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ORIGINAL ARTICLE

The roles actors play in policy networks: Central positions in strongly institutionalized fields

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Abstract

Centralities are a widely studied phenomenon in network science. In policy networks, central actors are of interest because they are assumed to control information flows, to link opposing coalitions and to directly impact decision-making. First, we study what type of actor (e.g., state authorities or interest groups) is able to occupy central positions in the highly institutionalized context of policy networks. Second, we then ask whether bonding or bridging centralities prove to be more stable over time. Third, we investigate how these types of centrality influence actors' positions in a network over time. We therefore adopt a longitudinal perspective and run exponential random graph models, including lagged central network positions at t1 as the main independent variable for actors' activity and popularity at t2. Results confirm that very few actors are able to maintain central positions over time.

Keywords: policy network; central network positions; ERGM; longitudinal analysis; Switzerland

1. Introduction

Network analysis has a long tradition in political science and policy studies: for more than three decades, policy scholars have explained political action, power hierarchies, and policy-making as relational patterns among public and private actors (Kenis & Schneider, 1991; Knoke et al., 1996; Laumann & Knoke, 1987; Pappi & Henning, 1998). Here, we focus on so-called policy networks, which are networks consisting of actors involved in the public policy-making that regulates state intervention and other activities in a specific field, such as health, transport, climate, or environmental policy.

In policy networks, few actors have direct control over policy outcomes. Rather, they maintain a myriad of network contacts to gain influence over policy-making processes. The institutional design largely divides actors in policy networks into two groups: formal policy-makers who can directly shape outcomes and those who only indirectly access decision-making. (Beyers & Braun, 2013). The latter group provides formal policy-makers with information, expertise, or support in exchange for influence (Bouwen, 2002; Henning, 2009). Actors additionally coordinate their influence activities with others in coalitions in order to compensate for their limited individual resources (Heaney, 2014). These different mechanisms give rise to complex networks among actors participating in public policy-making. Public policy can, therefore, be considered to be an outcome of a complex pattern of interactions between a variety of private and public entities, that is, a policy network (Leech et al., 2009).

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One prominent approach used to understand complex network configurations focuses on actors occupying central network positions (Smith et al., 2014). Centrality in a network comprised of individuals, organizations, or any other type of actor is often used in sociometric analysis to identify who is powerful (Everett & Valente, 2016; Freeman, 1979). This principle also holds true for the analysis of policy networks, where centrality has been used to identify actors with influence over public policy-making.

The aim of this article is to show how centrality can be a helpful concept when studying strongly institutionalized contexts such as policy-making and the roles actors play in related policy networks. In contrast to friendship or intra-organizational networks (McPherson et al., 2001; Tsai, 2001), where nodes are mostly individuals, policy networks are most often comprised of collective actors such as political parties, administrative agencies, and interest groups. Furthermore, tie formation and centralities are not only dependent on choices of the actors but are also heavily influenced by the institutional design and the rules of the policy-making process and the broader political system (Brass, 1984; Christopoulos & Ingold, 2015; Smith et al., 2014; for accidental vs. aspirational network positions, see also An & McConnell, 2015). Identifying who is central in these policy networks provides important insights into who occupies important positions within coalitions, and into actors' potential to exchange resources for influence or (indirect) access to formal decision-making. These aspects again have potential implications for final policy outputs and outcomes (Christopoulos & Ingold, 2015; Svensson & Öberg, 2005). In this context, we ask three questions: What types of actors hold central positions in a policy network? Are bonding or bridging centralities more stable over time? And, finally, do central actors influence tie formation or dissolution in policy networks?

To identify which actors hold central positions in a policy network, we first discuss different centralities that might be relevant in the context of public policy-making. We rely on the basic distinction between centrality based on bridging ties versus centrality based on bonding ties (Berardo & Scholz, 2010). Bridging ties are weak relations that rely on building bridges across groups of actors (see Angst et al., 2018). Such bridging relations might primarily be relevant in policy-making for those actors without formal decisional competences that aim to connect with others on an occasional basis. This might be true for interest groups, trade unions, and citizens' groups. By contrast, bonding ties are strong ties based on actors' embeddedness in dense relational environments. This is important for actors tasked with coordinating action in policy networks and taking on key roles in politics, that is, mainly state actors. Based on exponential random graph models (ERGMs), we examine how those different central positions influence the network in terms of tie creation over time. We investigate the collaboration network of Swiss climate policy over two decades and at three points in time. Data stems from interviews and surveys with collective actors, such as state agencies, political parties, and different types of interest groups involved in Swiss climate policy-making.

The remainder of the paper is structured as follows: first, we review the literature on centralities in policy networks and on how centrality is impacted by strategic and individual decisions, as well as institutional context. Second, we introduce hypotheses about what type of actor is able to occupy stable positions in policy networks and maintain them over time. In the third and fourth sections, methods, data, and cases are introduced. We then present descriptive results about actor type, timing, and central positions in policy networks before setting out the outcome of the ERGMs for network dynamics. Finally, we discuss the impact of central network positions—driven by bridging or bonding ties—on actors' interactions in highly institutionalized contexts.

2. Theory

Centrality is the most prominent network concept if one aims to identify nodes that hold a particular position within a network. Centrality is therefore often used as a synonym for network power or structural advantage (Smith et al., 2014). Furthermore, in policy network studies, centrality

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measures have been successfully employed to identify those actors playing a key role in policy processes (Knoke et al., 1996).

Central network positions can, on the one hand, be the result of actors' interests and strategies. Whether an actor is able to achieve such an advantageous network position depends on individual efforts and role-seeking strategies. In policy networks, political actors might therefore actively search for such positions by taking strategic action such as providing relevant information or reaching out to other actors. On the other hand, and particularly in networks embedded in a strongly institutionalized context such as policy-making, central network positions can also be the result of the overall network configuration, or of the larger institutional context in which the network is embedded. Some actors thus "fall" into central network positions not because they were seeking them out, but because of the relational strategies of other actors in the network (for a similar discussion on friendship networks, see An & McConnell, 2015). In contrast, other actors are empowered by the institutional setting of policy-making and thereby occupy central network positions: there is usually one administrative agency that is in charge of leading a policy-making process. This is an institutionalized role that further influences the relational profile of the respective actor in the policy network.

Institutionalized roles in networks or access to the formal authority of other actors may be exchanged for resources such as information, public support, or technical expertise (Henning, 2009; Knoke et al., 1996; Leifeld & Schneider, 2012). In this situation, ties between formal decision-makers and state officials on one side, and interest groups, political parties, research organizations or journalists, on the other, might be established. Alternatively, administrative entities responsible for a specific policy proposal may reach out to other public and private actors in formal or informal consultation procedures in order to recruit their support (see Feiock et al., 2012; Fischer, 2015; Gulati & Srivastava, 2014).

To sum up, the creation of ties between actors and the distribution of centralities in policy networks are not only the result of actors' choices but are also strongly dependent upon how institutional competences are distributed. However, a word of caution in relation to network boundary specification is pertinent here (see also Laumann et al., 1989): as we have identified, network theory assumes that an actor's network position (and centrality) is highly contingent upon its relationships with others. Thus, the number of nodes and ties are relevant. As a result, a researcher's over- or under-estimation on what constitutes a theoretically meaningful and methodologically feasible boundary, that is, which actors to include and what type of ties to consider, has a substantive impact on the structure we perceive.

Central actors can be public authorities or formal decision-makers but may also be any other type of actor. Central actors are thus defined according to their structural profile and not according to the type of formal competence they hold, even though the latter might impact upon the former. Occupying a central network position is a role an actor plays and is a structural construct rather than an actor's inherent attribute (see also Gould, 2002).

Even if the institutional context and related rules tend to be relatively stable in Western democracies, the dynamic nature of policy processes suggests that actors may gain or lose central positions over time. On the one hand, given that political actors constantly seek to impact policy-making, central actors are expected to strive for the stabilization of their central network position, while noncentral actors are expected to seek centrality (see also Stokman & Zeggelink, 1996). On the other hand, according to Burt (2005, 2002), network relations are dissolved when the interaction of interest is over. As a consequence, opportunistic relations may break down very quickly as exogenous factors change, whereas other relations might be more stable. We thus need to take into account the dynamic context of policy-making when studying policy networks among actors.

In a policy-making context, an important exogenous factor is the stage or phase of the policy process[1]: network relations depend on the phase of the policy process that actors are involved in, and actors' interest in establishing ties with others may change over time. In most policy studies, five to six stages or phases are distinguished, ranging from problem perception and agenda

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setting to policy formulation and introduction, or implementation and policy evaluation. The difference between the policy formulation and the implementation phases is such that attention shifts from the voting power of decision-makers to task execution and the implementation of decisions (Bardach, 1979; Fischer et al., 2012; Torenvlied & Thomson, 2003). The actors' interest in translating their beliefs and preferences into policy outputs is therefore stronger in the decision-making phase than in the implementation phase (Ingold & Fischer, 2014). As a result, different types of actors might strive to either hold central positions among diverse phases of the policy-making process or be formally competent for task execution in one specific phase, either of which might impact their centrality.

From these arguments, we maintain that tie creation in general and central positions in policy networks in particular are not only driven by an actor's strategic relational choices. Rather, in highly institutionalized contexts such as public policy-making, central positions are also strongly dependent on larger network structures such as coalition formation and the attributes of alters driven by institutional arrangements such as their status, resource dependence, or power (Agneessens & Wittek, 2011; Park & Rethemeyer, 2014). Alongside general tendencies toward tie maintenance (see Schaefer et al., 2010) or dissolution (Burt, 2002), centralities and other network structures are also heavily impacted by common rules, norms, and sanctions (Lazega et al., 2012), as well as the timing, phase, and maturity of the policy process.

2.1 Central positions in policy processes

To identify who holds central positions in a policy network, we consider different centrality concepts and measures that have historically been developed in network sciences (Brandes et al., 2012; Freeman, 1979; Smith et al., 2014). However, scholars studying networks and policy-making have most prominently relied on two distinct relational profiles: bridging or bonding relations, distinguishing between positions that connect otherwise unconnected parts of the network (bridging), and positions that are embedded within a dense part of the network (bonding) (see e.g., Angst et al., 2018; Berardo & Scholz, 2010).

Burt's concept of "structural holes" (Burt, 1992) is a prominent basis used to investigate central positions with a *bridging* character (see also Wellman, 1988). Following this perspective, the potential for having an influence in the network lies in weak or sparse ties that facilitate information flow and the diffusion of innovations between otherwise unconnected parts of the network (Zaheer & McEvily, 1999). Obtaining resources or information in this indirect way is particularly attractive to actors, as the cost of sustaining these indirect ties is low (Burt, 1992; Granovetter, 1973; Sherestha, 2012, p. 308). In policy networks, this might be particularly relevant for actors without formal decision-making responsibilities. Typically, unlike state authorities and elected officials, interest groups such as trade unions, consumer organizations, citizens' and business groups have limited resources related to public policy-making, both in terms of time and personnel, as their main tasks are not (only) related to politics. Engaging in bridging relations therefore provides them with an ideal way to establish contacts, both with other peers and state authorities and decision-makers.

H1: Actors without formal competences and decision-making responsibilities (e.g., interest groups) occupy and maintain central network positions in terms of bridging ties more often than actors with formal competencies.

In contrast to bridging centralities, Beyers & Braun (2013) argue that the (*bonding*) position of an actor provides an important explanatory factor regarding individual resource endowment and, as a result, the likelihood of influence in policy-making. Unlike loose bridging ties, strong bonding relations help to control and coordinate actions in policy-making. It is typically state authorities

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and administrative entities that can maintain sufficiently strong ties to shape public policy-making processes.

H2: Actors with formal competences and decision-making responsibilities (e.g., state authorities and administrative entities) occupy and maintain central network positions in terms of bonding ties more frequently than actors without formal competencies.

Previous studies on policy networks in natural resource management (Bodin & Crona, 2008; see also Angst et al., 2018), related to political participation (Beyers & Braun, 2013; Hampton, 2011) or agriculture and climate change (Dowd et al., 2011), found that bonding and bridging ties impact network structures and outcomes differently. Having many bonding ties is reflected by high interconnectedness and levels of reciprocity among political actors. This can then lead to trust-building and strength within a given community or process (see Coleman, 1986). Political scientists have found that bonding ties are an important precondition to political participation (Hampton, 2011) and are used to gain direct access to parties and politicians (in contrast to bureaucrats, see Beyers & Braun, 2013). Actors occupying central positions in terms of bonding ties might, therefore, be particularly active in their respective networks and interested in shaping ideologies and strategies to impact policy-making.

H3: Actors holding central network positions in terms of bonding ties tend to be *active* over time, that is, across all phases of the policy-making process.

In policy networks, central actors are also perceived as particularly important, and other actors attempt to build alliances with them (Fischer & Sciarini, 2015; Ingold & Leifeld, 2014). Centrality and brokerage can therefore be assessed from the perspective of the broker who is likely to be receiving returns by maintaining a structurally advantageous (but also potentially costly) network position (Burt, 2005), and also from the perspective of the benefits enjoyed by those with whom it is connected (i.e., social capital, information flows, trust, diffusion of risk, leadership, diffusion of innovations, etc.). Actors holding central positions in policy networks therefore not only actively influence the structure of policy networks but also function as important "attraction" points for others.

H4: Actors holding central network positions in terms of bridging or bonding ties tend to be *popular* over time, that is, across all phases of the policy-making process.

3. Methods

The following section describes how we identify actors holding central network positions. We first introduce central network positions driven by bridging (i.e., *effective size, honest brokerage*, and *across coalition degree centrality*), then central network positions driven by bonding ties (i.e., *constraint* and *within coalition degree centrality*). In order to operationalize both bridging and bonding ties, and in order to check the robustness of our results, we focus on several centrality measures for both. Those measures are the most widely employed measures used to assess bonding and bridging. Finally, we use betweenness centrality as a filter to identify both bridging and bonding effects (see also Angst et al., 2018; Brandes et al., 2012).

First, the wider the variety of network regions that an actor has ties with, the greater the potential for information benefits. *Effective size* (EffSize) can thus be seen as a centrality, based on bridging ties or a "count of ego's contacts discounted for clustering" (Burt, 2015, p. 152). It is

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calculated by the number of alters an ego is directly connected to, minus a "redundancy" factor (Borgatti et al., 1998, p. 4). A high score implies an actor connects otherwise unconnected clusters.

The second centrality representing bridging ties considered in this analysis is *pure honest brokerage* (HB Pure). There is literature on "honest brokerage" which employs a heuristic definition (Burke, 2005; Nitze, 1990). The new measure of "pure honest brokerage"[2] estimates the relevance of the brokerage of each actor to the total brokerage in the network. The pure brokerage measure (HB Pure) is calculated and normalized by weighing each actor's honest brokerage score (HBi) by the ratio of their brokerage pairs (Pi) to the sum of brokerage pairs in the network (SumP) (see Appendix 3). This is then normalized as a proportion. High scores therefore imply an actor's brokerage has a strong impact on the connectivity of the network.

A third way to operationalize central network positions driven by bridging ties is to identify actors lying *across two or more coalitions* (DegOther). Coalitions are defined as groups of actors sharing similar worldviews, preferences, or beliefs, and engaging in a nontrivial degree of coordination (Henry, 2011; Sabatier & Weible, 2007). Compared to the earlier measures, this centrality measure takes into account information external to the network itself (i.e., actors' worldviews, etc.). Through the assessment of the structural equivalence of actors' relational profile regarding ally and enemy structures (see Fischer, 2014; Ingold, 2011), actors with the same relational profile are assumed to be members of the same coalition. Two coalition members, therefore, share ally relations with each other and toward the same alters, as well as relate to members of the other coalitions through enemy relations. Only once coalitions and coalition members are identified, it is possible to then identify actors holding central positions within or between those coalitions. *Across coalition positions* are assessed *via the degree centrality* of an actor toward members of the opposite coalition(s). Normalized degree centrality, as used here, measures the number of ties an actor sends (out-degree) or receives (in-degree) in relation to the total number of possible ties in the network (see Scott, 2000). Across coalition brokerage, bridging ties toward ideologically different others is assessed via the relative number of relations toward members of all other coalitions.

The two central network positions driven by bonding ties are operationalized as follows. First, *within coalition positions* (DegOwn) relies on the basic calculations explained above with *across coalition positions* set out above. Actors occupying central network relations by being strongly connected with ideologically similar others are also assessed via *relative degree centrality*, but this time toward actors from their own coalition. For both within and across coalition brokerage, we rely on the average of their in- and out-degree centralities. Second, the central position based on *bonding ties* is assessed via *Burt's constraint* (*Constraint*), capturing the degree to which an actor's network is "concentrated in one contact" (Burt, 2005, p. 26), that is, the degree to which alters are constrained and are potentially strongly dependent on other actors that act as brokers in the network. *Constraint* can also be seen as the extent to which all of ego's relational investments directly or indirectly involve a single alter (Borgatti et al., 1998, p. 4). The more constrained the actor, the fewer the opportunities for action, and the lower the bonding character of the structural network position of this actor. An example of high constraint are actors that are pendant to well-connected alters or those whose alters are all connected to one another. Constraint depends on the local neighborhood of an actor.

One of the most prominent centrality measures is *betweenness* (Freeman, 1979). This is defined as the number of times an actor is on the geodesic between others. The greater the number of shortest paths an actor occupies, the easier it is for this actor to cut off indirect connections between other actors or manipulate information or other resources that travel through the network (Muñoz-Erickson et al., 2010; Scott, 2000). However, as well as those "bridging" characteristics, betweenness centrality can also have bonding dimensions when strengthening interconnections within their own coalition or an actor's neighborhood. We thus rely on betweenness centrality as a sort of "mainstream" network centrality measure (see also Borgatti & Everett, 2006; Brandes et al., 2012, about the radial and medial characteristics of centrality metrics).

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All of the centrality measures presented here are introduced in the respective models (see below) as lagged variables, that is, we test whether actors which were central at t1 are particularly active or popular in terms of collaboration at t2. More specifically, we operationalize activity and popularity terms as outlined in the hypotheses, that is, we distinguish between central actors with a higher propensity a) to send ties to others (activity) and b) to receive ties from others (popularity) at t2.

3.1 Case and data

Our analysis is based on data regarding a Swiss policy process in the field of climate policy. Climate policy in Switzerland is mainly designed, negotiated, and introduced at the national level. The leading agency is the Swiss Federal Office for the Environment (BAFU, see appendices 1 and 2), and major decisions relevant to the climate are taken by parliament and the government. In Switzerland, these public authorities are required to regularly negotiate policy solutions with a variety of different public and private actors that have the power to overrule governmental decisions through the activation of direct-democratic instruments (Lijphart, 1999). This consultative and consensus-driven style of policy-making (Lijphart, 1999) also impacts climate policy design: for almost two decades Swiss climate policy has been characterized by two equally powerful advocacy coalitions (Ingold, 2008; see also Kriesi & Jegen, 2001) that have conflicting views about how to shape climate change mitigation programs. The pro-environment coalition is in favor of mandatory reduction targets and the introduction of a CO2 tax, and the pro-economy coalition defends voluntary programs for firms and industry.[3]

Three periods of Swiss climate policy-making are analyzed. The period between 1995 and 2000 constitutes the policy formulation phase where the new act on CO2 emission reductions was negotiated, designed, and introduced. The second phase covered the period between 2002 and 2005. During that phase, the first revision of the act took place and conflicts between the opposing coalitions arose, as they had very different preferences about what policy instruments to introduce. To abate CO2 emissions, pro-economists wanted to continue with the preexisting voluntary measures, whereas pro-ecologists were in favor of the introduction of incentive measures. Finally, in 2005, the Swiss government decided to introduce a mix of both types of abatement measures; this compromise was strongly shaped by an intervention across coalitions by so-called policy brokers (Ingold & Varone, 2012). The third phase between 2008 and 2012 involved a major change: alongside climate mitigation, goals and measures for climate adaptation were also integrated into the new CO2 act. While this phase can be viewed as policy reformulation, empirical studies have shown that it was similar to the implementation of the old act, with some revisions of policy instruments (Ingold & Fischer, 2014).

Data for this research were gathered through surveys with the so-called political elite. Therefore, survey statements were coded from representatives of Federal agencies, private interest groups, political parties, trade unions, science, and environmental NGOs. We followed the premise that policy-making is shaped by collective actors and organized interests, rather than by individuals (Knoke et al., 1996). First, and following the decisional and positional approaches (Knoke, 1993), we identified those organizations within the political elite that participated in at least two of the pre-parliamentary and parliamentary venues for each of the three phases. We further added to the list actors holding formal competences and responsibilities in Swiss climate policy-making. This first list was then presented to 2–4 experts per phase. Using the reputational approach, they indicated actors that were particularly relevant in shaping climate policy outputs. They were also allowed to add actors to the original list.

We ended up with a set of 34 actors for which data were gathered in all 3 phases (see Appendix 1 for the full list of actors)[4] based on interviews and postal surveys conducted in 2004/2005 for the first 2 phases and 2012 for the last phase.[5] For all three phases, additional coding of written statements and policy positions was conducted (Ingold, 2008; Rohrer, 2012; Sutter, 2012). When

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Table 1. Descriptive analysis of central positions over time

		Effect. size	HB Pure	Degree within coalition	Degree across coalitions	Constraint	Betweenness
t1–t2	Stable above avrg. at t2 (% of t2)	78	75	54	64	69	57
	Correlation t1–t2	0.51	0.79	0.59	0.58	0.38	0.43
t2–t3	Stable above avrg. at t3 (% of t3)	64	40	33	18	35	50
	Correlation t2–t3	0.64	0.80	0.11	0.01	–0.19	0.43

answering the following question, each survey partner was presented with the predefined actors' list and asked "With which actors on this list did your organization strongly collaborate during (1) policy formulation of the CO2 act (1995–2000); (2) during the first revision of the CO2 act (2002–2005); (3) during the implementation and respective re-formulation of the CO2 act (2008–2012)?" A survey respondent indicating a strong collaboration with another actor on the list indicated a network tie between these two actors. Thus, answers to this question allowed us to create the collaboration network this study is based on[6]

To assess within and across coalition activities, coalitions were identified based on each actors' ally and enemy profile (see section above). Survey respondents answered the following questions, again having the full actors list at their disposition: "With whom did your organization share ally or, to the contrary, enemy relations regarding the design of Swiss climate policy during (1) policy formulation of the CO2 act (1995–2000); (2) during the first revision of the CO2 act (2002–2005); (3) during the implementation and respective re-formulation of the CO2 act (2008–2012)?".

Furthermore, we created actor type attributes "state authorities" (including executive actors, parties in parliament) and "administrative entities," as well as "pro-economic interest groups," and "pro-environmental interest groups" (see last column in table of Appendix 1 for actor types).

4. Analysis

Table 1 indicates whether actors' centrality is stable over time. For both time periods (t1–t2 and t2–t3), it reports the percentage of actors with above-average centrality scores at t2 (t3, respectively), which already indicates above-average centralities at t1 (t2, respectively), as well as correlations of centrality measures between t1 and t2 (t2 and t3, respectively). A low degree of stability over time, for example, actors with high centrality at t2 but not at t1, as well as low correlations, would provide further evidence that occupying central positions is a role played at certain points in time rather than a fixed attribute.

Overall, at the end of the first time period under study (t2), (i.e., at the end of the first decision-making phase), between 54% and 78% of the central actors at the earlier point in time were still in an above-average centrality position. Furthermore, actors' centrality scores between t1 and t2 showed reasonably high correlation scores ranging from 0.38 to 0.79. Stability during the second period of time was clearly lower and at the third time period (t3) (i.e., during policy implementation), only between 18% and 64% of the central actors were actors that were central at t2. Moreover, for most types of centralities (with the exception of *effective size* for which the correlation is higher between t2 and t3 than between t1 and t2), correlation coefficients were similar or lower in the third time period than for the first time period. These indicators for stability of centralities over time are admittedly rough but nevertheless provide an interesting overview.

First, the overall result supports our basic view that actors' centralities across the different stages of the policy-making process are not stable over time. Centrality can instead be seen as describing a role that actors play depending on the network, the exogenous context, and their own strategic behavior. Second, there is no identifiable difference in terms of stability between bonding and bridging positions. Both types of centralities were operationalized with several measures,

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and there is no consistent difference between both types of centralities. Third, a clear difference appears between time periods. While phases t1 and t2 are typical policy-making processes including negotiations and decision-making on policies, the third phase corresponds with a mix between implementation and the start of a new policy-making process. Thus, while given actors tend to keep their central network positions during both phases of decision-making, roles clearly change with the nature of the process: when it comes to implementation, new actors occupy central positions within the respective policy networks. Correlations between the centrality scores reported in Table 1 suggest that this tendency might be stronger for bridging types of centrality than for bonding types of centrality.

To investigate this in more detail, centralities for each actor and phase, as well as for aggregated actor types, are outlined in the table in Appendix 2. There are eight actors that managed to hold above-average positions over time, as well as with respect to more than half of the centrality measures. Earlier results confirm that these actors can be identified as exceptional agents in the policy network on the specific issue (Christopoulos & Ingold, 2015); and in-depth case study analysis showed that they had a strong influence over policy processes and outputs in Swiss climate policy (Ingold, 2008). Administrative entities score the highest in *betweenness* centralities, with half or more (50–75%) of the actors from this category having above-average values, ahead of pro-economic interest groups (27–45%) and state authorities (16–33%). The eight most central actors over time, as mentioned above, also come from these three actor groups. In the implementation phase, administrative entities are the most central actors. As outlined in hypothesis 1, interest groups score higher than the other actor types when it comes to bridging centralities (*effective size*, *honest brokerage*, and *across coalition positions*). On average, over all three types of bridging centralities and three time periods, 9–45% of interest groups show above-average centralities. Interestingly, interest groups also score highly in bonding ties (18–63%). Mainly, pro-economy interest groups have high *within coalition positions*, whereas pro-environmental interest groups score higher in *Burt's constraint* (somewhat contradicting hypothesis 2).

4.1 ERGM results

To analyze the influence of actors' centrality on their future network activity and popularity, we rely on ERGMs (Robins et al., 2007; Wasserman & Robins, 2005).[7] These models allow for three types of statistics to be taken into account, that is, node covariates, edge covariates, and endogenous network structures.[8] In the present case, node covariates correspond to the centrality of an actor at a given point in time, or to fixed attributes of whether actors are state actors or not. Second, edge covariates are time-variant characteristics of ties between two nodes (i.e., preference similarity between two actors). Third, endogenous network structures refer to the effects of the network on itself (Goodreau et al., 2009, p. 105).[9] We apply a tie-oriented instead of an actor-oriented approach (see Block et al., 2016), and thus an ERGM rather than a Stochastic Actor-Oriented Model (SAOM). This is justified by our assumption—which is key to our argument—that actors not only chose their ties and positions independently of context, but that they can also "fall into them" depending on, among other factors, the institutional context. We further employ separate ERGMs including time-lagged centrality variables for comparing centralities related to tie creation across time periods (t1–t2 and t2–t3).[10] This corresponds with a simple and straightforward way to analyze our third research question and, furthermore, allows us to identify differences between both time periods.

Results of the ERGMs appear in Table 2. Central network positions are assessed as described above. The six types of centralities (as already outlined in Table 1) are examined in separate models, and the respective centralities appear at the top of the table. We then run two models for each centrality measure, corresponding to the respective time periods. The first model corresponds to the time period between t1 and t2, analyzing how centrality at t1 impacts tie creation at t2, while the second model refers to the dynamics between t2 and t3, based on centrality at t2.

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Table 2. ERGM with lagged independent variables

	Bridging centrality						*Bonding centrality*					
	Model 1: Effective size		Model 2: HB Pure		Model 3: Degree other coalition		Model 4: Constraint		Model 5: Degree own coalition		Model 6: Betweenness	
	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3
Activity (effective size)	**0.06** (**0.03**)	0.04 (0.03)										
Popularity (effective size)	**0.13** (**0.03**)	**0.09** (**0.02**)										
Activity (HB Pure)			0.02 (0.01)	0.03 (0.02)								
Popularity (HB Pure)			**0.05** (**0.01**)	**0.08** (**0.02**)								
Activity (degree other coalition)					2.35 (1.34)	**–3.14** (**1.11**)						
Popularity (degree other coalition)					–1.93 (1.36)	1.48 (0.92)						
Activity (constraint)							**–0.68** (**0.30**)	-1.81 (1.76)				
Popularity (constraint)							**–0.65** (**0.30**)	**–5.79** (**1.83**)				
Activity (degree own coalition)									–0.06 (0.56)	0.13 (0.85)		
Popularity (degree own coalition)									**1.35** (0.53)	**2.89** (**0.84**)		

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Table 2. Continued

	Bridging centrality						*Bonding centrality*					
	Model 1: Effective size		Model 2: HB Pure		Model 3: Degree other coalition		Model 4: Constraint		Model 5: Degree own coalition		Model 6: Betweenness	
	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3
Activity (betweenness)											0.02 (0.03)	0.01 (0.02)
Popularity (betweenness)											**0.11** (**0.02**)	**0.06** (**0.02**)
State authorities' activity	0.09 (0.23)	**0.98** (0.39)	0.15 (0.23)	**1.10** (**0.40**)	−0.02 (0.24)	**1.27** (**0.45**)	0.10 (0.23)	**0.93** (**0.39**)	0.13 (0.23)	**0.93** (**0.39**)	0.12 (0.23)	**1.02** (**0.40**)
State authorities' popularity	0.08 (0.23)	−0.51 (0.44)	0.21 (0.21)	−0.09 (0.45)	0.26 (0.24)	**−0.86** (**0.42**)	0.12 (0.23)	−0.69 (0.43)	−0.00 (0.23)	−0.40 (0.44)	0.21 (0.22)	−0.34 (0.44)
Admin. entities' activity	−0.22 (0.26)	0.62 (0.41)	−0.13 (0.26)	0.70 (0.43)	−0.48 (0.31)	0.62 (0.46)	−0.21 (0.25)	0.54 (0.41)	−0.16 (0.25)	0.63 (0.41)	−0.13 (0.26)	0.59 (0.41)
Admin entities' popularity	0.42 (0.25)	**1.24** (**0.44**)	0.38 (0.23)	0.78 (0.44)	**1.02** (**0.29**)	**1.26** (**0.37**)	**0.73** (**0.23**)	**1.05** (**0.41**)	**0.74** (**0.24**)	**1.50** (**0.41**)	0.34 (0.23)	**1.13** (**0.43**)
Pro-economy IG activity	0.06 (0.23)	0.46 (0.41)	0.15 (0.21)	0.56 (0.42)	0.04 (0.22)	0.61 (0.45)	0.06 (0.24)	0.36 (0.41)	0.15 (0.24)	0.49 (0.41)	0.13 (0.22)	0.49 (0.41)
Pro-economy IG popularity	0.36 (0.23)	0.12 (0.47)	**0.46** (**0.21**)	0.20 (0.47)	**0.64** (**0.23**)	−0.02 (0.39)	**0.51** (**0.22**)	−0.18 (0.45)	0.37 (0.23)	−0.26 (0.46)	0.37 (0.22)	0.25 (0.47)
Pro-environment IG activity	0.20 (0.23)	−0.56 (0.54)	0.26 (0.23)	−0.47 (0.54)	0.14 (0.23)	−0.29 (0.54)	0.24 (0.23)	−0.44 (0.56)	0.26 (0.23)	−0.47 (0.53)	0.26 (0.22)	−0.55 (0.55)
Pro-environment IG popularity)	−0.25 (0.25)	−0.22 (0.53)	−0.09 (0.22)	0.21 (0.52)	−0.02 (0.25)	0.06 (0.44)	−0.17 (0.24)	−0.02 (0.50)	−0.15 (0.24)	−0.49 (0.54)	−0.09 (0.23)	−0.41 (0.56)

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Table 2. Continued

	Bridging centrality						*Bonding centrality*					
	Model 1: Effective size		Model 2: HB Pure		Model 3: Degree other coalition		Model 4: Constraint		Model 5: Degree own coalition		Model 6: Betweenness	
	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3	t1–t2	t2–t3
Preference similarity	**1.29** (**0.15**)	**2.05** (**0.27**)	**1.29** (**0.16**)	**2.11** (**0.27**)	**1.24** (**0.16**)	**2.16** (**0.27**)	**1.32** (**0.16**)	**2.04** (**0.27**)	**1.24** (**0.15**)	**2.02** (**0.27**)	**1.29** (**0.15**)	**2.06** (**0.27**)
Edges	**–3.59** (**0.39**)	**–4.69** (**0.61**)	**–3.23** (**0.38**)	**–4.43** (**0.59**)	**–3.59** (**0.40**)	**–4.22** (**0.55**)	**–2.82** (**0.45**)	–1.67 (0.99)	**–3.60** (**0.40**)	**–4.76** (**0.59**)	**–3.32** (**0.37**)	**–4.33** (**0.57**)
Reciprocity	**1.14** (**0.27**)	**1.25** (**0.46**)	**1.21** (**0.27**)	**1.29** (**0.46**)	**1.22** (**0.27**)	**1.43** (**0.45**)	**1.17** (**0.27**)	**1.28** (**0.46**)	**1.20** (**0.27**)	**1.22** (**0.47**)	**1.19** (**0.27**)	**1.30** (**0.47**)
Transitivity (GWESP, 0.1)	**1.11** (**0.24**)	**0.89** (**0.25**)	**1.12** (**0.25**)	**0.94** (**0.25**)	**1.35** (**0.23**)	**1.11** (**0.24**)	**1.26** (**0.24**)	**0.91** (**0.25**)	**1.29** (**0.24**)	**0.94** (**0.25**)	**1.16** (**0.23**)	**0.94** (**0.25**)
Transitivity (GWDSP, 0.1)	**–0.17** (**0.04**)	**–0.20** (**0.07**)	**–0.19** (**0.04**)	**–0.22** (**0.07**)	**–0.13** (**0.04**)	**–0.12** (**0.07**)	**–0.14** (**0.04**)	**–0.19** (**0.07**)	**–0.14** (**0.04**)	**–0.19** (**0.07**)	**–0.18** (**0.04**)	**–0.18** (**0.07**)
AIC	840.34	408.67	832.67	402.36	865.19	414.42	854.92	410.19	862.22	410.23	837.83	408.69
BIC	915.68	484.01	908.02	477.70	940.53	489.76	930.27	485.53	937.56	485.57	913.18	484.03
Log-likelihood	–405.17	–189.33	–401.34	–186.18	–417.60	–192.21	–412.46	–190.10	–416.11	–190.12	–403.92	–189.35

Bold figures indicate significant results at the conventional level of p-values of 0.05 or lower.
Results are robust if different actor types' activity/popularity variables are omitted from the model.

Three centrality measures indicate bridging types of centrality. *Effective size centrality* is related to actors' popularity *and* activity over time. The activity effect is significant during decision-making (t1–t2) but is not significant when passing to the implementation phase (t2–t3). But during both periods, actors with central positions in terms of effective size centrality are popular as collaboration partners for others, corresponding with a first confirmation of hypothesis 4. The same is true for actors that score highly with respect to *pure honest brokerage (HB Pure)*. They are popular collaboration partners during both time periods, but they are not particularly active. Actors with high *across coalition degree centrality,* that is, actors who collaborate between two coalitions, are not especially popular. During implementation, these actors are especially inactive, as they show a negative tendency to create collaboration contacts with others. This inactivity already appears from descriptive results in Table 1 showing that actors with above-average centralities are not able to keep them during all phases of the policy-making process. Thus, apart from *across coalition degree centrality,* we can confirm the first part of hypothesis 4: actors holding bridging centrality positions are popular over time.

Results differ when looking at the measures indicating bonding types of centrality. Actors which are central in terms of *Constraint* have a negative tendency to attract collaboration ties over time and, at least during decision-making, also tend to create few collaboration contacts. Furthermore, actors with strong *within coalition centrality* display a positive tendency to attract collaborative ties over time, but are not, on average, more or less active than other actors.

Being in a central network position according to *betweenness centrality* (last two models) does not seem to significantly pay off in terms of establishing collaborative ties toward others and over time. However, actors with high betweenness centrality are particularly popular in both the decision-making (t1–t2) and policy implementation (t2–t3) phases. Thus, contrary to our expectation (see H3 and H4), bonding actors are not particularly active, but those actors with high betweenness and within coalition centralities do attract ties from others over time (popularity).

Besides actors' centralities, the models include parameters for the outgoing and incoming ties of state authorities and administrative entities, as well as interest groups in both the pro-economy and the pro-environment coalition. These actor types are represented by dummy variables, as described in the data description. Results, however, reveal only limited effects of these actor types. First, *state authorities* such as political parties in parliament appear to be particularly active during implementation, but not during decision-making. *Administrative entities*, by contrast, appear to be particularly popular actor types in both time periods and in most models. Notably, the responsible agency, the Swiss Agency for the Environment (BUWAL), is active and popular in both periods and most models (see also Appendix 1 for actor types).

As an exogenous control variable, given that collaboration among political actors is strongly influenced by the similarity of their preferences (i.e., Sabatier & Weible, 2007; Scott & Christopoulos, 2017), we include *preference similarity*. The strongly positive effect shows that, unsurprisingly, actors with similar preferences tend to collaborate. Our models further include two structural properties of networks as controls, that is, the tendency of actors to reciprocate ties (*reciprocity*) and their tendency to create ties with actors to whom they are already indirectly linked (*transitive triplets*). As can be seen in Table 2, these structural features always have a significant influence on tie formation in all phases of policy-making processes. Finally, the edge parameter controls for network density.

5. Discussion

Considering all of the actors, our results indicate high volatility in terms of which actors occupy network positions based on centrality. In general terms, we have confirmed our basic assumption that centrality in policy networks assesses the roles actors may or may not play, and that most actors only occupy central network positions at given moments in the policy-making process.

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However, there is also a tendency that indicates that once actors occupy the most central network positions, they (1) keep this role over time and (2) combine bonding *and* bridging centralities. When looking at single actors' centralities (see also Appendix 2), we can see for example, that the five actors with the highest betweenness centrality at t1 also keep this role at t2 and t3. Even more interestingly, the eight actors occupying the most central positions in the network do so over more than half of the measured centralities when considering both periods. Looking at within and across coalition degree centrality, approximately one-fifth of all actors keep this role linking either coalition peers or members of the opposing coalition.

Turning more specifically to the question of what actor type occupies what type of central network position (bridging vs. bonding), we can confirm hypothesis 1: interest groups, and therefore actors without formal competences and decision-making responsibilities, have a stronger tendency toward bridging ties than other actors. Bridging ties might be easier to establish and might need less long-term engagement in a policy-making process than bonding ties. Typically, interest groups, in contrast to actors with formal competencies in a specific policy field, might only have a sporadic and short-term interest in politics, depending on the specific issue being discussed. This brings us to the test of hypothesis 2, which is not unequivocally supported. It is true that state authorities and administrative entities engage in bonding rather than in bridging ties and therefore seem to occupy central positions based on strong ties, trust-building, and coordination of the policy process. But so do members of the pro-economy coalition, and thus also actors without formal competences such as business interest groups and firms. The high level of activity of the pro-economy interest groups in the network is also further confirmed: as well as administrative entities, which are the most active group in policy implementation, a considerable part of the pro-economy interest groups also held high centralities over time. Their high bridging and bonding centralities in the third phase might be related to the target group role that those organizations have during policy implementation: they are the addressees of the majority of measures such as the CO2 tax or the climate penny, which were adopted to mitigate climate change in Switzerland since 2000 and 2005, respectively. Another explanation is that the ideal-typical consensus democracy of Switzerland has also always been strongly liberal-corporatist: interest groups—with economic interests in a dominant position—maintain strong relations with state authorities and thereby become central actors in these policy networks (see Gava et al., 2016; Sciarini, 2014; Sciarini et al., 2015).

Additionally, and in line with descriptive results, ERGM results emphasize the role that different actor types play in the different phases of the decision-making process (see again Table 2). Whereas state authorities actively reach out to other actors during implementation, when they are no longer making formal decisions, administrative entities are approached by others, because they, alongside state authorities, are responsible for organizing the policy-making process, including during the implementation phase. Half of our models also indicate that interest groups from the pro-economy coalition were particularly popular during decision-making. We thus conclude that central positions are occupied by different actors at different points in time (during the decision-making and/or implementation phases of the policy-making process). Although modern policy studies emphasize that the two stages of policy-making are not particularly distinctive and that multi-actor networks involving power games and conflicts are relevant for both phases (Lester & Goggin, 1998; Nakamura, 1987), we find that network positions change across different policy stages. As outlined in Table 1, network cohesion drops in the third period: a much lower number of actors are central in t3, compared to t1 and t2. Furthermore, the ERGM results (Table 2) show that things change in the third period, for example, activity terms related to within and across coalition degree centrality change coefficients from positive to negative and vice versa. This is related to overall centrality patterns in t3 considerably changing by comparison with the first to time periods. Collaboration, and playing key roles in policy implementation, seems to follow alternate institutional logic and patterns, rather than policy design and formulation (Knill & Tosun, 2012):

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most interest groups become inactive and only the few addressees of the policy, as well as formal implementers (mostly administrative entities), maintain network relations.

We have furthermore hypothesized that central positions based on bonding ties increase actors' activity over time (*hypothesis 3*), while both bonding and bridging positions influence actors' popularity (*hypothesis 4*). Both centralities based on bonding ties (*constraint* and *within coalition degree centralities*, see Tables 1 and 2) indicate no tendency for central actors to be active over time. But, interestingly, all three bridging centralities suggest no specific effect with respect to activity. Nonetheless, we still have to reject hypothesis 3. There is, however, more empirical support for hypothesis 4. Two out of three measures for bridging centrality (*effective size, pure honest brokerage*), one out of two measures for bonding centrality (*within coalition degree centrality*), and *betweenness* centrality indicate that central actors are popular as collaboration partners over time. However, while the degree to other coalitions (bridging centrality) shows no effect, centrality based on Burt's constraint (bonding centrality) indicates a negative impact.

The two measures based on within and across coalition centrality also display unanticipated effects. Both types of centralities not only depend on ties and alters of ego, but also upon a broader construct spanning the overall network. Coalitions are here conceived as large groups of actors sharing similar beliefs with each other and engaging in a nontrivial degree of coordination. If actors become central in this specific structure, either by holding a considerable amount of ties within (bonding) or across coalitions (bridging), this affects the overall network development in a particular way. Within coalition degree, centrality enhances the popularity of an actor as a collaboration partner over time, as opposed to bonding centrality assessed through Burt's constraint.

6. Conclusions

This article investigated the role of central actors in the highly institutionalized setting of public policy-making and related policy networks among actors. In policy-making, the creation and dissolution of relations among actors in general, and of central network positions in particular, are not only shaped by actors' individual strategies and ad hoc decisions, but also strongly depend on context: we argue that institutions of the political system strongly impact network configurations and investigate what type of actor is able to occupy or even maintain central network positions of different kinds and during which phases in the policy process.

Relying on descriptive network statistics and an ERGMs, we study network developments over time in Swiss climate policy. General results confirm our basic assumption that centrality is a role that actors play, as most actors do not keep central positions in the network over time. This central position is partly due to their own relational activity but is also related to how they are affected by other actors' embeddedness in the policy network. The actors occupying central positions in the network both within and across coalitions change over time. However, within one specific policy process, around one-fifth of all actors manage to keep their central role and engage in cross-coalition activity over several phases of the political process. Furthermore, centralities based on bridging versus bonding ties seem to be complementary: those actors who manage to occupy central positions do so by filling structural holes as well as maintaining strong ties within their close neighborhood. Finally, Switzerland has traditionally been a consensus-oriented, liberal-corporatist political regime with strong relations between interest groups and state authorities (Sciarini et al., 2015).

The results also provide something of an answer to the question of whether or not policy-making over time follows a logic of "tie preservation." In our case, the number of relations tends to increase between policy formulation and first revision, but, when looking at the overall process, including implementation, there is a general tendency for tie dissolution. Even the most central actors in the network tend to lose rather than create ties over time. Interestingly, one major

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exception exists: actors displaying a high number of within coalition relations, and thus being connected to ideologically similar others, tend to send and also attract ties over time, particularly during policy implementation.

We hypothesized that central positions based on bridging and bonding ties should explain the attraction of ties over time, while central positions based on bonding ties should be beneficial to tie creation. In general, we can conclude that, compared to what was expected, actors occupying bridging positions are less popular over time and actors in bonding positions are less active over time. In all, the tendency for tie popularity is evident for actors occupying bridging positions (Burt's effective size and pure honest brokerage), as well as for those having high betweenness and within coalition degree centrality.

We conclude that the few actors with highest centralities have a tendency to preserve their advantageous network position over time. Furthermore, we asked if central actors manage to create and attract ties significantly over time: again, there is no general tendency for such a mechanism. Future research should, however, further assess different centralities that are based on bridging versus bonding ties and confirm the diverging effects outlined here. Furthermore, our model is blind to the resources or motivations of actors participating in collaborative policy networks. It is thus important to include additional factors that might explain (1) why certain actors occupy central positions, (2) if they do so consciously or unconsciously, and (3) if they purposefully benefit from their relational profile. Generally, if actors manage to exploit network advantages systematically, it would be important in terms of effective and efficient policy design to know more about those central actors and their motivations in order to interpret their relational behavior.

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Conflict of interest. None.

Notes

1 We acknowledge the literature that criticizes the rather descriptive and static nature of the policy cycle approach (Sabatier & Jenkins-Smith, 1993) and points out that bargaining may happen throughout the whole policy process (Lester & Goggin, 1998; Nakamura, 1987).

2 Pure brokerage provides a measure of the relative impact of an actor's "honest" brokerage. This is required because "raw" honest brokerage does not entail information about the importance of a specific actor's brokerage to network connectivity. For the "raw" honest brokerage measure, see Appendix 3.

3 Note that these are two advocacy groups and not formal interest groups or parliamentary coalitions. The latter are characterized through formal membership, signatures, and statutes (Wright, 1996), whereas the former are said to be composed of collective actors joining their forces based on shared ideologies (Sabatier & Jenkins-Smith, 1993).

4 This set of public and private actors is often called "political elite." In Switzerland, as in other countries (for Germany see Leifeld, 2013; for regional U.S. politics Henry, 2011; for Swedish energy policy Nohrstedt, 2010), there is very rarely a fundamental change at the level of those actors entering and exiting the elite. We could therefore deal with predefined network boundaries and managed to obtain data from all those actors, not least because we relied on data gathering through interviews and direct contacts with those representatives.

5 Interviews for phases t1 and t2 were conducted in 2005, and data were gathered at the same point in time for both phases. We note that data for the first phase were therefore gathered in a retrospective manner. Results of Table 2, however, show that there is a considerable difference in density and tie formation between t1 and t2, which is why we are confident that the actors did not have the tendency to replicate the current situation onto the past. We furthermore conducted 55 interviews for the representation of 34 collective actors to take into account changes in personnel within these organizations and also to account for multiple answers per organizations. Data for the third period were collected in 2012. For all three periods, the response rate was thus 100%.

6 Close or strong collaboration is defined as an established network of interaction (see also Brummel et al., 2012). Survey partners were furthermore presented a definition of close collaboration, including the elaboration of joint policy proposals, the regular exchange about policy-relevant information, the joint attendance of policy venues, or the common coordination on how to share resources, personnel, or strategies in policy design or implementation. Similar to other policy studies (Sciarini et al., 2004; Fischer, 2015), we argue that strong and frequent collaboration is a relevant type of tie in policy networks: in

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contrast to information exchange or sporadic collaboration, it is not only driven by institutionalized relationships or competence distributions but also shows a high degree of coordination and ideology-based interaction among the involved actors (see also Henry, 2011; Ingold, 2011). However, we differ from Granovetter's (1973) differentiation between weak and strong ties when talking about bridging and boding centralities. In our reading of Granovetter, it is not the type of tie, but rather the intensity or structural surrounding of a node that then makes a tie bridging or bonding.

7 Given that observations of networks are, by definition, non-independent, the assumption that a tie between two actors is independent of other collaboration ties that both actors have is unrealistic. Standard regression models are based on the assumption of the independency of observations. Contrary to this, ERGMs avoid this assumption by treating the whole network as a single observation. They then calculate the probability of observing a given network as compared to all networks that could have been observed, given a set of statistics on the network (Cranmer & Desmarais, 2011).

8 Computation of the exact maximum likelihood of these models is impossible due to the high number of possible network configurations. Models are therefore estimated by Markov Chain Monte Carlo Maximum Likelihood (MCMC-MLE), which approximates the exact likelihood by relying on a sample from the range of possible networks to estimate the parameters (Cranmer & Desmarais, 2011). The algorithm proceeds by comparing the probability of a randomly selected network to the current network and then by deciding whether or not to accept the proposed network as the next step in the chain (Morris et al., 2008, p. 17). Iterations stop as soon as the differences between some characteristics of the observed network and the sample mean are no longer significant (p greater than 0.05).

9 For example, a reciprocity parameter assesses whether actors reciprocate an existing tie, that is, whether a tie from b to a can be explained by the fact that there is a tie from a to b. ERGM coefficients can be interpreted as the change in the conditional log-odds of observing a given edge in the network with each unit increase in a given network statistic, the rest of the network being constant (Hunter et al., 2008).

10 We still ran TERGM to check for robustness. With respect to the obtained results and effects of different centralities, the positive effects identified in the ERGMs are confirmed, and directions of effects are the same. In the TERGMs, and especially for the second time period, centralities have more positive effects. This might be due to the fact that even if changes between the two times are minimal, in the TERGM many dependencies of the latter network are explained by the former network, see Block et al. (2018). We present and interpret only the more conservative ERGM results.

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Appendix 1. Actors' list

Actors' abbreviation	Full name	Organization type	Actor type
AEE	Agency for Renewable Energy	Advisory organization for renewable energy issues	4
BFE	Swiss Federal Office of Energy	Federal Agency	2
BUWAL	Federal Office for the Environment	Federal agency	2
Cemsuisse	Association of the Swiss Cement Industry	Umbrella organization of Swiss cement producers	3
CVP	Christian Democratic People's Party	Government party, 15.3% vote share in 2011	1
Economiesuisse	Economiesuisse	Umbrella organization representing the Swiss economy, supported by more than 30,000 businesses of all sizes.	3
EFV	Federal Finance Administration	Federal Agency	2
EnAw	Energy Agency for the Economy	Representing the Swiss economy and industry in energy issues	3
Energieforum	Energieforum	Representing industry and private concerns in energy consumption issues	3
Equiterre	Equiterre	Green NGO	4
EV	Swiss Petrol Union	Organization representing 95% of the Swiss petrol industry (27 members in 2009)	3
Factor AG	Factor AG	Private consultation firm	3
FDP	Free Democratic Party	Government party, 15,1% vote share in 2011	1
FRS	Road traffic association	Umbrella organization of car importers and private traffic	3
Greenpeace	Greenpeace	Green NGO	4

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Actors' abbreviation	Full name	Organization type	Actor type
Grüne	Green Party of Switzerland	8.4 % vote share in 2011	1
HEV	Swiss Houseowners' association	Swiss Houseowners' association	3
Infras	Infras	Private scientific organization	5
NCCR Climate	National Competence Center of Research on Climate Change	Scientific organization of the Swiss national science foundation	5
OcCC	Advisory Body on Climate Change	Scientific organization formulating recommendations to the Swiss Parliament; member of the Swiss Academy of Natural Sciences	4
OEBU	Association for ecological integration in business management	Representing ecological and sustainable concerns within Swiss private sector	4
Proclim	Forum for Global and Climate change	Scientific organization; member of Swiss Academy of Natural Sciences	5
Prognos	Prognos	Private scientific organization	5
SECO	State Secretariat for Economic Affaires	Federal Agency	2
SGB	Swiss Federation of Trade Unions	Trade Union	4
SGCI	Swiss Association of Chemical and Pharmaceutical Industry	Umbrella organization of chemical and pharmaceutical enterprises and laboratories	3
SP	Social Democratic Party of Switzerland	Government party, 18.7% vote share in 2011	1
SVP	Swiss People's Party	Government party, 26.6% vote share in 2011	1
Swissmem	The Swiss Mechanical and Electrical Engineering Industries	Umbrella organization of Swiss mechanical, electrical and engineering industries (MEM industries)	3
TCS	Touring Club Switzerland	Organization for road traffic in Switzerland, more than 1,5 million members	3
TravailSuisse	TravailSuisse	Association of Trade Unions	4
UVEK	Federal Department of the Environment,	Federal Department	2
VCS	Association for Transports and Environment	Organization promoting public transport and environmental solutions in private transportation	4
WWF	World Wildlife Foundation	Green NGO	4

Note: Numbers in the last column correspond to actor type: 1 = state authority (party representatives in parliament and government), 2 = administrative entities; 3 = pro-economy interest groups; 4 = pro-environment interest groups; 5 = science.

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Appendix 2. Centrality measures over time by actor type

		Effective Size			Pure HB			Centrality other coal			Centrality own coal			Constraint			Betweenness		
		95	05	12	95	05	12	95	05	12	95	05	12	95	05	12	95	05	12
State authority	CVP	2.00	15.56	5.29	1.25	0.50	0.00	0.00	0.09	0.10	0.00	0.18	0.11	0.50	0.16	0.24	0.00	9.93	1.22
n=6	FDP	3.00	4.30	1.63	0.00	0.90	0.00	0.00	0.10	0.03	0.18	0.27	0.04	0.33	0.26	0.50	0.30	2.27	0.00
	Grüne	5.69	3.94	1.67	1.25	0.40	0.00	0.11	0.24	0.00	0.5	0.39	0.11	0.28	0.35	0.57	2.56	0.32	0.00
	SP	1.00	1.40	5.29	0.00	0.00	0.00	0.03	0.06	0.03	0.2	0.22	0.21	0.75	0.45	0.28	0.00	0.00	0.00
	SVP	4.00	3.88	1.67	0.00	0.10	0.00	0.00	0.08	0.03	0.18	0.23	0.04	0.26	0.24	0.46	2.07	0.13	0.00
	UVEK GS	2.00	4.86	4.60	1.25	1.90	5.67	0.31	0.46	0.18	0.03	0.11	0.18	0.50	0.24	0.36	0.00	1.16	2.01
	n above	***2***	***1***	***2***	***0***	***0***	***0***	***2***	***2***	***2***	***4***	***1***	***4***	***3***	***2***	***4***	***2***	***1***	***1***
	% above in group	***33%***	***16%***	***33%***	***0%***	***0%***	***0%***	***33%***	***33%***	***33%***	***66%***	***16%***	***66%***	***50%***	***33%***	***66%***	***33%***	***16%***	***16%***
	% above general	***14%***	***11%***	***17%***	***0%***	***0%***	***0%***	***17%***	***18%***	***18%***	***31%***	***8%***	***27%***	***20%***	***13%***	***22%***	***22%***	***14%***	***10%***
Admin. Entity	BUWAL	12.35	13.70	11.97	40.06	27.60	57.78	0.09	0.08	0.33	0.2	0.28	0.21	0.18	0.17	0.20	17.98	20.61	9.47
n=4	BFE	3.94	11.61	9.54	0.83	21.00	9.60	0.04	0.11	0.10	0.14	0.36	0.32	0.36	0.18	0.19	1.10	12.20	12.74
	EFV	2.00	2.50	1.00	0.00	0.00	0.00	0.16	0.10	0.10	0.08	0.11	0.07	0.56	0.36	0.64	0.54	0.08	0.00
	SECO	4.45	4.85	2.93	1.66	0.20	0.00	0.06	0.08	0.15	0.14	0.14	0.11	0.29	0.24	0.44	4.14	2.59	3.41
	n above	***3***	***2***	***2***	***1***	***2***	***2***	***3***	***0***	***4***	***1***	***2***	***4***	***1***	***1***	***2***	***2***	***2***	***3***
	% above in group	***75%***	***50%***	***50%***	***25%***	***25%***	***25%***	***75%***	***0%***	***100%***	***25%***	***50%***	***100%***	***25%***	***25%***	***50%***	***50%***	***50%***	***75%***
	% above general	***21%***	***22%***	***17%***	***17%***	***40%***	***50%***	***25%***	***0%***	***36%***	***8%***	***15%***	***27%***	***7%***	***7%***	***11%***	***22%***	***29%***	***30%***
Science	Infras	2.00	3.55	1.33	1.25	0.80	0.00	0.06	0.48	0.00	0.03	0.14	0.11	0.50	0.28	0.52	0.00	0.54	0.00
n=5	NCCR	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.04	0.00	0.00	0.43	0.00	0.00	0.00	0.00
	OcCC	1.50	3.75	3.00	0.00	0.40	3.15	0.02	0.07	0.04	0.06	0.28	0.04	0.78	0.34	0.38	0.00	0.14	1.89
	Proclim	1.50	4.56	1.00	0.00	0.90	0.00	0.05	0.04	0.00	0.06	0.28	0.00	0.78	0.30	1.00	0.00	0.38	0.00
	Prognos	1.00	1.83	0.00	0.00	0.00	0.00	0.03	0.15	0.00	0.03	0.11	0.00	0.71	0.39	0.00	0.00	0.10	0.00
	n above	***0***	***0***	***1***	***0***	***0***	***1***	***1***	***2***	***0***	***0***	***0***	***1***	***4***	***4***	***3***	***0***	***0***	***1***
	% above in group	***0%***	***0%***	***20%***	***0%***	***0%***	***20%***	***20%***	***40%***	***0%***	***0%***	***0%***	***20%***	***80%***	***80%***	***60%***	***0%***	***0%***	***20%***
	% above general	***0%***	***0%***	***8%***	***0%***	***0%***	***25%***	***8%***	***18%***	***0%***	***0%***	***0%***	***7%***	***27%***	***27%***	***17%***	***0%***	***0%***	***10%***
Interest group	Cemsuisse	1.25	5.71	4.06	0.00	0.10	0.70	0.00	0.04	0.05	0.18	0.45	0.07	0.54	0.25	0.35	0.00	1.62	0.67
Pro-economy	EV	5.00	10.65	7.13	6.42	13.90	0.95	0.00	0.04	0.05	0.27	0.55	0.04	0.27	0.20	0.30	10.03	5.15	2.50
n= 11	EnAw	0.00	7.15	4.63	0.00	1.50	2.80	0.10	0.08	0.08	0.00	0.18	0.11	0.00	0.22	0.29	0.00	2.92	1.80
	Energieforum	6.78	7.90	2.13	0.00	0.70	1.05	0.02	0.20	0.03	0.36	0.45	0.04	0.26	0.22	0.41	1.75	1.53	0.28
	FRS	5.28	9.36	5.25	1.25	1.00	0.70	0.00	0.05	0.00	0.36	0.59	0.00	0.28	0.21	0.35	7.33	7.47	5.74
	Factor	1.00	1.90	0.00	0.00	0.20	0.00	0.00	0.24	0.00	0.03	0.18	0.00	1.00	0.37	0.00	0.00	0.00	0.00
	HEV	3.00	5.32	1.00	3.75	1.50	0.00	0.02	0.11	0.00	0.14	0.41	0.00	0.33	0.25	0.60	0.00	0.36	0.00
	SGCI	3.38	3.80	0.00	2.00	1.50	0.00	0.03	0.08	0.00	0.18	0.07	0.00	0.33	0.28	0.00	0.87	0.12	0.00
	Swissmem	5.20	5.27	2.94	1.12	0.10	0.18	0.06	0.04	0.03	0.36	0.27	0.04	0.29	0.25	0.38	2.24	1.24	0.32
	TCS	1.50	3.17	2.58	0.00	0.10	1.58	0.09	0.42	0.03	0.14	0.32	0.04	0.64	0.30	0.41	0.00	0.08	8.51
	ecosuisse	9.97	12.00	8.97	27.80	14.70	12.87	0.03	0.20	0.05	0.55	0.73	0.07	0.22	0.19	0.27	7.76	11.69	10.31
	n above	***6***	***5***	***5***	***3***	***2***	***1***	***3***	***4***	***4***	***7***	***7***	***3***	***3***	***2***	***5***	***4***	***3***	***5***
	% above in group	***54%***	***45%***	***45%***	***27%***	***18%***	***9%***	***27%***	***36%***	***36%***	***63%***	***63%***	***27%***	***27%***	***18%***	***45%***	***36%***	***27%***	***45%***
	% above general	***43%***	***56%***	***42%***	***50%***	***40%***	***25%***	***25%***	***36%***	***36%***	***54%***	***54%***	***20%***	***20%***	***13%***	***28%***	***44%***	***43%***	***50%***
Interest group	AEE	2.00	4.00	2.00	0.00	0.00	1.05	0.09	0.22	0.00	0.06	0.44	0.00	0.52	0.31	0.50	0.00	0.49	0.00
Pro-environme	GP	1.83	2.72	1.00	0.42	0.60	0.00	0.03	0.05	0.00	0.03	0.39	0.04	0.57	0.42	1.00	0.00	0.06	0.00
n=8	OEBU	6.33	4.75	4.83	1.87	0.50	0.00	0.00	0.02	0.05	0.11	0.14	0.14	0.26	0.26	0.27	1.77	0.98	0.00
	SGB	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00
	TravailSuisse	1.00	1.00	0.00	0.00	0.00	0.00	0.03	0.10	0.00	0.1	0.00	0.00	1.00	0.65	0.00	0.00	0.00	0.00
	VCS	6.90	5.00	1.83	3.75	1.70	0.35	0.13	0.33	0.00	0.4	0.50	0.11	0.26	0.34	0.51	3.66	1.19	0.00
	WWF	4.00	21.39	2.75	4.08	7.60	1.58	0.16	0.15	0.00	0.08	0.78	0.14	0.31	0.13	0.38	0.00	34.03	0.00
	equiterre	1.25	3.25	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.07	0.00	0.61	0.31	0.00	0.00	0.23	0.00
	n above	***3***	***1***	***1***	***2***	***1***	***0***	***3***	***3***	***1***	***1***	***4***	***3***	***4***	***6***	***4***	***1***	***1***	***0***
	% above in group	***38%***	***13%***	***13%***	***25%***	***13%***	***0%***	***38%***	***38%***	***13%***	***13%***	***50%***	***38%***	***50%***	***75%***	***50%***	***13%***	***13%***	***0%***
	% above general	***21%***	***11%***	***8%***	***33%***	***20%***	***0%***	***25%***	***27%***	***9%***	***8%***	***31%***	***20%***	***27%***	***40%***	***22%***	***11%***	***14%***	***0%***
	Sum	64.11	119.60	60.89	5.20	9.65	2.36	1.76	4.61	1.41	112.10	197.63	101.99	14.47	10.11	11.80	100.00	100.40	100.00
	Average	**1.88558**	**3.51771**	**1.791**	**0.153**	**0.28**	**0.07**	**0.05**	**0.14**	**0.0416**	**3.297**	**5.813**	**2.9998**	**0.426**	**0.297**	**0.347**	**2.94118**	**2.9529**	**2.9412**

Note: Grey actors have above-average centralities. "n above" counts the number of actors within the respective category with above-average centralities. "% above in group" indicates the percentage of actors within that category of actors with above-average values. "% above general" indicates the percentage of actors belonging to that category as compared to all actors with above-average values. 95 and 05 indicate the first two phases of policy-making (t1 = 1995–2000; t2 = 2002–2005), whereas 12 indicated the last phase of policy implementation (t3 = 2008–2012).

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Appendix 3

Measure	Formula	Explanations to formula	Implications in policy analysis
Honest Broker	$\{g_i\{i, j, k \ldots\}$ $g_i = HB0_i + HB1_i + HB2_i$ $HB0_i = g_i - (HB1_i + HB2_i)$ $HB0_i = \frac{\sum_g j \neq k}{g_{ni}}$ Alternatively, this can be seen as a triadic relation solved for j. Transport, Energy and Communication $HB0_i = \frac{\sum T_{ijk}}{g_i}$ where <ni, nk> ≠ Lj	g_i = all lines between i and their alters j,k. HB0 number of alters that have no tie to one another divided by total number of ties. This is the null dyad between j k for all (j,k) who are alters of i HBI number of alters that have one directed tie by total HB2 number of alters that have reciprocal ties by total Lj is the set of lines within distance 2 of j	Honest brokerage calculates the degree to which an actor is the exclusive broker for his/her alters. It gives an indication of how many times an actor is the single intermediary between an alter and the rest of the network. An actor with high honest brokerage thus has particular control over information and may engage in trust-building and active policy design within the network.

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