Information Exchange Networks at the Climate Science-Policy Interface: Evidence from the Czech Republic, Finland, Ireland and Portugal

Abstract: Scientifically informed climate policymaking starts with the exchange of credible, salient and legitimate scientific information between scientists and policymakers. It is therefore important to understand what explains the exchange of scientific information in national climate policymaking processes. This paper applies exponential random graph models to network data from the Czech Republic, Finland, Ireland and Portugal to investigate which types of organisations are favoured sources of scientific information and whether actors obtain scientific information from those with similar beliefs as their own. Results show that scientific organisations are favoured sources in all countries, while only in the Czech Republic do actors obtain scientific information from those with similar policy beliefs. These findings suggest that actors involved in climate policymaking mostly look to scientific organisations for information, but that in polarized contexts where there is a presence of influential denialists overcoming biased information exchange is a challenge.

Keywords: Climate Change; Policy Networks; ERGM, Science-Policy Interface

Introduction

Despite the overwhelming scientific consensus that anthropogenic climate change is a serious problem that requires urgent and sustained policy action at all levels of government there remains a significant science-policy gap: governments are not enacting measures commensurate with the significance of the problem. Addressing climate change is made difficult by the inherent uncertainty of scientific research, the presence of competing producers of information seeking to define problems and influence decisions, and poor communication between scientists and policymakers (Bradshaw and Borchers 2000; Holmes and Clark 2008; Spruijt et al. 2014; Van den Hove 2007). In some cases where scientific information has had a limited influence on policy it has been attributed to the failure of policymakers to draw on the best available evidence (Sharman and Holmes 2010; Soomai, MacDonald, and Wells 2013). No wonder then that the United Nations has ranked reconnecting science and policy as fourth of 21 priority issues for the 21st century (UNEP, 2012).

The science-policy interface encompasses the ways in which scientific organisations, public authorities and other actors involved in policymaking produce, acquire and use scientific information to understand a problem, design policies and influence decision-making (Kettle, Trainor, and Loring 2017). The science-policy interface starts with the flows of scientific information between its producers and its users (van den Hove 2007; Liverani, Hawkins, and Parkhurst 2013). Policymaking uninformed by scientific evidence has been attributed to poor information flow at the science-policy interface (Dicks, Walsh, and Sutherland 2014; Soomai, MacDonald, and Wells 2013). The spread of useful information can be impeded by inadequate coordination (Holmes and Clark 2008) and be undermined by the presence of competing information (Runhaar and van Nieuwaal 2010). Scientific evidence is more likely to lead to good policy when it is exchanged effectively (Cvitanovic et al. 2015; Ranchod and Vas 2019), although this is not guaranteed (Cash *et al.*, 2003). Gaining an understanding of the dynamics of the interactions between science producers and its users is therefore the first step in improving the science-policy interface (Sarkki et al. 2015).

High quality scientific information explicitly acknowledges uncertainty and is produced using replicable processes of observation, experimentation and analysis. Scientific information, however, is not the only type of evidence that informs policy and policymakers do not have to prefer it over other evidence (Cairney 2016). Any information that supports or contradicts an assertion can be considered by policymakers as evidence, including that which is anecdotal or circumstantial. Thus, for scientific evidence to have an influence over policy it is not enough for it to just be available (supplied), it also needs to be in demand (Runhaar and van Nieuwaal 2010). The abundance and the variability in the quality of the information available about climate change makes it difficult for policy actors to screen out that which is unreliable or inaccurate. This is further amplified by the involvement of different types of organisations that supply information and that rely on different processes of information production. Policy actors might choose to obtain scientific information from *Scientific Organisations* because they believe that these actors are producing high-quality information. They might turn to *Public Authorities* because of their central role in the policy process or decide to seek information from *Information Producers*, such as think tanks, because they believe that these actors produce information of value that is unavailable elsewhere. This paper investigates which, if any, of these three types of organisations are favoured sources of scientific information in national climate policy processes. This is important because the information that flows among policy actors can influence policy (Soomai, MacDonald, and Wells 2013).

Because the foundation of the climate science policy interface is based on the information exchange relations among those that produce and those that rely on scientific information we can use network analysis to analyse the structure of these relations. This enables us to see how actors access and shape the science-policy interface as a field of power (Chilvers and Evans 2009). We apply exponential random graph models (ERGMs) to data from the Czech Republic, Finland, Ireland and Portugal to answer the following question:

(i) Which actor types are favoured sources of scientific information in national climate policymaking processes?

Beliefs have repeatedly been shown to influence the formation of relationships among actors in policy processes (Henry, Lubell, and McCoy 2011; James and Christopoulos 2018; König and Brauninger 1998; Matti and Sandström 2011). Biased assimilation among actors with similar beliefs occurs when actors are inclined to accept confirming information, while being critical of information that contradicts their beliefs. We therefore also investigate if actors involved in national climate change policymaking obtain scientific information from those with similar beliefs to their own.

(ii) Do actors obtain scientific information from those with similar beliefs to their own?

Results show that scientific organisations are favoured sources of information in all four countries, while public authorities and information producers are not. Only in the Czech Republic do actors obtain scientific information from those with which they share similar policy beliefs. This reflects the highly polarized nature of Czech climate politics and the presence of influential denialists. Focusing on the science-policy interface with the help of network analysis enables us to reveal the structures that shape the flow of information and which are likely to have an influence on national climate policymaking.

In what follows, we begin by introducing policy network analysis and by explaining how the approach can be used to examine the information exchange relationships among actors involved in a policymaking process. We then develop a series of hypotheses drawn from the policy studies literature. Following this, we describe our four cases, our data and methods, and present the results of our analysis. We conclude by discussing our findings and by making suggestions as to how scientific organisations might improve a country's response to climate change.

Theoretical Framework and Hypotheses

Addressing climate change is a process in which debates over the science and the possible responses are continuously deliberated among actors from across multiple sectors of society. When these actors engage with one another by creating different types of relationships they form a climate change policy network. Policy networks are meso-level social structures consisting of a configuration of social relations among interdependent actors, which form around policy problems. They are composed of the horizontal and vertical integration of actors' relationships that have developed over time (Bolleyer and Börzel 2010). Participation can be based on trust, obligation or self-interest, with policy decisions being made following the processes of learning, cooperation, collaboration, competition and negotiation. Policy networks are widely recognized as having an influence on the dynamics of the policymaking process and on policy outcomes (Knoke et al., 1996; Laumann & Knoke, 1987), and when well-structured they can be more effective at addressing environmental problems than formal institutions (Scholz and Wang 2006).

Policy networks can be observed, measured and analysed using theories and methods from the field of network analysis (Victor et al., 2017). Network analysis can be used to define the boundaries of a policy subsystem and to locate its participants, to map the structure of the relationships among them and to gain an understanding of how power is distributed (Muñoz-Erickson and Cutts 2016). This includes also network self-organization (endogeneous) processes where no attribute (exogeneous) variables, such as policy beliefs or actor type, may be necessesary to explain the observed network structure (c.f. Rivera, Soderstrom, and Uzzi 2010). For instance, a relationship between actors *i* and *j* can be a result of reciprocation where a sent tie from *i* is enough to motivate *j* to send tie back regardless of the actors' attributes such as policy beliefs. Using network methods, researchers can gain insights into the roles that different actors play, examine how subsets of actors interact and engage with one another as well as determine how they are organised and integrated into the network, while controlling both for actors' attributes and network self-organization (Gerber, Henry, and Lubell 2013; Henry 2011; Ingold and Leifeld 2016).

The complex web of interactions that characterize the exchange of scientific information among policy actors in a national climate policymaking process is a networked phenomenon. The network is formed by the public authorities, scientific organisations and other actors involved in the policy process and the exchange relationships among them, with the information being exchanged ranging from that which is scientifically rigorous to that which is not. Understanding the relative importance of different types of organisations as sources of information in a policy process and the extent to which actors' existing beliefs determine their attitude to scientific information are important because both can influence policy decisions (Soomai, MacDonald, and Wells 2013). In what follows, we develop hypotheses concerning different types of organisations as sources of scientific information in national climate policymaking processes, and present the belief homophily hypothesis (Henry, Lubell, and McCoy 2011).

Sources of Scientific Information

Some of the most well-known theories of the policy process have emphasized the importance of expert-based information in policymaking (Weible 2008). According to the Multiple Streams Framework, scientific information is sought out by policy entrepreneurs to identify problems and solutions as well as to help shape agendas and policy choices (Zahariadis, 2007). Punctuated equilibrium theory (Baumgartner and Jones 1993) argues that actors wishing to spur rapid and deep policy change will rely on scientific information to challenge the status quo and to incentive others to work with them for change. The advocacy coalition framework (Sabatier and Jenkins-Smith 2007) claims that actors in coalitions obtain information from scientific experts to deepen their knowledge and to strengthen their arguments when proposing ideas or when challenging their political opponents. The evidence-based policymaking perspective presumes a direct and unproblematic relationship between scientific evidence and policy designs and outcomes (Cairney, 2016). The common assumption in all these theories is that policy actors seek out scientific information from the organisations that are the most likely to produce credible and legitimate information. Scientists working at universities, research institutes, research-

orientated higher education institutions, and government funded research institutions are the most likely to be producing this type of information. We present the following hypothesis:

H1: Scientific organisations are favoured sources of scientific information

Scientific organisations are only one of many actor types with knowledge on matters concerning climate change. In particular, public authorities are often key sources of information in policymaking (Fischer, Ingold, and Ivanova 2017; May, Koski, and Stramp 2016). Public authorities (i.e. government departments, administrative agencies, and political parties) are likely to have different attitudes toward scientific uncertainty to those working at scientific organisations. Researchers working within public authorities do not only have fealty to the scientific community but also to the government of the day, whose policy choices they may be required to justify or defend (Bradshaw & Borchers, 2000). The information produced by public authorities is likely to be particularly salient as it feeds into policy documents, decisions and pathways. We test the following hypothesis:

H2: Public authorities are favoured sources of scientific information

Researchers working for public authorities may have an incentive to conceal uncertainties from the public out of a fear of diminishing their credibility or of reducing public support for government policies. This may cause policy actors to see inadequacies in the research that they produce, which, in turn, can lead them to rely on other sources besides scientific organisations or public authorities for scientific information, such as professional associations, advocacy groups, think tanks and companies that produce research for profit (May, Koski, and Stramp 2016). We label these actors *Information Producers*. The bureaucratic monopoly of expertise on matters related to a particular policy issue or subsystem has been weakened by the growth of these actors. In cases where these actors are issue advocates (Pielke 2007), the information that they produce may lack legitimacy

and credibility (Cash et al. 2003). Policy actors may turn to these organisations for information if they do not trust scientific organisations or public authorties, if they are seeking out information that undermines the scientific consensus, if it supports their own views or because they can use it to further their own interests. We present the following hypothesis:

H3: Information producers are favoured sources of scientific information

Belief Homophily

The presence of ties among actors with similar policy beliefs is a recurring finding in the policy networks literature (Fischer and Sciarini 2016; Henry 2011). The phenomenon is observed as a systematic bias in how and from where actors obtain information (Henry, Lubell, and McCoy 2011). This bias can occur because actors prefer to draw on information that supports their views rather than undermining them (Jasny et al. 2018) and or because they prefer to work with those with whom they agree. Having close relationships with like-minded actors can also be a sign of political advocacy since coalitions are known to coalesce around similar beliefs (Sabatier & Jenkins-Smith 2007). If actors are relying on those with similar beliefs to their own for scientific information it may indicate the presence of competing actors with conflicting values and interests, which is likely to undermine evidence-based policymaking.

Missing from previous studies investigating how beliefs are associated with network ties is an examination of the relationship between actors' beliefs about science and of those of the actors from which they obtain scientific information. Understanding this relationship in climate politics is important, especially given how climate science has been politicised or caused political polarisation (McCright and Dunlap 2011a; McCright and Dunlap 2011b; McCright, Dunlap, and Marquart-Pyatt 2016). Organisations that benefit from the status quo have an incentive to disregard credible and legitimate research showing human influence on the climate, which may lead them to rely on scientific information that lends credence to their pre-existing climate sceptic beliefs or denialism. On the other

hand, those alarmed by scientific projections predicting detrimental impacts on human and natural systems due to anthropogenic climate change may rely on research findings that conclude that more drastic policy action is required. These arguments are in line with recent research that has suggested that actors in conflictual policy subsystems are more likely to form relationships based on shared beliefs (Weible, Heikkila, and Pierce 2018). By examining the association between network ties and both science and policy beliefs, this paper builds on previous policy networks research that has focused on technical and political beliefs (Fischer, Ingold, and Ivanova 2017; Leifeld and Schneider 2012).

H4a: Actors are more likely to obtain scientific information from those with whom they share more similar policy beliefs

H4b: Actors are more likely to obtain scientific information from those with whom they share more similar scientific beliefs

Cases, Data and Methods

Country Case Descriptions

We take a comparative approach to analysing information exchange networks at the climate science-policy interface. The study analyses four EU countries: Czech Republic, Ireland, Finland, and Portugal. Our case countries are all relatively small EU unitary democracies with a high level of human development.

The Czech Republic is a predominantly consensual parliamentary democracy characterized by a bicameral parliament, multiparty system, and prevailing practice of executive power-sharing in coalition governments (Hloušek & Kopeček 2002). The country's climate change policy over the past decade is the weakest of our case countries, with a mean ranking of 28th (2009-2019) on the Germanwatch Climate Change Performance Index (CCPI) (Germanwatch 2018). The country's response to climate change has been crucially influenced by a transition process that followed the fall of the communist regime in 1989 (Vlček & Černoch 2019). The economic transformation brought a rapid

decline of heavy industry that will allow the country to achieve its EU2020 emissions reduction targets (EEA 2016) and to meet the climate targets under the EU's 2030 climate & energy framework without substantial policy changes (MZP 2017; EEA 2018a). However, the Czech Republic ranks, with its low energy efficient industry and coal-dependent economy (IEA 2016), as the fourth highest CO2 emitter per capita in the EU (EEA 2018b). The climate policy subsystem is highly contentious and centres on key energy-related issues of coal phase-out, nuclear energy expansion, and failed support for renewables (Vlček & Černoch 2019). Energy industry incumbents exert a powerful influence over national climate policy (Ocelík et al. 2019). The public view on climate change is more sceptical than the European average, with only 38.9% of the population believing that the climate is definitely changing and 37.3% believing that human activity is the main cause (EVS, 2018).

Finland is a Nordic consensual corporatist democracy, where broad coalition governments are the norm, and tripartite negotiations between business, labour and the state influence policymaking in many areas. Its climate policy over the years has not been as ambitious as other European countries. It's mean rank on the CCPI over the past decade is 27th. Finland's climate change policy has been strongly conditioned by its energy policy, under the mandate of the Ministry of Economy and Employment. The national economy is dependent on energy-intensive export industries such as steel, machinery and paper. At 11.1 tonnes per capita, Finland's emissions are markedly higher than the EU average (7.8t) (EEA 2018b). In this context with strong tripartite institutions and an energy-intensive economy, business and labour peak organisations and the largest political parties have long held a relatively consensual view that economic growth should be prioritized over climate change mitigation. However, there is a coalition of environmental organisations, green and left political parties that are challenging the prevailing consensus (Gronow & Ylä-Anttila, 2016), as well as some recent changes in policy direction, such as the 2015 Climate Change Act and a pledge (non-binding) by the government in 2019 that the country would be carbon neutral by 2035. Finland has risen to 10th place in the 2019 Germanwatch index. Climate science deniers are extremely marginal in all public and policy debates. The long-

term weakness of Finland's climate change policy, thus, seems not to be driven by doubts of whether climate change is real and anthropogenic but rather, by political and economic power structures that change very slowly.

Ireland is a highly centralised Westminster-style parliamentary democracy in which executive power is usually concentrated in the hands of single-party-majority cabinets. Ireland's mean rank on the CCPI over the past decade is 19th. However, in the past few years the country has markedly fallen in the rankings, placing 48th in 2019 as the worst ranking country in Europe (Germanwatch 2018). Without a radical change in the breadth, the depth and the urgency of its response to climate change, Ireland will fail to meet its EU renewable energy targets (European Commission, 2017), its EU2020 emissions reduction targets (EPA, 2017) and its targets under the EU's 2030 climate & energy framework. The country has been labelled a climate laggard by both the Irish Taoiseach and by academics (Little & Torney, 2017). The Climate Action Plan 2019 may herald the start of Ireland taking the problem seriously. The climate policy subsystem is particularly contentious, with many actors disagreeing on significant policy issues (Wagner & Ylä-Anttila, 2018a) and failing to learn from those with beliefs dissimilar to their own (Wagner & Ylä-Anttila, 2018b). Actors representing the country's business interests, the agricultural sector in particular, have had a disproportionate level of influence on the country's past climate policy choices. 69% of the public and 92% of scientists believe that the earth is warming due to climate change, while 68% of the public and 92% of the scientists agree that climate change is mostly due to human activity (Amárach Research, 2017).

Portugal is a parliamentary democracy, in which the main centre-right and centre-left parties alternate in government, either alone or in coalition with similar-minded parties. Portugal has consistently been a strong performer in climate change policy over the past decade, with an average ranking of 10th in the CCPI. There is a widespread political consensus on climate change, although when it comes to political decisions, economic interests usually trump environmental considerations. The country's climate policies began the turn towards the current level of ambition in 2006, when the threat of having to pay for emissions under the EU's Emissions Trading System pushed the

government into action. Renewable energy policies have been the most successful: the country achieved 28.5% of renewables in gross final energy consumption in 2016, with a 2020 target of 31%. Recent developments include the creation of the Ministry for Environment and Climate Action, the publication of the Roadmap for Carbon Neutrality 2050 and the National Integrated Energy and Climate Plan, all of which saw the light of day in 2018 and had a strong contribution from scientists. Earlier, in 2015-2016, twenty-six Municipal Strategies for Adaptation to Climate Change were designed through an intensive participative process (Schmidt et al 2018). Climate change denial in Portugal is rare; only 3% of the population doubts that the climate is changing, 6% believes it has mainly natural causes and only 12% are not worried. The Portuguese are among the most worried about climate change in Europe (87%) (ESS 2018).

Data

We used a survey instrument designed for the Comparing Climate Change Policy Networks (COMPON) research project to collect data from the organisations in the four national climate policy networks. Data covers respondents' beliefs about the science of climate change, their policy preferences and their network interactions. In Portugal, policy actors were identified in an analysis of the coverage of climate change in national newspapers (Horta, Carvalho and Schmidt 2017). The actors in the other three national networks were identified using Laumann et al.'s (1983) decisional, positional, and reputational approach. An actor meets the decisional criterion when they participate in the making or the influencing of policymaking. They meet the positional criterion if they hold a key role in the political subsystem, this includes political parties, government departments, state bodies, and other significant economic, social and political non-state actors. Actors meet the reputational criterion when they are known to be influential by experts with a knowledge of the subsystem. For example, In Ireland we identified scientific actors by consulting with a climate policy expert at the Irish Environmental Protection Agency, an ex-special advisor to the Taoiseach and a leading climate scientist at University College

Dublin. Information about each country's climate change network and the response rates are presented in Table 1. Non-respondents are excluded from our analysis.

Table 1 about here

We collected two types of relational data: the source of science network and the collaboration network. In each country, the questionnaire listed all the actors that were identified as being in the national climate policy network and asked respondents to identify organisations (i) from which they sourced scientific information, and (ii) with which they collaborated with regularly.

We collected data on organisations' beliefs about climate science by asking respondents to indicate on a five-point Likert scale (No, totally reject = 1, Neutral = 3, Strongly agree = 5) their response to the following statements (i) Climate change is currently occurring, (ii) Human activities are an important driver of current climate change, and (iii) climate change science is still too uncertain to be a basis for policy. We collected data on policy beliefs by asking respondents to indicate on the same five-point Likert scale their opinion of 13 different climate policy issues (see supplementary materials).

Scientific organisations in our analysis are universities, research institutes, research-orientated higher education institutions, and government funded research institutions. Public Authorities in the networks are the national political parties and the government departments and administrative agencies involved in national climate policy. Information producers are all the other actors in the network that informed us in their response to our questionnaire that they often engaged in scientific/technical analysis (specifically, in data analysis, policy analysis, or the production of research documents). It may be worth noting here that our research design looks at information flow between all actors in the network - not just where the public authorities with the most responsibilty for making policy decisions get their information. This choice enables us to use Exponential-family random graph models (ERGMs) to understand the dynamics of the entire network, and refrain from

making complex qualitative judgements concerning the relative power of different public authorities in the climate policy processes of the different countries.

Methods

The formation of scientific information exchange ties among actors in a policy network are not only shaped by actors' attributes and beliefs but also by the ties between other network actors. This means that when trying to explain information exchange behaviour in a policy network it is necessary to use an approach that accounts for relational dependencies. ERGMs are statistical network models that take the relationships among actors in a network as the dependent variable and which enable researchers to try to explain the mechanisms that generate a network's structure (Goodreau et al, 2008). ERGMs allow an evaluation of the extent to which a network is a function of covariates, dyadic variables (edge covariates) and endogenous network sub-structures. A well-specified ERGM includes exogenous covariates and endogenous network variables that work together to generate a network that is isomorphically similar to the observed network (i.e. the dependent variable). We run our models using the ergm package from the Statnet suite of packages available for the statistical programming language R (Goodreau et al., 2008).

Models

The dependent variables in our models are the source of science networks of the four countries. We use the responses to the survey question that asked each respondent to inform us from which other organisations they obtain scientific information to construct $n \times n$ adjacency matrices that map the information exchange relationships in each of the case countries. The rows and columns in the matrices are the actors in the networks, with the presence or absence of ties encoded using binary elements.

We test the hypotheses that specific types of organisations (H1: Scientific Organisations, H2: Public Authorities, and H3: Information Producers) are favoured sources of scientific information by investigating if these actors receive more incoming ties (i.e. others indicate that they are sources of scientific information) than would occur by

chance. We test the hypothesis that actors are more likely to seek scientific information from those with whom they share similar policy beliefs (H4a) with an edge covariate variable created using respondents' opinions of the 13 climate policy ideas. We use the responses to create a dissimilarity matrix that contains the Manhattan distance between the preferences of each pair of actors. We then subtract each dissimilarity value from the maximum dissimilarity value to create an undirected and valued matrix that represents in a quantitative form the similarity in the preferences of each pair of actors (Leifeld and Schneider, 2012). The larger the value in a cell *ij*, the more similar the policy beliefs of the pair of actors *ij*. To test the science beliefs hypothesis (H4b) we transformed the scientific beliefs data using the same method and include the resulting matrix as an edge covariate in our models.

We include a control for existing collaboration ties with a variable constructed using the collaboration network data. We convert each country's collaboration data into *n x n* adjacency matrices, where the rows and columns are the actors in the networks and where each cell *i,j* contains the value 1 if actor *i* claimed to collaborate with actor *j* and a 0 if they did not.

We include several endogenous network variables in our models. The first of these is the edge statistic, which represents the baseline propensity for scientific information exchange ties to be formed. Next, we include a mutual term to capture the likelihood that pairs of actors will exchange scientific information. We include the geometrically weighted edgewise shared partner (GWESP) term (Hunter, 2007) to model the presence of triadic closure. This variable captures how frequently two directly connected actors are also indirectly connected to one another through a third actor. We include the geometrically weighted dyad-wise shared partner (GWDSP) statistic to capture the presence of configurations where actor i and actor *j* are both connected to actor *k*, regardless of whether *i* and *j* are connected to each other (Hunter, 2007). We include the geometrically weighted in-degree (gwidegree) term and the geometrically weighted out-degree (gwodegree) to account for the distribution of incoming and outgoing information ties in the networks.

Results

Survey results show that the vast majority of the actors in each of the countries believes in anthropogenic climate change and supports a broad range of different climate policy ideas (supplementary materials). The overwhelming majority of actors in Finland, Ireland and Portugal believe that human activities are an important driver of climate change and that the science is not too uncertain to be a basis for policy (supplementary materials). The Czech Republic differs in that over a quarter of respondents agreed that climate science was too uncertain to be a basis for policy.

Table 2 presents our ERGMs results. We find that scientific organisations are favoured sources of information in all countries (*H1*), and that public authorities (*H2*) and information producers (H3) are not favoured sources anywhere. We omit the information producers hypothesis from the Portuguese model as it does not converge on a reliable estimate because there are too few of these actors in the network.

Table 2 here

The Czech Republic is the only country in which actors are likely to obtain scientific information from those with policy beliefs similar to their own (H4a: *Policy beliefs*). There is no relationship between actors' scientific beliefs and their network ties in any country (H4b: Scientific beliefs). As expected, policy actors in all countries are likely to collaborate with the actors from which they obtain scientific information.

The edge terms are comparable to the constant term in other statistical models. The mutual term is only positive and significant in Finland. It is negative and significant in Portugal, implying that scientific information is exchanged less than would occur by chance. In all countries the GWESP statistic is positive and significant. The GWDSP statistic is negative and significant in the Czech Republic, Ireland, and Portugal. We exclude the term from the Finnish model as it inhibits model convergence. The significant GWESP results indicate that pairs of actors that are connected because at least one of them obtains scientific information from the other are more likely than chance to have multiple

shared partners, where these partners are either provided with or named as a source of scientific information. The GWDSP results indicate that when neither actor in a pair obtains scientific information from the other then they are unlikely to obtain scientific information from the same third actor (or for either of them to be named by a third actor as a source of scientific information). Interpreted together, these results suggest that the actors in these three countries are more likely to have patterns of science information exchange ties that close triads than they are to have patterns of ties that leave them open.

The gwidegree term is negative and significant in Finland and Ireland, indicating that most of the actors in these countries have a similar number of incoming ties. In the Czech Republic and Portugal the estimate is insignificant. The gwodegree term is negative and significant in the Czech Republic, Ireland and Portugal, implying that most of the actors in these countries have a similar number of outgoing ties. The term is excluded from the Finnish model as it also inhibits model convergence.

We maximize model fit for the Finnish data by including a term to capture intransitive triads and two receiver effect terms for two actors that are favoured sources of science but are not a scientific organisation, a public authority or an information producer. The two actors are Suomen Tuulivoimayhdistys ry (The Finnish Wind Power Association) and Teknologiateollisuus ry (Technology Industries Association). They are most likely named as sources of information by many actors due to their specialised techno-scientific expertise. The negative and significant estimate for the intransitive term combined with the positive estimate for gwesp term indicates that Finnish actors tend to close triads and avoid leaving them open.

Discussion and Conclusion

How information is used in policymaking is shaped by the actors involved, how they are connected and the dynamics of their relationships (Oliver and Faul 2018). The structure of the networked relationships among policy actors shapes the flow of information between them (van Kerkhoff and Lebel 2006), which, in turn, has an influence on policy decisions (Soomai, MacDonald, and Wells 2013). The first step in understanding how information

shapes policy involves ascertaining from where actors source information and determining which factors lead them to rely on particular sources for information. The objectives of this paper have been to determine if scientific organisations, public authorities and information producers are favoured sources of scientific information and to establish if policy actors obtain information from those with similar beliefs to their own.

Results show that scientific organisations are favoured sources of information in all four countries and that public authorities and information producers are not. This is positive in the sense that the most salient scientific information in all four countries comes from the organisations most likely to be producing credible and legitimate information. As the effects of climate change become more apparent and governments face more pressure to act, it is important that the lines of communication between scientific organisations and policymakers remain open if the science-policy gap is to be bridged. If they are not, opportunities for other less neutral actors to fill the void will open-up.

Only Czech policy actors are found to obtain scientific information from those with similar policy beliefs to their own, whereas scientific beliefs are not associated with information exchange ties anywhere. A relatively high share of Czech actors (over a quarter) also agreed that climate science was too uncertain to be a basis for policy. This is indicative of the high level of conflict in the country's national climate policy subsystem. Previous research has found two competing coalitions in the subsystem and a significant presence of denialists (Vidomus, 2018). According to Weible (2008), scientific organisations tend to be aligned to coalitions with similar beliefs in this type of an environment. Coalitions in turn seek such sources of scientific information to legitimise and implement their policy positions (Weible, 2008). A gap between legitimate climate science and climate policy may open up where there is a strong denialist presence and conflictual climate policy, as the Czech Republic case illustrates. In such cases, it would help if credible and legitimate scientific information were to be actively, iteratively and inclusively communicated to policymakers (Cash et al. 2003) and if actors' reliance on belief affirming information could be reduced.

We acknowledge that understanding the science-policy interface involves more than just mapping and analysing the information exchange relations among the actors involved in the production and the use of scientific information. But analysing these relations is an important first step in understanding how scientific information shapes climate change policymaking. Another limitation of our study is that our research design has not allowed us to examine the decision-making power of the actors in the four countries' networks. Public authorities are responsible for decision-making, but the roles and the abilities of the different types of these actors to decide policy varies across countries and for different types of decision-making processes. For example, some policy decisions need an Act Of Law, but the ability of political parties to introduce and see legislation passed can depend on parliamentary rules and arithmetic. In some circumstances, government departments and administrative agencies may be able to take decisions without consulting the government, while in other they may need their explicit approval. Thus, further inquiry into which public authorities are responsible for which climate policy decisions in each country and how do these particular organisations obtain and use scientific information in their decision making is a task for future research.

By investigating from where policy actors obtain scientific information and the role that their beliefs play in shaping their decisions about from where they obtain it this article contributes to governance research in at least three ways. First, by identifying the relative importance of different types of organisations as favoured sources of scientific information this article adds to the literature analysing how experts participate in politics (Gutiérrez, 2010) and to that which analyses information supply in policymaking (Boswell, 2012). Policy actors are subjected to a near constant stream of information about climate change from a variety of different sources, which makes it difficult for them to determine what is useful, reliable and accurate. Our results showing that scientific organisations are the most favoured source of information in all four countries suggests that policy actors may share similar procedures for organising incoming information (Walgrave and Dejaeghere, 2017). As boundedly rational actors, they are perhaps using a shortcut, such as the representativeness heuristic, to evaluate the importance of different types of actors as

producers of scientific information (ibid). This would lead them to obtain scientific information from scientific organisations primarily because of the fact that they are scientific organisations, and not because they have any a priori knowledge about which actors produce information that is reliable and accurate. Using heuristics allows actors to reduce the costs associated with screening and selecting the information that they will later process to inform policy development (Jones and Baumgartner, 2005). This does not mean that actors believe or will act on the information that they obtain, merely that they use a strategy to filter information. Indeed, the less than adequate policy responses in the four countries suggests that climate change is not being taken as seriously as the science demands.

Second, interest-based perspectives on governance have sought to ascertain how much influence different types of actors have in policymaking processes (Baekgaard, 2015) and to understand how power is exerted (Carstensen and Schmidt, 2018). The ability of actors to exercise their interests depends on their position in a policy network as well as how resources and power are distributed. Those that control and grant access to valuable resources, such as information, can have influence over both policy debates and choices. Our analysis shows scientific organisations to be at the centre of the four climate change policy networks. The fact that the information and expert power that this bestows upon these actors has not translated into significant influence over policy choices may be because the scientific information that they produce is descriptive rather than policy prescriptive. This has the advantage of allowing scientific organisations to remain objective and to some extent above politics, but whether being detached is appropriate or desirable when national governments face a serious policy problem is contested (Pielke, 2007). Added to this, our results showing that neither public authorities nor information producers are highly favoured sources of scientific information implies that their influence over how others understand the science of the problem is relatively limited.

Third, by focusing on scientific information and actors' beliefs this article contributes to contemporary debates in the governance literature about the role of ideas in policymaking processes (Harrison, 2002; Gieve and Provost, 2012; Baumgartner, 2013; Cox

and Béland, 2013). Scientific information can be a means for realising good governance because it injects realism into policy debates, whereas its absence makes this less likely. Democratic systems are more likely to meet the challenges that they face if public discourse and policy are based on accurate and unbiased information about what we know and don't know about a problem. That scientific organisations are the most favoured sources of scientific information in the four cases analysed here increases the likelihood that national climate policy debates in the four countries are informed, to at least some degree, by evidence. However, having scientific evidence at the centre of a policy debate is not enough because science does not dictate how the costs of climate action should be distributed. This is why examining actors' beliefs is important. As the Czech case shows, when a large proportion of actors question the science and when their beliefs determine from where they obtain information, a policy subsystem can become highly conflictual, leading to policies that are not in line with scientific evidence.

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