scientific experts in advising on environmental health risks. *Risk Analysis*, *33*(10), 1844–1857. https://doi.org/10.1111/risa.12020

Spruijt, P., Knol, A. B., Vasileiadou, E., Devilee, J., Lebret, E., & Petersen, A. C. (2014). Roles of scientists as policy advisers on complex issues: A literature review. *Environmental Science & Policy*, *40*, 16–25. https://doi.org/10.1016/j.envsci.2014.03.002

Steel, B., Lach, D., List, P., & Shindler, B. (2001). The role of scientists in the natural resource and environmental policy process: A comparison of Canadian and American publics. *Journal of Environmental Systems*, *28*(2), 133–155.

Tyler, C. (2013). Scientific advice in Parliament. In R. Doubleday & J. Wilsdon (Eds.), *Future directions for scientific advice in Whitehall*. University of Cambridge's Centre for Science and Policy; Science Policy Research Unit (SPRU) and ESRC STEPS Centre at the University of Sussex; Alliance for Useful Evidence; Institute for Government; Sciencewise-ERC.

United Nations Statistics Division. (2019). *Methodology: Standard country or area codes for statistical use (M49)*. United Nations, Department of Economic and Social Affairs. https://unstats.un.org/unsd/methodology/m49/

Weiss, C. (2003). Scientific uncertainty and science-based precaution. *International Environmental Agreements*, *3*(2), 137–166. https://doi.org/10.1023/A:1024847807590

Weiss, C. (2006). Precaution: The willingness to accept costs to avert uncertain danger. In *Coping with uncertainty* (pp. 315–330). Springer.

Zucman, G. (2019). Global wealth inequality. *Annual Review of Economics*, *11*(1), 109–138. https://doi.org/10.1146/annurev-economics-080218-025852

Figure 1

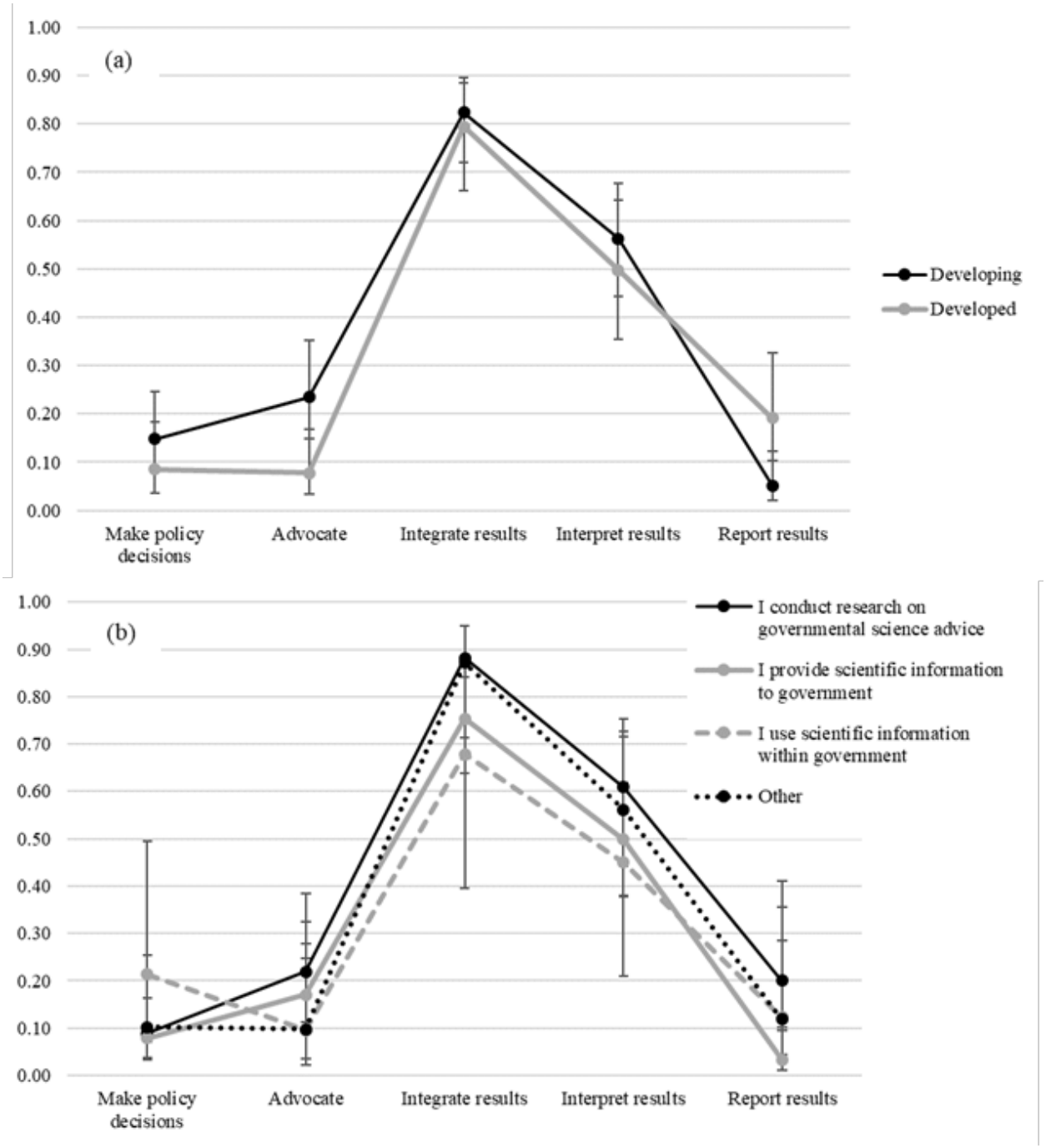
(a)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Make policy decisions
Advocate
Integrate results
Interpret results
Report results
Developing
Developed
(b)
I conduct research on governmental science advice
I provide scientific information to government
I use scientific information within government
Other

Table 1

Table 1. Integrating scientific results in policy is the most commonly selected role by international experts. *(DG=developing; DD=developed; RSA=research science advice; PSI=provide scientific information; USI=use scientific information; O=other)*

	Total *n*=168	DG *n*=85	DD *n*=83	RSA *n*=43	PSI *n*=72	USI *n*=17	O *n*=34
1) Report scientific results	12.0%	6.6%	17.4%	22.2%	4.9%	10.5%	16.7%
2) Report and then interpret the results	53.0%	56.0%	50.0%	60.0%	49.4%	47.4%	55.6%
3) Integrate scientific results in policy decisions	79.2%	80.2%	78.3%	86.7%	74.1%	68.4%	86.1%
4) Advocate for specific policies	18.6%	27.5%	9.8%	26.7%	18.5%	15.8%	11.1%
5) Make decisions about policy	11.5%	15.4%	7.6%	11.1%	8.6%	26.3%	11.1%

Table 2. Experts' rationale why scientists should participate in specific policy roles *(DG=developing; DD=developed; RSA=research science advice; PSA=provide science advice; USI=use scientific information; O=other)*

		Total *n*=158	DG *n*=81	DD *n*=77		RSA *n*=40	PSI *n*=68	USI *n*=17	O *n*=31	
Need for communication	Reduce misinformation	1.3%	2.5%	0.0%		0.0%	0.0%	0.0%	6.5%	*
	Address lack of scientific understanding	10.8%	13.6%	7.8%		20.0%	10.3%	0.0%	6.5%	
	Two-way communication	34.2%	34.6%	33.8%		32.5%	26.5%	29.4%	54.8%	
	One-way communication	18.4%	22.2%	14.3%		20.0%	19.1%	35.3%	3.2%	*
Outcomes	Improved decision-making	40.5%	43.2%	37.7%		35.0%	39.7%	52.9%	45.2%	
	Meeting societal needs	9.5%	8.6%	10.4%		5.0%	11.8%	5.9%	9.7%	
Limitations	Scientists do not understand policymaking	4.4%	4.9%	3.9%		7.5%	2.9%	5.9%	3.2%	
	Advocacy politicizes science	5.7%	3.7%	7.8%		2.5%	5.9%	5.9%	9.7%	
	Science is only one factor	7.6%	1.2%	14.3%	**	7.5%	11.8%	0.0%	0.0%	
	Scientists have ideological beliefs/values	3.2%	2.5%	3.9%		2.5%	2.9%	11.8%	0.0%	
Context dependent		7.0%	0.0%	14.3%	***	10.0%	1.5%	5.9%	16.1%	*

***p<.001, **p<.01, *p<.05

Table 3. The model's fixed effects reveal significant differences between the roles for scientists in policy and an interaction between development status and policy roles.

	F	*df1*	*df2*	*p*
Corrected model	8.586	27	877	0.00
Development	0.409	1	177	0.52
Policy role	45.324	4	877	0.00
Experts' system role	2.231	3	184	0.09
Development x Policy role	3.798	4	877	0.01
Development x Experts' system role	0.788	3	172	0.50
Policy role x Experts' system role	1.176	12	877	0.30

Table 4

Table 4. Pairwise comparisons illuminate significant contrasts between role preferences and between developing and developed nations for each role.

		Odds ratio	Contrast estimate	*SE*	*t*	*df*	*p*
Report results	- Interpret results	0.10	-2.30	0.34	-6.67	877	0.00
	- Integrate results	0.03	-3.63	0.37	-9.82	877	0.00
	- Advocate	0.71	-0.35	0.39	-0.88	877	0.38
	- Make policy decisions	0.89	-0.11	0.39	-0.29	877	0.77
Interpret results	- Report results	9.97	2.30	0.34	6.67	877	0.00
	- Integrate results	0.27	-1.33	0.28	-4.71	877	0.00
	- Advocate	7.03	1.95	0.32	6.16	877	0.00
	- Make policy decisions	8.89	2.19	0.32	6.91	877	0.00
Integrate results	- Report results	37.57	3.63	0.37	9.82	877	0.00
	- Interpret results	3.77	1.33	0.28	4.71	877	0.00
	- Advocate	26.52	3.28	0.34	9.56	877	0.00
	- Make policy decisions	33.51	3.51	0.34	10.25	877	0.00
Advocate	- Report results	1.42	0.35	0.39	0.88	877	0.38
	- Interpret results	0.14	-1.95	0.32	-6.16	877	0.00
	- Integrate results	0.04	-3.28	0.34	-9.56	877	0.00
	- Make policy decisions	1.26	0.23	0.37	0.63	877	0.53
Make policy decisions	- Report results	1.12	0.11	0.39	0.29	877	0.77
	- Interpret results	0.11	-2.19	0.32	-6.91	877	0.00
	- Integrate results	0.03	-3.51	0.34	-10.25	877	0.00
	- Advocate	0.79	-0.23	0.37	-0.63	877	0.53
Developing - Developed	Report results	0.23	-1.47	0.59	-2.48	877	0.01
	Interpret results	1.30	0.26	0.38	0.69	554	0.49
	Integrate results	1.22	0.19	0.45	0.44	877	0.66
	Advocate	3.66	1.30	0.50	2.60	877	0.01
	Make policy decisions	1.87	0.62	0.55	1.13	877	0.26