Title

The Science-Policy Relationship Hierarchy (SPRHi) Model of Co-Production: How Climate Science Organizations Have Influenced the Policy Process in Canadian Case Studies

Abstract

Can better functioning science-policy relationships (SPRs) address the seeming discrepancy between the scientific consensus on climate change and the insufficient ensuing policy outcomes? Certain scholarly works on science-policy interfaces and evidence-based policy are optimistic, while the literature on research utilization is pessimistic. The field of science, technology, and society (STS) and the concept of co-production advance a broader view, suggesting that more holistic (i.e. institutional or systemic) changes may offer a way forward. This article synthesizes causal claims from such literatures into an analytical framework of potential pathways from co-productive SPR characteristics to policy action. It then investigates, through expert interviews, three climate SPRs in Canada: a municipal-level case between the Pacific Climate Impacts Consortium (PCIC) and local communities, a provincial-level case between the Pacific Institute for Climate Solutions (PICS) and the Climate Action Secretariat (CAS), and a national-level case between the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) and the federal government. In light of the analytical framework, the cases suggest a theoretical hierarchy of function for SPRs: incidental interaction (at the bottom), basic partnership, interactive dialogue, and true co-production (at the top), each of which can be coupled with a supplementary network (to the side). This template is presented as the Science-Policy Relationship Hierarchy (SPRHi) Model. Collectively, the cases and the model reveal causal pathways that may explain why any given SPR ends up functioning the way it does (e.g. external political conditions are important), implying prescriptions for improvement. Besides the analytical framework and

model, the main contribution is the finding that co-productive strategies are unlikely to lead to concrete policy changes on their own, but are crucial for cultivating soft policy influences and side benefits.

Keywords

Adaptation; Canada; Climate Change; Co-Production; Evidence-Based Policy; Research Utilization; Science-Policy Interfaces

Introduction

Contemporary social problems have precipitated an explosion of academic, political, and public interest in "evidence-based policy" (Davies 2004) and "knowledge mobilization" (Levin 2008). While the "intelligence" (i.e. information gathering) function of governments has been studied for many decades (see Wilensky 1967), these concepts have renewed interest in the idea that the relevant knowledge of experts (e.g. academic scientists) has traditionally been underutilized by decision makers. The implication is that the policy process is instead based too heavily on ideology and opinion, leading to science-policy "deficits" or "gaps" for particular social issues (e.g. see Bradshaw and Borchers 2000). However, scholars in the areas of science, technology, and society (STS) and research utilization have questioned this perspective. The former casts doubt on the objectivity and authority of science (Latour 1987, Van Buuren and Edelenbos 2004, Van Kerkhoff and Lebel 2006), thus questioning whether all such "deficits" can or should be avoided (Irwin 2014), and opposes the "gap" metaphor altogether as oversimplifying the complex relationships between science and policy (Van Kerkhoff and Lebel 2015). The latter demonstrates that the use of external research by policy makers has inevitably been low, slow, and invisible (e.g. Weiss 1977, Weiss 1980), which suggests that identified science-policy "gaps" (if such a characterization is even appropriate) cannot easily be bridged. If the ideal of evidence-based policy is ultimately quite naïve, what is to be done about perpetually insufficient policy outcomes for unprecedented global challenges like climate change?

A brief history of the prevailing scientific opinions and policy responses for climate change will be instructive in beginning to tackle this question. The Intergovernmental Panel on Climate Change (IPCC) reports are arguably "the most authoritative and strongly supported statement on climate change that has ever been made by the international scientific community" (IPCC 1990). Since its first report in 1990, the IPCC has implemented more rigorous processes,

such as a thorough protocol for dealing with errors, which facilitate an even stronger consensus (IPCC 2013). Even through to the most recent report in 2014, the IPCC's key message has remained remarkably consistent: a "business-as-usual" scenario for greenhouse gas emissions will lead to severe climate consequences; the earlier there is substantial policy action, the more likely it is that such disaster can be averted and the easier such policy action will be (IPCC 1990, IPCC 2014).

In response to the IPCC's recommendations, however, climate policy outcomes for mitigating emissions have generally been very poor across the globe. This is best exemplified by the failure of the 1997 Kyoto Protocol, an initiative motivated largely by the first and second reports of the IPCC. For developed countries, the average target was a reduction in yearly greenhouse gas emissions to 4.2% below 1990 levels by 2012 (NEAA 2011). Three nations were able to meet or exceed this target in a meaningful way (i.e. the United Kingdom, Germany, and Sweden), but emissions rose in many of the participating countries, and even more substantially in non-participating countries, such that, altogether, annual global greenhouse gas emissions increased by nearly 50% between 1990 and 2010 (IEA 2012). Behind the scenes, climate change action has remained essentially controversial in the eyes of the media, politicians, and the public, especially as it often seems to imply curbing consumption or economic growth. The interdisciplinary, interjurisdictional, and intertemporal nature of climate change further complicates the response. As a political issue, climate change is both a quagmire and a minefield, incredibly complex and extremely important.

So, while the *general* ideas of "evidence-based policy" and bridging "science-policy gaps" may be naïve, climate change appears to be a *specific* example of some obstruction in the interface between science and policy. It has been characterized as a policy failure by a number of authors (e.g. Bradshaw and Borchers 2000, Moser and Dilling 2011, Sheikh 2016, Sundqvist et

al. 2015) and even the STS literature acknowledges that, while we tend to overestimate the commonality of science being excluded from decisions where it can make an important contribution, such situations *can* and *do* occur (Van Buuren and Edelenbos 2004, Van Kerkhoff and Lebel 2015). The key consideration in analyzing potential problems in the interface between science and policy is to acknowledge that the context of the particular issue and government under question matters (Irwin 2014, Van Kerkhoff and Lebel 2015). That is, we should be very wary of the general claim that policy makers systemically under-use evidence, and even be a little cautious of the sub-claim that there is a "science-policy gap" specifically for climate change. If we want to investigate ways forward for climate policy outcomes, what we *can* do is examine the climate science-policy interface in a specific national context. As with all explorative inquiry, it is possible such an investigation will *start* to build theory that *may* apply to science-policy interactions for climate change, or in general, in other cases, but making grand abstract claims about EBP or science-policy gaps is not a productive objective, given the above analysis.

Canada offers precisely this sort of interesting national case of climate (in)action, since it initially ratified the Kyoto Protocol in 2002 and then withdrew in 2011. This is not to suggest that there was much action in the interim, however. Indeed, the last few federal governments in Canada have been criticized for overall lack of leadership (see White 2010), active suppression of climate research (see Nature 2012), and too much deference to provincial governments (see McGregor 2015). Recent Auditor General reports found that the current government is not on track to meet its new Paris Accord commitments and has prioritized planning over actual implementation, for both mitigation and adaptation goals (OAGC 2017a, OAGC 2017b, OAGC 2018).[1] There has been perhaps more action at the sub-national level, with carbon pricing policies

[1] Of course, climate mitigation and adaptation policy should not be conflated. It is possible for a government to generate sufficient policy outcomes on one but not the other, and the science-policy interfaces for the two of them

already implemented by several provinces (e.g. see Lachapelle et al. 2012) as well as climate partnerships or networks formed at both the regional (e.g. see Houle et al. 2015) and municipal levels (e.g. see Gordon 2016). However, the provinces have traditionally lagged in comparison to the American states (Rabe 2007), and more recently have abandoned commitments in lockstep with the states (Rabe 2016), while the broader regional and municipal networks have been only marginally productive (Gordon 2016, Houle et al. 2015). The relationship between climate science and policy outcomes at all levels of government in Canada is at the very least curious, and offers an interesting case for potentially furthering our broader understanding of science-policy interaction for climate change.[2]

This leaves us with several interesting questions. How are any seeming discrepancies between existing climate evidence and policy outcomes in Canada best explained? What challenges exist within the interface between climate scientists and Canada's policy-makers? Is it possible to address these challenges and mobilize climate knowledge more effectively? Can the relationships between Canadian science and policy be improved to facilitate more substantial climate outcomes? In attempting to answer such questions, this article aims to map the influences of science-policy relationships (SPRs) on climate policy decisions in Canada, in the broader context of political change. That is, it acknowledges there are many causal factors that affect climate policy outcomes, and investigates the real potential of SPRs to contribute to this mix. The article proceeds through the following sections. First, the relevant literature on research utilization, science-influenced policy, and co-production is reviewed to show competing conceptions regarding the role of science in policy change. Second, an analytical framework is

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will differ. However, the specific differences are not critical for this article, the motivation for which is simply that there is room for improvement in both climate mitigation and adaptation across all levels of government in Canada.

[2] Note that, for the purposes of this article, "science" refers to both the natural sciences and the social sciences. Discussion will typically occur in the context of the former, but it is not mean to exclude the latter.

extracted from pertinent pieces of literature that present specific models of policy influence, in order to comprehensively illustrate the variety of pathways from diverse SPR inputs to various policy outcomes. Third, the research design, a comparative analysis of three SPR cases explored through interviews, is described in detail. Fourth, results from the interviews are reported and discussed, mapping the specific influences of climate SPRs in the chosen cases onto the analytical framework. Fifth, a new theoretical construct, the Science-Policy Relationship Hierarchy (SPRHi) model, is extracted from the synthesized results. It is then applied to the cases to suggest some possible ways forward for climate action in Canada. The model is meant to contribute to general theory about science-policy interfaces, but will require further testing, acknowledging the unique context of individual cases.

Theoretical Background

The contextual and case-focused lens of this article necessitates that broader political factors be briefly acknowledged before examining the specific potential effects of science-policy relationships. That is, there are many different determinants, besides the direct interaction between scientists and policy-makers, which may explain the seeming discrepancy between climate science and policy outcomes in Canada. Kingdon's (1984) multiple streams framework is one conceptualization which synthesizes various causal factors into three streams: problem (e.g. indicators, events), policy (e.g. available resources, existing instruments), and politics (e.g. government ideology, public opinion, interest groups). He argues that the streams need to align, which happens unpredictably, in order for policy change to take place (see Zahariadis 2014 for the most contemporary description and Real-Dato 2009 for other synthetic approaches). The interpretation of this article is that climate scientists can be part of the problem stream and social scientists may propose solutions in the policy stream, but this means that direct relationships

between researchers and policy-makers can only influence a small part of the overall process. Acknowledging that science-policy relationships could be an important, but never the only, factor in explaining (in)action on issues like climate change, let us explore the different schools of thought on the level of influence they actually have in reality and whether this level can or should be changed through different practices.

One relevant school of thought, from the discipline of political science, is that which surrounds theories of research utilization. Scholars of this topic are interested in explaining how research flows, or does not flow, into the policy process. The most exemplary author is Weiss (1977), who contends that the use of information by policy-makers can range from the immediate application of any recommendations (i.e. ideal rational model) to a general sensitization to highlighted concepts (i.e. enlightenment model). She uses interview evidence to illustrate that reality tends to fall much closer to the latter than the former; policy-makers use research generally to orient themselves toward problems when setting the decision agenda more than they utilize its specific recommendations during policy implementation. Ultimately, she concludes that there is an important role for researchers in challenging political priorities broadly, but that utilization of their research would be difficult to notice in such a context. Subsequent studies have shown that policy-makers will often say that they have made use of research but then find it difficult to give a concrete example (Weiss 1980) and that the decision environment is saturated with information such that the challenge for policy actors is to filter, not simply gather, information (Daviter 2015). Thus, research utilization by policy-makers tends to be portrayed as naturally low, slow, and invisible (also see Lindquist 1988, Shulha and Cousins 1997).

Moreover, this body of literature contributes some general concepts that are relevant to the science-policy process. Weible (2008) draws on previous work in the area, suggesting that there are basically three main types of information use: instrumental, such as in the ideal rational

model specified by Weiss (1977); political, such as justifying previous decisions (Sabatier 1988) or giving the public an impression of informed decision making (Feldman and March 1981); and learning, such as in the long-term enlightenment model specified by Weiss (1977). Furthermore, he argues that in "adversarial subsystems", such as the controversial debates over climate change, political use of information will be high, but genuine learning and instrumental use will be low. Altogether, this conceptual area highlights that the policy process can make use of information inputs in a variety of ways, but that those inputs rarely have a noticeable effect on policy change. The underlying assumption is that other causal factors such as political ideology and public opinion (see Kingdon 1984) have a stronger influence than research.

There are also important pieces of literature that are, in contrast, optimistic about the potential of scientists to productively influence (or at least, inform) policy, although they do not appear to belong to any one distinct field. Some discuss evidence-based policy, others focus on science-policy communication, and a few come from natural scientists (i.e. ecologists) writing reflexively about their own field. The most salient of these are fairly explicit in making recommendations for scientists that will allegedly increase their chance of influencing policy outcomes. For example, Likens (2010) suggests that scientists should have policy and media training, avoid jargon, actively provide clear press releases, be especially careful with statistical information and uncertainty, and consider innovative ways to communicate. Mead (2015) maintains that academia must change its career incentives and instead reward researchers for having government experience, interests outside their own narrow field, and the ability to communicate to audiences outside of academia. Cairney et al. (2016) argue that scientists should leave their traditional comfort zone of objectivity and be willing to combine emotion with fact, tell simple stories, and be opportunistic with the timing of released information. They recognize, though, that scientists are not always in the position to adopt these strategies and also include

more “pragmatic” suggestions, such as engaging in science-policy networks. All of these recommendations are based on the idea that discrepancies between science and policy can start to be addressed if academics change their tactics.

Some of the scholars in this area, however, are a little less explicit with their claims. Rather, their analysis operates on an underlying assumption that science-policy processes can have a meaningful effect on outcomes. Pielke (2007), for instance, identifies different roles that scientists can adopt when interacting with policy-makers (i.e. pure scientist, science arbiter, issue advocate, honest broker). While each role allegedly has its place (see also Spruijt et al. 2014), his main thesis is that decision-making is compromised by the existence of too many issue advocates, who promote particular policy positions based on their scientific knowledge, and not enough honest brokers, who attempt to clarify the trade-offs of various policy alternatives. He does not explicitly state that individual scientists who shift to more appropriate roles can expect more policy influence, but there is a clear assumption that the strategies used by scientists can make a difference in the policy process. Howlett (2009), more broadly, argues that policy failures are to be expected when government agencies have insufficient “policy analytical capacity” – such as lacking understanding for relevant theoretical and applied research, or not having access to external sources of expertise. He makes no recommendations for scientists at all (i.e. the article is aimed more at how the policy process itself can improve), but his analysis suggests that the way evidence is incorporated into decision-making procedures matters. Instead of viewing low research utilization as something that is naturally commonplace in the policy-making process, this body of literature sees a problem that can be fixed with the right approaches. Ultimately, there are two competing understandings in the bodies of knowledge relevant to information inputs for policy.

Literature from the field of STS, especially on the concept of co-production, takes a more holistic view of this dichotomy and can help interrogate the two competing hypotheses. Two main conceptualizations of, or orientations toward, co-production have materialized in this literature. The first is descriptive, analytical, and critical of traditional or naïve understandings of science – "this is how things actually are" – but the second is normative, instrumental, and pragmatic in offering ways to improve science-policy interactions – "this is how things could be" (see Duncan 2017, Van Kerkhoff and Lebel 2015, Wyborn 2015, Wynne 2007). A central author for the former view is Jasanoff (2004). Rather than conceiving of science and policy as separate spheres, she observes that "the realities of human experience emerge as the joint achievement of scientific, technical and social enterprise: science and society, in a word, are *co-produced*, each underwriting the other's existence" (p. 17). Other scholars also embrace this "constructivist" view, arguing that science is not neatly distinct from society or government, is neither subordinate nor superior to policy, and is not as objective as has traditionally been assumed (e.g. Hoppe 2005, Van Buuren and Edelenbos 2004, Van Kerkhoff and Lebel 2006). Science is socially constructed, as are the boundaries between it and other social realms (see Douglas 2009, Guston 2001, Jasanoff 1987, Latour 1987, Turnhout et al. 2007). This directs our attention to "boundary work" at the intersection of science and policy, rather than one realm or the other.[3] While this lens from STS, along with its critiques of traditional assumptions about science and society, is extremely useful, it does not offer much productive direction for actually improving science-policy relationships (Hoppe 2005, Van Kerkoff and Lebel 2006, Van Kerkhoff and Lebel 2015).

[3] In particular, boundary organizations are those which liaise and mediate between the two, while also having lines of accountability to each (Guston 2001). Boundary objects are tools such as archives, atlases, diagrams, or forms that have different meanings in the two realms but have a common enough structure to make them recognizable to both as a means of translation (Star and Griesemer 1989).

Thus, in order for STS to offer guidance for science-policy dilemmas around issues like climate change, the normative orientation should be considered alongside the descriptive orientation. This view is well articulated by Van Kerkhoff and Lebel (2015): "the other use of coproduction refers to shared knowledge production at a project or program scale… an agenda, a call to configure and conduct our knowledge- and decision-making processes in particular ways" (p. 2). In their (2006) analysis, practical recommendations for improvement are founded on norms which emphasize the duality or mutuality of science-policy relationships: participation, integration, negotiation, and learning. Suggestions from this perspective look more like design characteristics or institutional mechanisms for science-policy processes and relationships as a whole, rather than one-sided tactics for scientists alone (see Newman and Head 2015), as in the "optimistic" literature above. For instance, Cash et al. (2002) propose boundary management strategies such as employing skilled liaisons or "translators" between the spheres and using boundary objects as a starting point for common understanding. Such strategies will allegedly lead to the production of knowledge that holds the traits of credibility, salience, and legitimacy in balance, and thus is more likely to be used. Cash et al. (2003) recommend frequent meetings, institutionalized partnerships, attention to other stakeholders, and an expectation of accessible messaging. As a final example, Brugnach and Ingram (2012) highlight the importance of selecting leaders who can establish trust and facilitate collaboration.[4] Much of this literature shares an emphasis on face-to-face meetings, as well as the acknowledgement that pursuing co-production can be broken down into component "mechanisms" or "features" or "capacities" (also see Sarkki et al. 2015 and Van Kerkhoff and Lebel 2015). That is, a given science-policy

[4] The work of Foss (2007) is also instructive, although he writes on the topic of "knowledge governance" rather than co-production and is from the field of business administration, not STS. His mechanisms include organizational structure, job design, reward systems, and standard procedures, the appropriateness of different approaches depending on the type of knowledge being managed.

relationship can have any number of co-productive elements; attempting to classify it as either co-productive or not may be inappropriate.

Instead of viewing the policy process as a barrier between science and action, then, co-production suggests that scientists and policy-makers can productively influence one another, particularly if the focus is on mechanisms or processes *within* science-policy relationships rather than strategies that might be employed by only one realm or the other. This perspective accommodates the inertia of the policy process, as described by the research utilization literature, as well as the potential for change, as highlighted by the literature optimistic about scientific inputs. It informs the analytical lens of this article, in the context of broader policy change.

Analytical Framework

Recall that the purpose of this article is to map the real influences of SPRs on policy decisions, in the context of Canada and climate change. The focus on SPRs, in particular, flows from the relevant literature, which discusses broad influences of "science" in *general*, but ultimately makes its most pertinent and practical observations about *specific* relationships between scientists and policy-makers (e.g. see the body of work on co-production). Here, a SPR is defined as any relationship between a specific ministry, branch, or agency within government and a specific science department, research group, or institute external to government (typically from academia). The latter usually has a particular interest in the policy implications of its work. Such a description offers more focus than some of the above literatures (e.g. it is narrower than the definition of science-policy interface), but is still broad enough to capture a range of relationship types (i.e. below, the terms "partnership" and "dialogue" will denote specific types of relationships). This section establishes a broad analytical framework that details the range of SPR inputs, policy outcomes, pathways between the two, and intervening factors. It is informed

by the lessons of the theoretical background, acknowledging that policy outcomes are rarely influenced neatly or directly by science, that there are many strategies scientists might pursue in an attempt to influence policy-makers, and that more holistic co-productive mechanisms may be the most promising pathways to better outcomes. Such breadth is appropriate for exploratory qualitative research (see Beach et al. 2016) that is also context-sensitive (recall Irwin 2014, Van Kerkhoff and Lebel 2015). The literature already reviewed above is synthesized with relevant additional literature to flesh out possibilities for the framework.

Helpfully, some scholars in the related fields have already established spectrums that are relevant to this article. Lindquist (1988), from the research utilization literature, perceives three fundamental types of information that flow into the policy process: basic data, specific analysis, and broader research. Complementarily, Pielke (2007), from the science-policy interfaces literature, specifies four roles for scientists: pure scientist, science arbiter, honest broker, and issue advocate. Considered together, these two scholars suggest that there are essentially three important types of information inputs, on a rough spectrum from objective to subjective: basic data, advice (i.e. predicting the effects of various policy decisions), and advocacy (i.e. for a particular policy decision). The implication is that policy-makers are generally more open to the former types, but that the latter types have more influence when they are genuinely considered. Recall the dimensions of information quality (i.e. credibility, salience, legitimacy) defined by Cash et al. (2002), which might be influenced by the initial type of information. In turn, there are Weible's (2008) categories describing the ultimate effects of that information (i.e. instrumental use, political use, learning use), to which Fischer and Leifeld (2015) would add side effects such as networking and legitimization for parties involved in collaborate science-policy exchanges. Finally, recall the diversity of political factors in Kingdon's (1984) multiple streams framework (e.g. public opinion, government ideology, interest groups) and the variety of co-productive

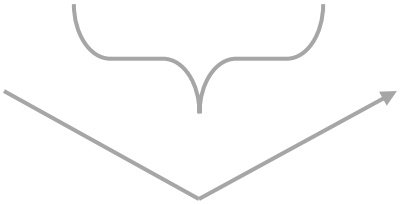
mechanisms identified in the previous section (e.g. frequent face-to-face meetings, accessible messaging, employing liaisons and leaders). There is a vast range of variables involved in the relationship between SPR inputs and policy decisions.

How does existing literature make sense of this unwieldy breadth? Only a few pieces explicitly outline precise pathways from SPR inputs to policy influence. Cash et al. (2003), for example, claim that three institutional features (i.e. treating boundary management seriously, boundary managers being accountable to both scientists and policy-makers, joint production of boundary objects like models and reports) improve boundary management (i.e. communication, translation, and mediation between scientists and policy-makers), leading to higher quality (i.e. credible, salient, legitimate) scientific information that is more likely to be used by policy-makers. Other works highlight input characteristics such as interdisciplinarity, entrepreneurial strategies, and iterativity; external factors like available resources and historical context; intermediate outputs such as information quality, boundary work, and networks; and ultimate outcomes like innovation and uptake by civil servants (see Lemos and Morehouse 2005, Rietig 2014, Tuinstra et al. 2006). Given these observations, a comprehensive analytical framework that encompasses a variety of potential pathways should include four sets of factors: characteristics of the SPR and the scientific information involved (i.e. inputs), outcomes (e.g. benefits), intermediate steps between inputs and outcomes, and external factors or conditions that affect the SPR or compete with scientific input to influence policy outcomes. See Table 1 for a diagram of this framework. The examples in each category have been extracted from the above literature.

It should be possible to map any pathway from SPR inputs to policy outcomes through this framework. For example, Rietig's (2014) pathway would highlight entrepreneurial strategies (i.e. effective messaging) as an input characteristic, quality of information and perceived neutrality as intermediate steps, political receptivity (i.e. political interest) as an external

External Conditions
e.g. focusing events
e.g. other jurisdictions
e.g. pressure groups
e.g. individual personalities
e.g. public/political interest

Input Characteristics
e.g. frequent meetings
e.g. type of information
e.g. stakeholder involvement
e.g. effective messaging
e.g. boundary organizations



Policy Outcomes
e.g. ideal rational use
e.g. technical use
e.g. political use
e.g. indirect enlightenment
e.g. side effects

Intermediate Steps
e.g. fruitful communication
e.g. quality of information
e.g. stable network
e.g. neutrality and trust
e.g. boundary objects

Table 1 Diagram of a Comprehensive Analytical Framework for SPR Pathways

condition, and technical or political uses of information as policy outcomes. The framework is meant to encompass all such possible factors and pathways (also see Sarkki et al. 2015 and Schmid et al. 2016). Most importantly, it explicitly accommodates contrasting perspectives on whether the low influence of science on the policy process is inevitable. That is, of the left box and the top box in Table 1, which is generally more important? Can communication strategies or the institutional characteristics of a SPR have a substantial effect on policy outcomes? Or is it a combination of input characteristics and external conditions that best describes the reality of scientific influence? These possibilities inform the empirical investigation in this article, which examines case studies of climate SPRs intended to be influential, to see whether such efforts were successful. The driving question being asked is: what are the real effects of SPR inputs on the climate policy process in the context of other (external and political) causal factors?

Case Selection and Methods

Now that a specific theoretical question has been established, recall the broader issue motivating the research in this article. There seems to be a discrepancy between the consensus climate science and ensuing policy outcomes internationally, but this is best examined on a case-by-case basis. Canada is a particularly interesting case in this regard due to its inconsistent stance on the Kyoto Protocol, but also for another reason: the bodies of literature reviewed above pay little attention to it, tending to focus instead on the US or the UK. When articles do consider the unique context of Canada, they tend to have other shortcomings; they may be too dated (Desveaux et al. 1994), not sufficiently empirical (e.g. Bocking 2009), too focused on only one part of the science-policy interface (e.g. Ford et al. 2013), or concerned with policy sectors other than the environment (e.g. Howlett 2009). This leaves them unable to answer the questions posed above, in the context of Canada and climate change. Selecting Canada as a case for empirical research on questions about the influence of (climate) science in the policy process attends multiple gaps in the existing literature.

To begin with, understanding Canada's policy action, or potential lack thereof, on climate change requires an appreciation of its recent political history. The country has been governed by the centre-oriented Liberal Party from 1993 to 2006 (i.e. at the time of the Kyoto Protocol's ratification), by the right-leaning Conservative Party from 2006 to 2015 (i.e. at the time of Canada's withdrawal from the protocol), and by the Liberal Party again since 2015. Despite its ratification of the Kyoto Protocol, the former Liberal government's environmental record received criticism for a lack of substantive action and leadership (see Macdonald 2009, VanNijnatten and Boardman 2009, Winfield 2009, White 2010). The governing style of the Conservatives led to new allegations of muzzling government scientists and strategically suppressing climate research (see Cuddy 2010, Nature 2012, Greenwood 2013, CAUT 2014).

Although the new Liberal government came into power only recently, it has made plans regarding climate change action and carbon pricing (see LPC 2016). While initially desiring to achieve consensus with the provinces (see Fitz-Morris and Tunney 2015, McGregor 2015), which is par-for-the-course in Canada's federalist system, it has recently decided to mandate carbon pricing for all provinces (Harris 2016), but the recalcitrance of Saskatchewan and other regions could still be a major barrier (Mason 2016). The research reported in this article took place during the last few years of Conservative rule.

Of course, Canada is not simply a case of total climate inaction. There are examples of action, especially at the provincial and municipal levels, which should be acknowledged. In terms of mitigation at the provincial level, there have been regional agreements among provinces and US states, such as the Joint Climate Change Action Plan (see Selin and VanDeveer 2005), the Western Climate Initiative (see Houle et al. 2015), the Midwest Greenhouse Gas Reduction Accord, and the International Carbon Action Partnership (see Engel 2009). However, some of these initiatives have lost their initial momentum (Houle et al. 2015) while others have encountered barriers such as concerns of regional competition and lack of interest at the federal level (Selin and VanDeveer 2005). As for action by individual provinces, governments in both British Columbia and Quebec have had some success in implementing carbon pricing initiatives without losing much electoral support (Harrison 2012, Lachapelle et al. 2012), but provincial action has historically lagged behind, or in lockstep with, that of US states (Rabe 2007, Rabe 2016).[5] Mitigation efforts at the municipal level include, for instance, the Partners for Climate Protection network, which includes 247 Canadian municipalities (Gordon 2016). However, its

[5] Of course, things are more complicated at the time of this writing. For example, there is a federally-imposed requirement that every province implement a carbon pricing scheme to start in 2019, Alberta has its own new carbon pricing initiative (see Tasker 2016), and Ontario implemented and then ended a cap-and-trade program (see Rieti 2018).

success has been limited; more support from upper levels of government will ultimately be needed (Ibid.). The municipalities of Delta, Vancouver, and North Vancouver have also been studied in the literature as examples of climate action, but have similarly encountered a variety of obstacles (see Burch 2010). As for adaptation, there certainly are cases of action at the subnational level, but these also tend to be limited in their potential, due to institutional constraints, policy inertia, weak management, or other issues of "policy capacity" (see Craft and Howlett 2013, Newman et al. 2013). Across all levels of government in Canada, for both mitigation and adaptation, then, there is room for more effective action and better policy outcomes. I hope to make a small contribution to this challenge by examining science-policy relationships.

The research question and the analytical framework, as outlined in the above section, are exploratory and context-sensitive, but are also informed by existing work. This merits a qualitative study of a small number of case relationships, appropriate for initiating new theory in a largely inductive fashion (see Beach and Pedersen 2016, Mahoney and Rueschemeyer 2003, Ragin 2014 p. 69, Yin 2013). The specific methodology is effectively comparative case analysis, which can be used "to find potential causes of social phenomena" (Beach et al. 2016 p. 228) and entails "a wide-ranging comparative probing to search for possible candidate causes, a process that often takes the form of a brainstorm where we cast our net widely" (Ibid. p. 242). While the cases should be causally similar (because the analysis does not benefit from the averaging correction of quantitative work – see Beach and Pedersen 2016), both similarities (i.e. "Which condition is shared by all the cases?") and differences (i.e. "Which conditions are present when the outcome is present and absent when the outcome is absent?") among the cases can be used to detect possible causal conditions (Beach et al. 2016 p. 243). This methodology matches the above analytical framework well; there is an outcome of interest (i.e. policy action) and a range of

possible identified causes, of which SPR inputs are the most interesting for our purposes. Thus, this research concentrates on three cases of interaction between climate scientists and climate policy makers within Canada, aiming to investigate them qualitatively through interviews and then compare them to develop general theory about the contextual influence of SPR inputs on policy outcomes.

The first case is a local-level relationship between the Pacific Climate Impacts Consortium (PCIC) and municipalities in the province of British Columbia (BC). PCIC is a non-profit research organization, based in Victoria and established in 2008. It focuses on regional climate impacts, climate analysis and monitoring, and hydrologic impacts in the province. The staff of about 20 people consists primarily of climatologists, data analysts, and hydrologists, supported by a few administrators and communications personnel. Broadly, PCIC's goals include bridging the gap between climate research and its application, making practical information available, and stimulating collaboration among climate stakeholders (PCIC 2014, PCIC 2015). The organization interacts indirectly with any municipalities that access its free online tools and information. For example, the Plan2Adapt tool estimates climate impacts in various regions to assist adaptation planning. PCIC is also occasionally contracted by individual municipalities to do more specific research on a particular region or help develop and review an adaptation plan, which requires more frequent and direct communication.

The second case is a provincial-level relationship between the Pacific Institute for Climate Solutions (PICS) and the Climate Action Secretariat (CAS), a branch of the BC provincial government tasked with coordinating action on climate change. PICS is a collaboration among four BC universities, based in Victoria and established in 2008. Like PCIC, one of its objectives is to understand climate change impacts, but it also focuses on broader socioeconomic implications, policy options, and outreach to the general public. The formal staff of PICS consists

of only two directors and a few administrators and coordinators; most of the research is conducted through a network of scientists, primarily at the partner universities, that are provided funding (PICS 2015). The mandates of both organizations mention collaboration and outreach, so CAS and PICS interact in a number of ways: regular phone calls and lunch meetings, presentations given by PICS researchers to a CAS audience, collaboratively developing materials for PICS short courses offered to non-academics, white papers and briefing notes published by PICS and targeted toward CAS and other government departments, mutual review of reports, and jointly hosting seminars or workshops.

The third case is a national-level relationship between the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS), now known as the Canadian Climate Forum (CCF), and the federal government of Canada. CFCAS was a research institution with federal funding from the previous Liberal government, based in Ottawa and created in 2000. Its goal was to strengthen the country's scientific capacity to address climate change and offer a scientific basis for related policies. Primarily, this was pursued through the provision of grants for climate science research at universities (CFCAS 2001). Funding for CFCAS was discontinued by the Conservative government, and the organization rebranded itself as CCF in 2012, shifting its focus toward outreach and promoting science-informed decision making (CCF 2013). However, as there was never a time when both CFCAS/CCF and the federal government were particularly interested in collaboration, interaction between the two actually has been quite rare. The best example is the three seats for government representatives on the CFCAS board, although these were usually vacant under the Conservatives. Other interactions typically have been indirect, conferences or workshops hosted by CFCAS/CCF, for instance, which representatives of government occasionally attend.

Each case has both a science and a policy partner, the former always being a research organization. While none of these are boundary organizations per se, they do perform boundary work (see Guston 2001). Importantly, there is variation between the cases in terms of the SPR inputs; PCIC provides basic data on impacts, PICS offers policy recommendations, and CFCAS/CCF has yet to establish a stable collaboration with the government at all. They also manifest at different scales, which leads to helpful overlap in understanding the broader context of each. This is instructive for examining the research questions, but the three cases were specifically chosen because they embody a natural set. PCIC and PICS are headquartered in the same building at the University of Victoria and receive funding from the same provincial endowment, while PICS and CFCAS/CCF have engaged in funding partnerships and have some overlap in their directors (CCF 2014, PICS 2014). All three organizations are basically part of the same climate science community and have similar mandates. They were selected carefully and deliberately for this reason, in order to hold additional factors outside the co-productive characteristics of the SPRs themselves relatively consistent between the cases (i.e. they are causally similar), which is crucial if persuasive claims are to be made using comparative case analysis (see Beach and Pedersen 2016).

A case-oriented, small-N methodology merits qualitative (i.e. non-numerical, non-statistical) methods, in order to appreciate the complexity of the various factors under consideration (see Ragin 2014 p. 69), such as those identified by the analytical framework. Interviews, as a research tool, offer many benefits in this regard: they allow access to publicly unavailable information; they are a quick means of knowledge gathering; they provide insight into the context or atmosphere surrounding the issue-at-hand; and they can lead to further sources of information and other contacts through “snowballing” (Bogner et al. 2009, Richards 1996). Between January and April of 2014, potential interview participants were recruited from the

relevant organizations, some through publicly available staff or member lists and others through the referral of previous interviewees. They were approached via email and given a brief description of the project. If interested, they were provided with a consent form and the interview topics. Ultimately, 20 people were interviewed. See Table 2 for a summary of participants. Some of the latter interviewees seemed less immersed in and knowledgeable about the cases (by their own admission), so the potential pool of participants was likely exhausted at that point.

CASE	REPRESENTING SCIENCE	REPRESENTING POLICY
municipal (7 total)	2 scientists (PCIC) 1 intermediary (other organization)	3 planners (various municipalities) 1 intermediary (provincial government)
provincial (7 total)	2 scientists (PICS)	5 civil servants (CAS)
federal (6 total)	3 scientists (CFCAS)	2 former civil servants (federal government) 1 former politician (federal government)

Table 2 Summary of Interview Participants

The interviews themselves were one-on-one, oral, and audio-recorded, following a semi-structured and open-ended format. Participants were not expected to adhere strictly to the provided list of topics, so that the variety of factors highlighted by the analytical framework could be explored. This allowed respondents to "teach" the interviewer about the situation (Dexter 1970 p. 5), sharing a more consistent chronological narrative (Richards 1996 p. 202) and organizing answers within their own frameworks. This approach was important for the exploratory aspect of the research questions. The general purpose of the planned interview topics, however, was to encourage the interviewee to describe and evaluate the SPR being discussed. In particular, they were pressed to assess the degree to which outcomes of the relationship were caused by types of scientific input and co-productive strategies versus political forces and other external factors (see the appendix for a list of interview topics). Important or recurring ideas were

extracted as paraphrases or quotations from the interview recordings and "coded up" (Lockyer 2004) inductively into major themes to answer the research questions. That is, the data were interpreted by the researcher for their significance to the objectives of the study, which is consistent with an exploratory and qualitative methodology (see Charmaz 2003). The process was necessarily subjective, but the methodology and subsequent interpretations and reasoning are intended to be transparent so that they remain open to scrutiny (see Hays and Singh 2012 Ch. 8). Emerging themes are summarized in the following section.

Results and Discussion

In attempting to map the influences of SPR inputs and other factors on the policy process for the selected cases, four major themes materialized from the interviews. First, it is possible for SPR inputs to have a direct and concrete effect on policy outcomes, especially through co-productive characteristics. However, this is quite rare, other factors like political interest generally playing a larger causal role. Second, while the indirect and long-term influences of SPR inputs are very difficult to measure, they are probably much more important than the direct effects. Third, co-productive relationships between science organizations and policy agencies offer several side benefits for both parties, such as shared resources for joint projects, which do not necessarily influence the policy or research direction. These side effects, like the indirect influences, also seem more important than the potential for SPRs to alter policy outcomes directly. Fourth, the cases demonstrated a number of characteristics that seemed to conflict with (normative) co-production but matter for establishing a trusting and functioning relationship to begin with. Such prerequisite attributes deserve analysis, even though they do not, by themselves, affect policy outcomes or even side benefits. This section discusses the four themes, drawing on

example quotes and paraphrases from the interviews and comparing the three cases to make tentative general conclusions about SPRs.

SPR Inputs Can Directly Influence Policy Outcomes, but This Is Quite Rare

From the three cases, the best example of direct policy influence concerns a decision made by the municipality of Castlegar based on information from PCIC. A scientist interviewed from that case said:

> One of the vulnerabilities that they identified was flooding issues from intense precipitation events, and they had a look at their existing infrastructure and realized that one of the things they could do inexpensively was to simply clean out the culverts more often, and they did that. And the following year, they had the extreme precipitation event… and because they had increased the frequency of the maintenance of the stormwater system, it was able to handle it. So it was a real success story of really going after the low-hanging fruit.

This technical use of information could only occur because PCIC had made data about climate impacts available and had established connections with various municipalities and intermediaries. More broadly, evaluations of the organization, mentioned by another participant, showed that PCIC is valuable to its policy partners primarily because it helps them prioritize which impacts to address, another technical use of information. At least two interviewed planners explicitly credited the organization's co-productive focus on users as a major factor in facilitating such successes. That is, PCIC actively seeks and responds to feedback from users of its services, acknowledges a variety of user types, and gives attention to presenting information clearly with the particular audience in mind. The PCIC case in particular, then, demonstrates that science organizations pursuing co-productive strategies can directly facilitate technical uses of information by a policy partner.

However, the Castlegar story is basically the only concrete example of direct influence from all three cases. For the most part, interviewees were very unsure about any other examples

they came up with, or had trouble coming up with examples of influence to begin with (recall Weiss 1980). Others, mostly from the policy side, were quite skeptical of the potential for SPRs to affect policy outcomes at all, even if they saw them as generally beneficial. For example, interviewees from the CFCAS case explained that, even under the previous Liberal government, Environment Canada's climate scientists did not have a direct link to policy makers and climate policy meetings were more about negotiation than considering scientific input. More specifically, one interviewee from CAS said:

> No amount of facts or evidence is going to convince a government that's not – even a government that has been a leader in the past and is kind of on pause – you're not going to convince them with an academic paper. So I think the willingness is the first necessary condition.

These accounts suggest that political factors (e.g. public opinion) are the more immediate cause of most climate policy decisions, at least in the examined cases. SPR inputs can be important, but are rarely the limiting factor, which suggests that altering the design of SPRs is unlikely to facilitate direct changes in policy outcomes.

The Indirect and Long-Term Influences of SPR Inputs Are More Important

Despite the dearth of examples suggesting direct influence, the interviewees were collectively quite positive in their assessment of the cases. They were under the general impression that SPRs are broadly helpful for "building awareness" and "mainstreaming" climate change, even though they had trouble identifying direct successes like the Castlegar story. Instead, they depended more on guesswork and supposed examples. In the PICS case, one scientist pointed out that a forum held by the organization *may* have changed the provincial government's priorities on electricity export. The CFCAS case study revealed the *possible* minor influence of a drought study *perhaps* leading to new government recommendations for farmers

about which crops to plant. In the long term, these climate policy decisions may very well have been influenced by SPRs through an indirect "enlightenment" function (recall Weiss 1977), but there is no way to measure this complex effect concretely, especially since the respondents themselves were uncertain. Still, even though indirect and long-term effects are challenging to identify, they may be far more important than the direct effects elaborated in the above section, if the general enthusiasm of the interviewees is taken to indicate underlying potential for SPRs.

Indeed, respondents managed to suggest several possibilities for long-term influence that would otherwise be difficult to measure. Regarding a briefing for government on the most recent IPCC report, hosted jointly by PICS and CAS, a representative of the latter observed:

> The effect of that wasn't that somebody went to that workshop and they had a brainstorm and they were like "okay, I get this now, I'm going to go immediately back to my desk and change something" – that didn't happen. But now we have 300 people who wouldn't have paid attention to this report who paid attention to this report. Maybe, a year and half from now, two years from now, they start working on a new policy… when they start designing something new, they have information at their disposal.

This kind of "enlightenment" function is complemented by the broader public awareness facilitated by some SPRs. Public outreach and stakeholder engagement, which are both co-productive characteristics, can establish "buy-in" and build a broader knowledge base, making it easier to act on climate change in the future. One PICS scientist explained that it is difficult for government to pursue policy directions that the public does not support, which means that it may make more sense for science organizations to inform the public rather than policy makers, influencing the decision process indirectly. This is the current strategy of CCF. Finally, a few interviewees from the provincial case reported that SPRs help to "hold the line" – that is, encourage government to stick with climate initiatives already implemented and maintain forward momentum. This means that even when SPR inputs are not the limiting factor for further policy action, it is important to preserve a science-policy link so that action can be taken when an

opportunity arises (see "coupling" and "windows" in Kingdon 1984). All of these potential long-term effects are significant, and may be worth pursuing through co-productive SPRs, even if the outcomes are unpredictable (see "exploration" versus "exploitation" in Lindquist 2009).

Effective SPRs Offer Several Side Benefits to Both Parties

The cases examined did not demonstrate much policy influence that was both substantial and measurable. However, there may be other reasons to pursue co-productive SPRs. First, consider the potential side benefits for scientists. All three cases included situations where feedback from policy makers helped scientists improve their messaging and communication skills. Recall, for instance, the focus on user feedback in the PCIC case. One PICS scientist contributed a supplementary explanation:

> Political winds change, so we pick up on that – we have to read the political tealeaves. And because we are so committed to trying to help, we need to get insight from CAS as to which direction the political winds are going at the present time and where they might be next week. So they kind of help us with that. [The head of CAS] and I will talk often and he'll say "here's where things are going from the inside view in politics" and that helps me to frame our research and we try to use the language that the politicians will understand best.

That is, talking to policy makers improves the general capacity of scientists to talk to other potential partners such as the public, different governments, and stakeholder groups. Another advantage, evident in the PCIC case, is that successful interactions can build reputation and promote further dialogue with new partners (recall Fischer and Leifeld 2015). One scientist reported that roughly half of the communities that approach the organization with a question or proposal do so because they were aware of some other project. SPRs may also provide researchers with access to government data, modelling tools, or on-the-ground research partners, as seen in the PICS and CFCAS cases. It may be reasonable, then, for science organizations to

pursue relationships with policy agencies to improve their general communication, expand their networks, and advance their research.

Second, there are a number of potential side benefits for policy makers as well (for further information, see Richards 2017). SPRs are mutual learning opportunities, so civil servants may come away with improved climate literacy and science translation skills. Municipal planners in the PCIC case reported that this helped them to talk about the issue of climate change with other relevant government departments. Another benefit, which was seen in both the PCIC and PICS cases, is that information put together by the science organizations often allowed civil servants to avoid conducting redundant research themselves, saving time and money. One of the biggest benefits for policy makers is that they can leverage the perceived neutrality of the science organization. Witness this statement from a representative of CAS:

> Another observation I would make about PICS is that they have a convening power. They can bring people together. They can bring academics, and local governments, and federal government, and provincial government, and stakeholders… whereas if we're convening something, it's the regulator convening… if they're the convenors, they have more of a neutral stance and that means we can come as participants in the same way that other people come.

Basically, this "convening power" allows the government to engage in dialogue with certain stakeholder groups that would not otherwise be inclined to do so. The PICS case also pointed to the minor benefits of shared financial resources as well as policy makers being able to indirectly access current research and academic literature. Both can facilitate joint projects (see "boundary objects" in Cash et al. 2003). Given the emphasis that interviewees placed on a variety of side benefits, SPRs are probably worth pursuing by both sides, even if actual influence on policy outcomes (or research directions) is doubtful. These benefits are more likely when co-productive characteristics, such as frequent meetings and attention to other stakeholders, are present.

Certain Prerequisite Characteristics Are Required for a SPR to Function

The final broad observation extracted from the interview responses focuses on the early stages of a SPR, prerequisites that must be met before it can function productively. That is, the focus is not on the "policy outcomes" box of the analytical framework, but on the "input characteristics" and "intermediate steps" aspects. The most obvious prerequisite requirement for a SPR is willingness on both sides. This is well illustrated by the CFCAS case, where initial funding and interest existed under the previous Liberal government, but then the relationship waned (e.g. the three seats for government representatives on the CFCAS board were generally vacant) and died (e.g. funding was not renewed) under the Conservatives. The lack of political interest caused CFCAS to rebrand itself as CCF and engage with a broader network of stakeholder groups instead, in an attempt to influence policy indirectly.

However, even when mutual interest is present, as in the PCIC and PICS cases, there are still a few initial hurdles that must be navigated to establish an effective relationship. Scientists must have their academic freedom guaranteed, or they may be unwilling to provide data and advice that conflicts with the government's current policy priorities in any way. Similarly, policy makers must be assured that the involved scientists are credible and will not cross the line into advocacy (see Cairney et al. 2016 p. 401). Basically, trust needs to be built among both parties. The following two quotations, the first from an intermediary in the PCIC case and the second from a PICS scientist, exemplify this requirement well:

> That isn't a very useful – for researchers or for scientists – that's not how policy works and it's not really a welcomed role. There are researchers who give us policy advice, sometimes advice that we solicit, and other times unsolicited advice. Solicited advice is generally considered, but the unsolicited advice typically goes nowhere. But that's not what PCIC does.

> We are fully independent. PICS does not, in any way – we do not feel the least bit of pressure or obligation politically to respond… it, in no way, compromises our independence. So if we come up with a result the government will not like to hear,

> that will not stop us from putting that result out there in front of the public. But I do make sure that everything we do is constructive.

There was a lot of sensitivity around autonomy in the responses, even though interviewees were generally optimistic about SPRs. They need to be seen as safe and mutually beneficial before they can function. In practice, this means that scientists, for example, have to restrict the information they provide to basic data and advice, rather than advocacy, so that policy makers do not see them as stepping outside of their role (recall Lindquist 1988 and Pielke 2007). Of course, there is an interesting tension between this requirement and the general logic of co-production, which privileges mutual exchange and aims to be more influential. Such complexity will be mapped out, alongside the other themes identified above, in the following section.

Theoretical Model

It is important to consider the themes extracted from the interviews in light of the initial analytical framework. Rational and technical uses of information (i.e. concrete influence) are rare policy outcomes in the context of these cases, decisions of such magnitude being influenced primarily by external political conditions and not the relationship between science and policy. On the other hand, co-productive input characteristics can certainly facilitate side benefits for both scientists and policy makers (e.g. shared resources, access to information). As well, they are perhaps capable of influencing policy outcomes in an indirect and long-term fashion (i.e. soft influence), which would qualify as an enlightenment use of information. Establishing a relationship to pursue any of these benefits, however, requires certain external conditions (e.g. mutual interest) and intermediate steps (e.g. established credibility and neutrality). In a rough sense, this brief summary realistically maps the potential influences of SPRs on policy decisions, at least in the context of these Canadian cases. In aiming to generate broader theory that might

apply to science-policy interactions around other issues in other jurisdictions, though, this section elaborates such a causal map and proposes the SPRHi model as a new theoretical structure, adding additional details from the interviews. That is, while the analytical framework is useful for contextualizing the *variety of possible* pathways from SPR inputs to policy outcomes, the new model maps out the *most important* pathways, as revealed by the case studies. It suggests that SPRs can be classified into a framework of five types based on their level of co-production: supplementary network, incidental interaction, basic partnership, interactive dialogue, and true co-production (also see Hunt and Shackley 1999 p. 147). The hierarchical organization (also see Van Kerkhoff and Lebel 2006 p. 468) reveals the potential mechanisms required for improving any given relationship. Here, each piece of the model will be presented and discussed individually (see Figure 1 for a visual outline).

Fig. 1 Graphical Overview of the Science-Policy Relationship Hierarchy (SPRHi) Model

Conditions for a Supplementary Network

A relationship with a greater diversity of participants beyond merely academic natural scientists and government policy-makers (e.g. government scientists, academic social scientists, other relevant institutions, other levels of government, other societal stakeholders, the public) is likely to have a higher degree of soft policy influence (e.g. raising awareness about the given issue, broadly educating policy actors, expanding influential coalitions, finding windows of opportunity, maintaining momentum) as the network will embody more expertise, connections, and opportunities. Messaging strategies (see "dialogue" below) can be used to recruit and connect with the various groups. This is dependent on the very existence of such participants to begin with, as well as their willingness to participate. Importantly, this causal pathway is not really part

of the "hierarchy" and can be pursued along with any of the other types of SPRs, or even when no science-policy partnership has been established; other forms of partnership (e.g. scientists plus the private sector) can still have soft influence (see issue expansion in Cobb et al. 1976 and venue shopping in Albæk et al. 2007). These do not necessarily qualify as SPRs, but are very important to recognize in the context of scientific inputs to the policy process. CCF's relationship with stakeholder groups, despite the lack of interest from the recent Conservative government, is a good example of a supplementary network.

Conditions for a Basic Science-Policy Partnership

A partnership cannot begin to function unless certain requirements are met.[6] First, the science partner must be seen as credible and neutral, such that it is worthwhile for the policy partner, which usually comprises civil servants from a government agency rather than elected politicians, to engage. Second, there must be a guarantee of protection for basic research and academic freedom, such that it is safe for the science partner to engage. This may be more likely at lower levels of government where there is less of a power dynamic at play (i.e. municipal governments are much less likely to have jurisdiction over funding or policy decisions that could affect university research). Together, these characteristics may manifest as a mutual restriction on direct advice and influence, facilitating an atmosphere of trust (also see Cairney et al. 2016 p. 401). Third, actual meetings must occur in some form. All of these characteristics are dependent on external commitment in favour of maintaining the partnership. This could come from a formal institutional obligation, general organizational culture (perhaps dependent on the level of

[6] The term "partnership" is imposed by the framework, and is somewhat arbitrary. As noted in the above section, interviewees were generally very careful when speaking about autonomy, and might not necessarily agree with describing their respective SPRs as partnerships, even if meeting the model's criteria. There is terrific diversity across cases of SPRs, and it may not be possible to develop labels that will intuitively appeal to everyone involved.

government), enthusiastic individuals on both sides, or general political interest (perhaps reacting to recent relevant events). Ultimately, there are no immediate benefits, other than symbolic ones perhaps, that directly result from meeting these prerequisites, but they do facilitate the stability and trust necessary for dialogue to occur. The CFCAS case under the previous Liberal government is a good example of a basic partnership. Relationships that do not meet the criteria for a basic partnership can be considered merely incidental interaction (e.g. the CFCAS case under the Conservatives).

Conditions for an Interactive Science-Policy Dialogue

Once a basic science-policy partnership has been established, it can become an interactive dialogue by employing co-productive strategies and characteristics: informality (i.e. contact outside of meetings, sharing information, cordial interaction), messaging (i.e. using accessible language, linking ideas together, highlighting success stories – see Richards and Carruthers Den Hoed 2018), and others (i.e. frequent meetings, shared facilitation, appointed liaisons). These characteristics facilitate cooperation, the sharing of quality information, coordination (i.e. joint projects), and general amicability, which naturally lead to side benefits for both scientists (e.g. access to government data, promotion of research, improved messaging) and policy-makers (e.g. research efficiencies, access to academic information, resource sharing, convening power, improved literacy – see Richards 2017), as well as soft policy influences (see "network" above). This pathway can, intuitively, be strengthened by the presence of competent individuals, flexible institutional structures, or constructive organizational cultures. The relationship between PICS and CAS is a good example of an interactive dialogue.

Conditions for True Science-Policy Co-Production

If a dialogue between scientists and policy-makers incorporates elements of true co-production (e.g. holding one another accountable, open to broad discussion, soliciting and accepting feedback from one another, identifying and resolving disagreement), it opens channels for direct and concrete mutual influence. This can lead to actual changes in policy (e.g. adjustments to implementation, prioritizing different issues, even official legislation), depending on the available windows, assuming there are no external logistical barriers. It may also change the direction of scientific research. The chief limitation of this pathway is that opening channels for influence inherently challenges the prerequisite trust and credibility (see "partnership" above), especially if the science organization primarily provides explicit advice rather than basic data. Thus, in order to pursue such outcomes, the relationship must be particularly secure (perhaps dependent on the level of government), involve particularly proficient individuals, or be based on particularly high political interest. Opening channels of influence will also be easier if initiated by the desire to receive, not give, feedback and advice, as it is less likely to violate trust. PCIC's relationship with municipal partners is the example closest to true co-production from the case studies, although the (direct) influence in that case is somewhat asymmetrical, being stronger in the policy-to-science direction.

Providing further context for the model, there are some external conditions that are consistently important throughout the hierarchy, but not necessarily required for any given level. These include a general government commitment to evidence-based policy; low levels of government, where trust seems easier to establish but relationships are likely to have less influence; and individuals that are both proficient at and interested in boundary work. Theoretically, any SPR (not just Canadian ones concerned with climate change) could be placed

on the hierarchy, which would imply conditions or design characteristics that need to be present in order for it to move to the next level. To demonstrate the general utility of the SPRHi model, the remainder of this section will apply it back to the cases, generating insights and recommendations that were not provided by the interviewees themselves.

In the national-level case of CFCAS/CCF, the crucial external condition of political interest was absent under the Conservatives. The organization's rebranding as CCF and renewed focus on broader networking was a reasonable reaction to this. In terms of the SPRHi model, CFCAS/CCF was unable to establish a basic partnership and thus was left with only one option for policy influence, pursing it indirectly through a supplementary network. However, the more interesting application of the model is to the CFCAS years under the Liberals. Political interest was present, so establishing a basic partnership was possible, but the relationship failed to go any further. CFCAS was not particularly interested in policy influence at that point and thus did not employ any co-productive strategies. The SPRHi model suggests that this was a wasted opportunity; political interest is fleeting and so it must be leveraged when it is present (see "windows" in Kingdon 1984), which could result in a more permanent and productive partnership. One lesson for SPRs in general, then, is that political interest is difficult to predict and should not be taken for granted. The shift from a basic partnership to an interactive dialogue is almost entirely dependent on co-productive strategies and characteristics that can be controlled by either side, so there is little reason to stop at the level of a basic partnership, unless the relationship is just being established. Also, since the federal government recently shifted back to Liberal rule, CCF should again try to establish a basic partnership, while maintaining its supplementary network.[7]

[7] This analysis also suggests that science organizations wishing to engage with the policy process may choose between two essential strategies: "influence from within" – partnering with a willing government agency to

Turning to the provincial-level case of PICS, the existing SPR certainly qualifies as an interactive dialogue, given the level of interest on both sides, the established mutual trust, and the co-productive characteristics that are present. Interactive improvements, such as appointing official liaisons and holding broader meetings between government and academia, could facilitate further side benefits and soft influences, according to the SPRHi model, but interviewees made this observation on their own. Far more interestingly, the model implies that the PICS case has not yet approached true co-production; direct mutual influence is highly constrained, even though the partners are ostensibly open to feedback from one another. As the model states, opening channels of influence naturally challenges the trust and credibility that were necessary to establish a basic partnership. For example, if PICS were no longer seen as independent from the government, how could it lend its convening power to joint events? Because of this tension, any changes should be approached slowly and carefully, perhaps through meetings which, at first, encourage feedback only slightly franker than usual. Proposing such discussions will probably be received more positively if centred on the desire to receive feedback or mutually exchange feedback rather than the desire to give feedback. This respects the other side's autonomy, regardless of which side is the initiator.

As for the municipal-level case of PCIC, it was the most positively evaluated by its associated interviewees and reaches the highest level in the SPRHi model, being the only case with a concrete example of policy influence. It is thus quite difficult to make suggestions for improvement. The interviewees did not identify any glaring deficiencies, and any recommendations they made were generally already being pursued by the organization or its

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influence policy directly – or "influence from without" – cooperating with a coalition or broader network, and perhaps being openly critical of government, to influence policy indirectly (also see Coreau 2017 pp. 4-7). These may be mutually exclusive, however, as it is difficult to establish trust for a partnership after public criticism.

partners, at least informally. The SPRHi model can interrogate the status quo a little more deeply, however. Although the PCIC case roughly qualifies as true co-production, the channel of direct influence operates primarily in one direction; scientists solicit and incorporate feedback from users, but avoid giving much policy advice in return, focusing instead on basic data. This is not to say that the scientists lack the capacity to give useful policy advice, but that they deliberately refrain from stating it outright to maintain an air of neutrality. Hence, there is some potential for improved co-production. The challenge is that, as in the PICS case, shifting to a mutual exchange could undermine the prerequisite credibility and perceived neutrality of the organization. Attempting change by communicating a desire to receive feedback is not an option for PCIC scientists, because they are already doing that. Perhaps they could simply ask, after all the basic data has been communicated, if planners would like to hear their opinions or advice on possible priorities or potential actions for the given community. This would be a shift from the role of "science arbiter" toward that of "honest broker" (see Pielke 2007). The SPRHi model, then, helps prescribe courses of action for SPRs, or at least explains why improvement may not be possible in given cases, due to the presence or absence of certain given conditions.

Conclusion

This article started from the premise that many causal elements affect possibilities for political change. It sought to map out the realistic potential of SPR inputs to influence policy outcomes as part of the mix, using the analytical framework as a guide. Interviews with scientists and policy makers involved in three cases of SPRs (i.e. PCIC, PICS, CFCAS) demonstrated that such inputs, even if co-productive, are unlikely to have a concrete effect by themselves. Rather, they are only one part of a constellation of causes that must come together to facilitate major

change (see Kingdon 1984), as demonstrated by this summative quote from a municipal planner in the PCIC case:

> A few things lined up for us – pine beetles, snow management, [an interested university researcher]… I was available. I had a budget… [a regional partnership] came along at the right time. We were ready because we already had an adaptation plan, so we could roll right into that. The [sustainability plan] was happening… and our [official community plan] was updating. All of that just fit into place one thing after another, so it was kind of luck, in a way, that worked out the way it did for us… It wasn't something that was front and centre.

However, co-productive inputs can, on their own, help to facilitate side benefits and soft policy influences; the latter may be difficult to measure but that does not mean they are unimportant. In addition, certain external conditions are necessary to establish basic science-policy partnerships and may be a crucial factor in achieving true co-production without undermining foundational trust. Regardless of given political factors, science organizations can always pursue soft influences through broader supplementary networks. This overall understanding (i.e. the SPRHi model) should be applicable to SPRs generally, even thought it was developed around the issue of climate change in Canada. Its application in other cases may lead not only to fresh insights for those situations (acknowledging, of course, the unique nature of each distinct jurisdiction and issue) but also a refined understanding of the model itself (see Veselý 2017).

This article makes several contributions to the broader literature. First, it adopts a more holistic view of the various causes and effects within science-policy interfaces. This allows it to propose the more sophisticated pathways of the SPRHi model, in comparison to the relatively narrow processes in existing works (e.g. Rietig 2014). Second, it demonstrates the importance of political conditions and other external causal factors to the "optimistic" literature, which often seems to assume that altering scientific inputs will lead to direct changes in policy outcomes (e.g. Cash et al. 2002). However, this does not warrant a simple conclusion that merely declares the research utilization literature to have the more accurate understanding of how science influences

policy. Rather, the third contribution is illustrating that policy change is not the only relevant outcome; the co-productive characteristics and strategies suggested by the "optimistic" and STS literature can result in very important side benefits, even if they do not have a direct influence on policy. Altogether, the SPRHi model attempts to bring the relevant literatures together and offer a more comprehensive understanding.

The focus on climate change and Canada was also important for facilitating this article's contribution. Climate change is a particularly complex policy problem (see the introduction and recall Weible 2008), for which genuine political interest is often insufficient. This forced the model to make allowances for SPRs that were not particularly close or collaborative, and for many outcomes, benefits, and goals besides direct influence on policy action. Canada's political landscape highlighted the evolving strategies and functions of SPRs under changing governments (e.g. the shift to a "supplementary network" strategy in the national case) and priorities (e.g. the "holding the line" function in the provincial case). In this sense, the *specifics* of the problem and cases selected for analysis helped inform the *generality* of the resulting theoretical understanding.

But what does this article contribute to the actual problem of insufficient climate policy outcomes in Canada and globally? What can the findings offer in terms of facilitating action on climate change? Despite the SPRHi model's capability to suggest potential improvements for individual climate SPRs, these cannot be presented as a solution to the broader issue. One of the main findings of this article was that external political conditions matter greatly – changing the design of relationships between science organizations and policy agencies will have little impact on the core of the problem, which is insufficient political interest and public support for climate action. Over the long term, soft policy influences may be very important and are certainly worth pursuing through co-productive strategies, but their contribution is unpredictable and difficult to measure. Perhaps the most appropriate approach for influence-oriented scientists (and civil

servants) is to acknowledge that political interest fluctuates, plan to exploit it when it peaks, and get all the necessary connections and information together in preparation. Indeed, the recent return of the Liberals to power in the federal government may present just such an opportunity, if scientists and civil servants employ the right co-productive strategies (see "policy entrepreneurs" in Kingdon 1984).

Compliance with Ethical Standards

The process of recruiting and interviewing participants was approved by the research ethics board of the host university.

Disclosure of Potential Conflicts of Interest

The author declares that there are no known conflicts of interest.

Appendix: List of Guiding Interview Topics Sent to Potential Participants

1. Introduction:
   -Please take a brief moment to introduce yourself, your position, and your background.
   -Briefly describe the given 'science-policy relationship' (SPR) and surrounding institution(s).

2. What are the specific (design) characteristics of the SPR?
   -What is its history?
   -Who participates? How diverse are the participants? How consistent?
   -How often does communication occur?
   -How much focus is put on back-and-forth discussion versus information dissemination?
   -Who facilitates the interaction (e.g. runs meetings)? Is this a shared responsibility?
   -In what ways are the participating groups accountable to one another?
   -How close is the relationship between the participating groups? Is it positive?

3. What does it achieve in practice? What are the associated successes or challenges?
   -To what extent does the SPR achieve goals set out for it (and goals of the institution)?
   -How frequently does interaction result in plans being made or 'action items' being declared?
   -How is communicated information generally used by the groups that receive it?
   -In what ways do you, personally, benefit from this SPR?
   -More broadly, are climate policy actions taken by this jurisdiction sufficient and effective?
      -How often do scientific findings appear to be the main reason for such action?
   -What other successes or challenges are associated with the SPR and institution?

4. How are the identified successes and challenges tied to design of the SPR or institution?
   -*For each one*, what is the likely cause? Above aspect of design? Another factor? Unknown?

5. What alternative institutional arrangements or SPR designs might be considered?
   -What are the main design changes that could address the identified shortcomings?
   -What sorts of difficulties might be encountered in bringing about these changes?
   -How might other jurisdictions or SPRs change to realize the same identified successes?

6. Conclusion:
   -What role does the public play in this SPR and institution? Should it be involved?
   -In what ways is climate policy action in this jurisdiction connected to other jurisdictions?
   -Broadly, how effectively do you think climate science is translated into policy action?
   -Overall, what is needed to ensure a productive translation?
   -Do you want to add anything else? Further elaborate on any earlier answers?

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