

# Information exchange networks among actors for the implementation of SDGs

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## ABSTRACT

This article emphasizes the importance of actor networks for the implementation of the Sustainable Development Goals (SDG), and suggests how a network perspective can contribute to our understanding of (global) sustainability governance. Actor networks are often driven by homophily, as actors tend to interact with those similar to them. Yet, not least in a context sustainability governance, heterophily of actor cooperation is claimed to be beneficial. In contrast to homophily, heterophily represents situations where actors cooperate with those that are different, and thus combine diverse sets of knowledge and competences. Based on the case of Swiss actors involved in the implementation of the SDG 6 on water in countries of the global South, we use social network analysis and qualitative interview data to study how homophily and heterophily influence actors' information exchange. According to quantitative network data, information exchange between actors is indeed influenced by homophily regarding the type of actor and the policy forums actors are participating in. Nevertheless, we also find evidence for heterophily, as actors tend to exchange information with actors with different methodological foci. Furthermore, qualitative interview data show that actors perceive heterophilous network ties as beneficial for SDG implementation.

## 1. Introduction

As a strategy of global sustainability governance, having defined the Sustainable Development Goals (SDGs) can be considered a process of goal setting (Biermann et al., 2017; Kanie and Biermann, 2017). The non-binding goals on the international agenda now need to be implemented as policies, strategies or action plans within individual countries (O'Connor et al., 2016; Jiménez-Aceituno et al., 2019; Pineda-Escobar, 2019; Breu et al., 2020; Firoiu et al., 2019). Yet, especially the non-binding character of the SDGs requires bottom-up implementation by governmental authorities in interaction with private firms, civil society, and other actors, and at national, regional and local levels (Biermann et al., 2017; Hajer et al., 2015).

Given the broad set of relevant actors for SDG implementation processes, and the interactions of these actors, network concepts and methods can make a useful contribution to the debate on (global) sustainability governance. Interactions among many different actors can be considered instances of network governance, where actors jointly work towards policies, strategies, and similar outcomes (Newig et al., 2010).

Such a focus on networks among actors is also emphasized by SDG 17 that calls for "Strengthen[ing] the means of implementation and revitaliz[ing] the global partnership for sustainable development" (UN, 2015). Sharing knowledge and exchanging information in networks is a potential first step for establishing actor cooperation in network governance (Keast et al., 2007; Margerum, 2008).

Actor interactions in network governance are often driven by homophily, describing the tendency of actors to interact with those similar to them. Yet, not least in a context of sustainability governance and SDG implementation, the important role of interactions across different actors and the related bridging of topical and societal sectors have been repeatedly emphasized (O'Connor et al., 2016; UN, 2015; Barzola et al., 2019; Kamphof and Melissen, 2018; Hoff, 2018; Pärli and Fischer, 2020; Messerli et al., 2019a). Heterophily, as the contrary to homophily, describes such mechanisms where actors tend to interact with those dissimilar to themselves. Heterophily in network governance allows to combine diverse sets of knowledge and competences.

In this article we address these two counter-acting mechanisms in network governance and in regard to SDG implementation, by asking:

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### *How do heterophily and homophily influence information exchange among actors involved in SDG implementation?*

We seek answers to this question by studying information exchange among Swiss domestic actors involved in the implementation of SDG 6 in countries of the global South. SDG 6 aims at “ensuring availability and sustainable management of water and sanitation for all” (UN, 2015). Switzerland is an exemplary case of an industrialized country of the global North with extraterritorial responsibility when it comes to SDG implementation, as well as a prime example of a political system relying on collaborative network governance among a multitude of public and private actors. For our analysis, we rely on quantitative and qualitative data on information exchange among different types of actors, including government agencies, non-governmental organizations, research institutes, and others. We analyze the quantitative network data relying on exponential random graph models (ERGMs). This allows us to assess whether information exchange is steered by homophily, or, by contrast, heterophily—more or less than what would be expected in a random network. We assess homophily and heterophily with respect to six actor dimensions: actors’ organizational type, actors’ topical portfolio, actor’s methodological portfolio, actors’ size, actors’ experience, and actors’ affiliation to forums, defined as “issue-based intermediary organization” (Fischer and Leifeld, 2015). We then contrast and complement findings from the quantitative analysis with qualitative statements by survey respondents and from expert interviews.

This article contributes to the literature in several ways. First, empirical research on the implementation of SDGs at the national levels is still scarce. National-level governance processes related to SDG implementation have mainly been addressed from a conceptual or normative point of view, emphasizing participation, the crucial role of research, and policy coherence (Biermann et al., 2017; Meuleman and Niestroy, 2015; Glass and Newig, 2019). Second, whereas network approaches have been used to study SDG interactions (Pham-Truffert et al., 2020), this article relies on theoretical elements of network governance and related empirical methods of network analysis to study interactions of actors involved in SDG implementation. Such a perspective focusing on actors has been conspicuously absent from the literature on SDG implementation (Bennich et al., 2020). More broadly, this article also demonstrates the potential of network concepts and methods for the study and discussion of issues of (global) sustainable development. Third, results contribute to the literature on network governance and sustainability governance by highlighting how different actor dimensions and related homophily and heterophily structures influence actor interactions (Henry and Dietz, 2011; Leifeld and Schneider, 2012; Scott and Ulibarri, 2019). Introducing network concepts and methods to the debate on (global) sustainability governance is important not least with respect to SDG 17 that specifically focuses on collaborative partnerships. Networks, in that sense, can also be understood as tools for fostering and analyzing collaborative projects and actor integration. Fourth, analyzing how homophily and heterophily with respect to different actor dimensions influence information exchange sheds light on potential bottlenecks and opportunities for the practice of SDG implementation. More specifically, recognizing potential bottlenecks and opportunities in relation to the six actor dimensions can inform related reports and guidelines (Breu et al., 2020; Messerli et al., 2019a).

The remainder of this article is structured as follows. The following section presents different dimensions of homophily and heterophily. We then present the case, data and analytical methods, before we present and discuss results from our analysis. Broader implications and limitations of our work is discussed in the conclusion section.

## **2. Sustainability, network governance, and actor dimensions**

The literature on sustainability governance and the governance of natural resources has argued that successful governance requires – among others – the integration of different actors representing different sets of knowledge, interests, and resources (Kumar and Banerjee, 2012;

McGee and Jones, 2019; Olsson et al., 2006). Such integrative approaches have further been set forward as a means for jointly addressing complex sustainability problems (Biermann et al., 2017; Kozar et al., 2019; McAllister and Taylor, 2015; Bowen et al., 2017; Patterson et al., 2017). For example, Biermann et al. (Biermann et al., 2017) have emphasized the importance of bodies able to coordinate between many different actors, as well as the role and inclusion of civil societal groups, in order to foster sustainability transitions (see also Patterson et al. (2017)). McAllister and Taylor (2015) focus on the importance of so-called “partnerships” and the integration of diverse types of knowledge for successful governance of sustainability challenges.

These instances can be labelled as instances of network governance, where actors act interdependently with others in order to produce collective outcomes such as policies or strategies (Pierre and Peters, 2019; Carlsson and Sandström, 2008). Network governance is often contrasted to traditional hierarchical ways of decision-making (Sörensen, 2016). A pre-condition for effective problem-solving in network governance is the exchange of knowledge and information among actors (Keast et al., 2007; Margerum, 2008). Whereas information exchange does not guarantee that policies and strategies can be successfully elaborated, and that actors finally agree, it can be seen as a first step towards further outcomes.

One aspect of network governance is the focus on interactions of actors that are different to each other, by e.g. representing different sectors. Sectors are defined in different ways, including topical sectors such as energy, water, or food, or societal sectors such as government, academia, or civil society (Maag and Fischer, 2018; Berkes, 2009; Berkes, 2002). A common claim in the public policy literature is that the governance of policy sectors has to become more integrated to solve today’s complex policy issues (Metz et al., 2020; Tosun and Lang, 2017; Trein, 2017). Cooperation across sectors has also been attributed an important role for achieving policy goals in any implementation process (O’Connor et al., 2016; McGinnis, 2011; Capano et al., 2015; Deslatte and Stokan, 2020).

Despite the abundance of claims in its favour, and the potentially inherent character of network governance for facilitating cross-sectoral connections, interactions across actors that are different with respect to the sector they belong to – or any other dimension that characterizes them – are often complicated and hard to achieve in reality. Since actors’ specialization has been considered a successful solution to manage public activities for most of the 20th century, cross-sectoral coordination is an often untrained practice. Governments are inherently multi-organizational and are divided into numerous specialized sub-units (ministries, agencies, departments) organized along sectoral lines of policy fields (health, infrastructure, environmental policies etc.) (Bouckaert et al., 2016). Not only political and administrative power is hierarchical, but also resource allocation, communication and information flow, performance management and quality control tends to follow these lines (Bouckaert et al., 2016). More generally, and beyond a focus on organization of government, actors have different backgrounds and languages, different logics of internal organization, different roles, as well as, different values and interests that complicate interactions (Crona and Parker, 2012; Fischer et al., 2019; Vangen et al., 2015).

Therefore, network governance and related actor networks are in reality often shaped by homophily, which is one of the most prominent mechanisms in networks and social situations in general (Henry and Dietz, 2011; Scott and Ulibarri, 2019; McPherson et al., 2001). The logic of homophily drives actors towards cooperating with others similar to themselves (Borgatti et al., 2018). Interacting with similar people requires less effort as certain core ideas and ways of thinking and functioning are shared (McPherson et al., 2001). Within the field of network governance, homophily is defined as “the degree to which two actors in a network interacting with each other have certain similar attributes” (Newig et al., 2010). While homophily, given lower efforts, often leads to more efficient information exchange, it can also lead to a narrow focus, missing out on potential for synergies, innovation and new ideas

(Granovetter, 1973).

To study homophily and heterophily, we distinguish between six dimensions that actors can be (dis)similar on. These dimensions represent the different potential meanings of sectors discussed above, as well as further actor dimensions. Fig. 1 illustrates the six dimensions and related logics of homophily (left hand side) and heterophily (right hand side). First, based on the idea of societal sectors, we consider the similarity or difference between their organizational types. That is, they can be, e.g., a government actor, a non-governmental organization (NGO), an actor from academia, or from the private sector. As argued in the literature on network governance and collaborative governance, different types of actors have different and sometimes opposing goals, organizational structures, and professional languages, and they fulfill different functions in the political system (Maag and Fischer, 2018; Huxham et al., 2000; Edelenbos et al., 2011; Ansell and Gash, 2008). Thus, while two different administrative units tend to cooperate comparatively easily, this is often more complicated between, e.g., a research institute and an administrative office. These differences, however, potentially also represent different competences and knowledge sets that might be beneficially exchanged or combined for SDG implementation.

Second, in line with the idea of topical sectors, we take into account the sub-structure of the SDG in terms of the targets as well as the connection between two strongly related SDGs (e.g. agriculture and energy). Actors can thus be characterized by their topical focus and we further use this focus to assess similarities or differences between actors. These foci can range from water and sanitation, to water quality, ecosystem management, and to agriculture. For example, related to SDG 6, it is easier for two actors with the same interest of, e.g., improving the engineering behind urban wastewater systems, to exchange information, than for an actor interested in improving the engineering behind urban wastewater systems and another one specialized in the social integration of women for water management. Also, more generally, the literature on network governance and related policy theories has shown that actors with similar goals and beliefs tend to form network ties (Ingold and Fischer, 2014; Sabatier and Weible, 2007). However, we again also assume that information exchange among actors involved in different topics relevant for SDG 6 would be beneficial for the implementation of the SDG, along with ideas of integrated water resource management (Biswas, 2004; Galaz, 2007; Ingold et al., 2016). Further, several studies show that the SDGs are strongly interconnected and that taking these interconnections into account could support SDG implementation (Messerli et al., 2019a; Pham-Truffert et al., 2020; Griggs et al., 2017; Nilsson et al., 2018; Messerli et al., 2019b).

Third, we consider an actors' methods applied when working on SDG 6 implementation. Actors can have methodological expertise in many fields, from technology to policy advocacy. Actors might thus have an interest in mixing different methodological foci when aiming at the implementation of SDGs.

Fourth, actors can be of different size in terms of their personnel, and respective resources. Research on network governance has repeatedly emphasized the importance of resources and resource-dependency for understanding how actors chose network ties (Ingold and Fischer, 2014; Stokman and Zeggelink, 1996; Pfeffer and Salancik, 2003). Larger actors might have more capacities for implementation and be more attractive partners to smaller actors, whereas smaller actors are potentially more flexible to adapt to context and specific requirements. Information exchange between smaller and larger actors might thus again be beneficial for the SDG implementation process.

Fifth, as another form of resources, actors can differ with respect to their experience in working with SDG 6. We take into account actors with little experience specifically with SDG 6, and actors with long-term experience in the water sector and related sustainable development aspects. The combination of both perspectives in information exchange can bring long-term expertise, on the one hand, and new and external ideas in the respective SDG implementation process, on the other hand.

Sixth, institutional opportunity structures are important factors influencing networks (Pärli and Fischer, 2020; Leifeld and Schneider, 2012). That is, actors can be similar or dissimilar in terms of their institutional affiliation to water-related forums (Pärli and Fischer, 2020; Fischer and Leifeld, 2015). While research has shown that actors participating in the same institutions tend to create network ties, exchange among actors active in different forums might be beneficial for SDG implementation, as different types of knowledge and ideas can flow through information exchange networks.

Following the arguments in the literature, we expect homophily on these six dimensions to play an important role in structuring actors' interactions in the governance network. Yet, we also expect to see differences between the six dimensions with respect to how strongly homophily (or heterophily) structure the information exchange network among actors.

### 3. Materials and methods

#### 3.1. Switzerland and SDG 6

Domestically Switzerland already performs well with respect to the targets formulated under SDG 6: the amount of water resources, the quality of drinking water and connection rate to sanitation is very high as well as technically sophisticated (Blanc and Schädler, 2014). However, Switzerland has a high virtual water use. Only 18% of the water consumption happens inside the country while the other 82% accrue abroad for example for the production of water intensive crops. Especially the imports from countries that suffer from severe water shortage are problematic in this respect (Gnehm, 2012), by hampering the producing countries' efforts in reaching SDG 6.1 "access to clean water". Switzerland, as many other industrialized countries of the global North, has thus high spill-over effects in countries of the global South and thus an extraterritorial responsibility when it comes to SDG implementation (Sachs et al., 2019). Besides this specific case context, the UN resolution on the Agenda 2030 asks all countries to not only implement the SDGs nationally, but also support other countries in their implementation (UN, 2015; Messerli et al., 2019a).

Switzerland is a typical case of collaborative network governance, given its small size, dense network structure, and strong interactions between public and private actors in all aspects of governance and public decision-making (Sciarini et al., 2015; Fischer and Sciarini, 2016). Accordingly, the set of Swiss actors active in the field of water in countries of the global South is diverse and densely connected, including governmental, civil society, private industry and academic actors. Regarding governmental actors, water has been a core topic of the Swiss Department for Development and Cooperation for a long time. Regarding civil society, several major Swiss development organizations such as Helvetas or Caritas have water as one of their core topics. In the private industry sector, several transnational companies providing technical solutions for clean water and sanitation are based in Switzerland. Finally, Switzerland has several academic actors within the field of water in countries of the global South. For example, the Swiss Federal Institute of Aquatic Science and Technology (Eawag), has a research group working on mostly technical solutions for clean water and sanitation in countries of the global South. Further, the University of Geneva established the "Geneva Water Hub", a centre focusing on hydrogeopolitics, conflicts and peace.

In Switzerland, several forums offer a space for actors with different backgrounds to exchange and to connect, and thus contribute to the implementation of SDG 6. Based on document research and our

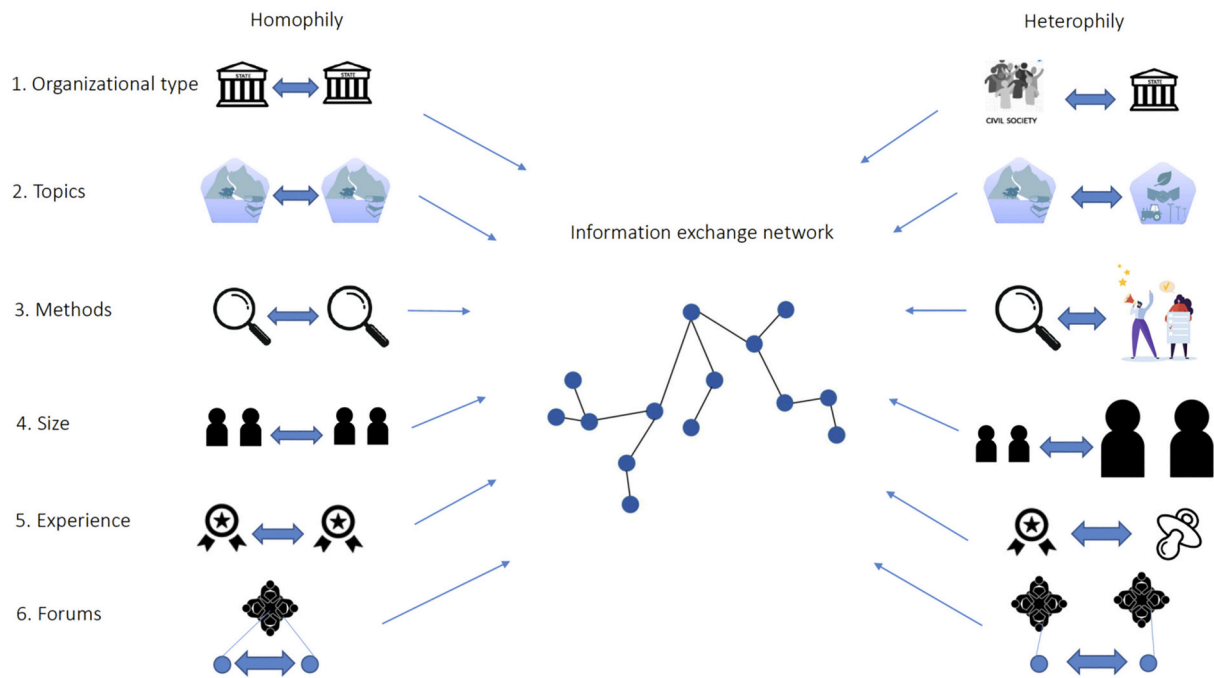


Fig. 1. Six actor dimensions and logics of homophily and heterophily.

qualitative data gathering, we have identified four Swiss forums relevant for the implementation of SDG 6 in countries of the global South (Pärli and Fischer, 2020).<sup>1</sup> The forums all have different organizational structures, cover different topics, and attract different actors. Three of the forums have different foci within the field of water and sustainability. The Swiss Water Partnership (SWP) for example is specifically working towards the integration of the private sector, while the forum AGUASAN considers itself a “community of practice, mostly working on access to water and sanitation. The forum RésEau is organized by the Swiss Office for Development Cooperation and aims at connecting public administration actors with other actors. The fourth forum the Sustainable Development Solutions Network (SDSN) has a broader focus and aims at fostering the implementation of the Agenda 2030 and the SDGs in general by emphasizing the interconnections of the SDGs. Together, these forums represent the set of forums where relevant aspects of SDG 6 implementation in countries of the global South is discussed among actors (Pärli and Fischer, 2020).

### 3.2. Operationalization and data collection

Information exchange among actors is the dependent variable of our analysis, while the similarity between the six different actor dimensions represent our main independent variables. Data for this analysis stem from an online survey using single and multiple-choice questions as well as an open question asking the actors about what they personally experience as fostering or hindering for information exchange. The survey was sent to 142 previously identified actors, which in our case are organizations. An organization needed to fulfill the following three conditions to be included in the analysis: 1) being based in Switzerland, 2) working on the implementation of the SDG 6 in countries of the global South and 3) being related to SDGs or the Agenda 2030. We used a broad range of secondary sources such as the member lists of forums covering water in the development context, participant lists of events on the topic

and research databases (ARAMIS, P3, CORDIS) to establish a first list of actors.

During the survey campaign respondents were able to add additional actors that were not already on our list. Nine additional actors fulfilling the criteria above were mentioned during the survey, but were not included, given they were mentioned by only one respondent. We consider actors to be collective organizations (Fischer et al., 2017), since organizations rather than individuals have the relevant resources and organize long-term exchange among actors. Thus, we contacted one person per organization and stated that they were asked to represent their organization. Overall, this resulted in 71 answers included in the network analysis, corresponding to a response rate of 50% (see Appendix 1, Table A1 for a list of actors).

To identify the information exchange network, we presented the list of actors to each survey respondent and ask the respondent to indicate with which other actor they exchanged information regarding SDG 6. In the survey, we asked separately whether an actor was providing information to another actor on the list, or whether the actor received we assume that an individual in an organization filling out the survey might not be information from another actor on the list. Based on our separate survey questions on the provision and the receiving of information we follow Borgatti et al. (2018) and rely on the transpose of the one matrix to fill out the other and vice versa. This procedure creates two complete matrices, one presenting who received information and the other one who sent information. We then use the Boolean combination method in UCINET (Borgatti et al., 2002) to combine the information provision matrix with the transposed information sending matrix. If actor A stated to provide actor B with information this would then result in an information exchange tie, even if actor B did not state to receive information from actor A. We used this technique as aware about all the information exchange partners of the organization.

We further distinguished between political and technical

<sup>1</sup> For the studied field we considered the following forums as relevant: AGUASAN (aguasan.ch), RésEau (<https://www.shareweb.ch/site/Water>), the Swiss Water Partnership (SWP, [swisswaterpartnership.ch](http://swisswaterpartnership.ch)) and the Sustainable Development Solution Network Switzerland (SDSN, [sdsn.ch](http://sdsn.ch)).



information (Leifeld and Schneider, 2012; Fischer et al., 2017).<sup>2</sup> We proceeded as described above with both types of information, and then combined these into a variable for information exchange by adding the two networks. Two actors thus share an information exchange tie once they either exchange political or technical information. Given that for the independent variables we relied on the attribute data of the actors collected through the survey, we excluded all the actors that did not fill out the survey from our information exchange network.

The independent variables, with which we are assessing the importance of homophily and heterophily, respectively, in the SDG implementation information exchange network are summarized in Table 1.

Finally, as control variables, we include a) node covariates controlling for in-degree and out-degree centralities of all categories used for the assessment of homophily (unless method and topical focus, where we assess in-degree and out-degree of the number of methods and topics, given their large number), and b) endogenous network mechanisms of reciprocity, and triadic closure. Reciprocity controls for the mechanisms

that actors in networks tend to reciprocate ties, triadic closure controls for the mechanisms that actors tend to have common partners in networks (Leifeld and Schneider, 2012; Berardo and Scholz, 2010).

### 3.3. Qualitative data collection

We complemented the network analysis with more qualitative data. This included two open questions in the survey: The first question asked the participants about factors they perceive as fostering or hindering information exchange regarding the SDG 6. The second question asked participants about their ideas on how the information exchange regarding the SDG 6 could be improved. A large majority of the participants (81.25%) answered the open question on fostering factors for information exchange regarding the SDG 6. We coded the answers based on a preliminary literature review and the screening of the answers (O'Cathain and Thomas, 2004). The results from the open questions provide an additional, complementary perspective to the analysis of the information exchange networks. Additionally, we conducted four semi-structured interviews with Swiss experts from academia, civil society, the government and the private sector working on the implementation of the SDG 6. We used the same interview guideline for all the conducted interviews.<sup>3</sup>

## 4. Results

In line with our theoretical arguments on network governance, we rely on methods of network analysis. Network analysis focuses on ties between different actor nodes, as well as the patterns and distributions of these nodes and ties (Ingold et al., 2016; Griggs et al., 2017). Homophily and heterophily are one of the important patterns - and mechanisms associated with observed patterns - in networks. Exponential Random Graph Models (ERGM, for a more detailed explanation see Appendix 2) (Robins et al., 2007) allow for statistical inference on network data, and can thus identify tendencies for homo- or heterophily.

In Table 2, we present two models, and we do so for a) the network of general information exchange, including both technical and political information, b) the network of technical information exchange, and c) the network of political network exchange (see Fischer et al., 2017). The first model for each of the three networks includes the six different homophily variables along with controls, the second model additionally splits up the homophily variable for actor type into three different types of actors (private actors as reference category). Additional models in Appendix 3 (Table A2) present results for models that split up the forum and topic categories into sub-categories. Results are overall robust to these modifications, but we do not discuss these models as the specifications are not of key theoretical relevance. In Table 2, parameters with significance levels at the conventional threshold  $p$  lower than 0.05 appear in bold. Alpha parameters for GWESP and GWDSP parameters are set at 0.5.<sup>4</sup> Goodness of fit assessments of both models show good model fit. The graphical representations of goodness of fit for the first two models in Appendix 4 indicate that only edgewise shared partners are underestimated by the models.

Both models for the network of general information exchange (columns 2 and 3 in Table 2) suggest that homophily is an important factor

**Table 1**  
Description and operationalization of six actor dimensions.

| Variable                 | Description  | Operationalization in survey  |
|--------------------------|--|---|
| Same organizational type | Assesses whether belonging to the same actor type increases chances for information exchange. Actor types include public administration, academia, civil society and the private sector.   | Respondents were asked to indicate the organizational type (single choice).   |
| Similarity topics        | Assesses whether similarity of actors in terms of water-related issues they are involved in influences information exchange. Water-related issues relate to the different sub-goals of the SDG 6 (e.g. sanitation and hygiene, water quality or drinking water). | Respondents were asked to indicate all the sub-goals of the SDG 6 the organization was working on (multiple choice question).   |
| Similarity methods       | Assesses whether similarity of actors in terms of the methods and approaches they use to tackle the water-related issue (e.g. technology/engineering, advocacy or policy/law) influences the tendency to exchange information.                                   | Respondents are asked to indicate all the methods they were using while working on the implementation of the SDG 6 (multiple choice).   |
| Similarity size          | Assess whether actors of similar size tend to exchange information.  | Respondents were asked to indicate the size of their organization (single choice)   |
| Similarity experience    | Assesses whether actors with a similar level of experience working on SDG 6 and related issues tend to exchange information.   | Respondents were asked to indicate how long their organization is working on water or water related topics (single choice).   |
| Similarity forums        | Assesses whether the number of joint memberships of actors in four forums dealing with SDG 6 in Switzerland influences information exchange.   | Respondents were asked to indicate the level of participation in each forum. As a membership we counted if an organization uses more than 30% of the forum's services (single choice question). |

<sup>2</sup> We defined technical information as *information on technical or scientific aspects of the implementation or monitoring of the SDG 6 or related SDGs* and political information as *information related to political affairs that allows your organization to organize with others during the policy process and influences our organizations working priorities and strategies*.

<sup>3</sup> The interview guideline included one part on the main goal, the activities and the organizational structure of the organization of the interview partner. The second part included questions on the role of the organization regarding the implementation of the SDG 6, including the contribution of the organization (information exchange, connecting different actors, etc.). The third part included the personal opinion on factors fostering or hindering information exchange regarding the implementation of the SDG 6.

<sup>4</sup> A model with slightly higher alpha parameters for GWESP and GWDSP parameters (0.7) results in weaker model fit (higher AIC / BIC), substantive parameters (size and direction of effects, significance) do not change.

**Table 2**  
EGRM results,  $p < 0.05$ .

|                          | All ties 1             | All ties 2             | Technical 1            | Technical 2            | Political 1            | Political 2            |
|--------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Same organizational Type | <b>0.41</b><br>(0.06)  |                        | <b>0.47</b><br>(0.06)  |                        | <b>0.46</b><br>(0.08)  |                        |
| Both NGO                 |                        | <b>0.13</b><br>(0.06)  |                        | 0.12<br>(0.08)         |                        | 0.13<br>(0.10)         |
| Both Government          |                        | <b>0.29</b><br>(0.06)  |                        | <b>0.34</b><br>(0.07)  |                        | <b>0.35</b><br>(0.08)  |
| Both Academia            |                        | <b>0.27</b><br>(0.08)  |                        | <b>0.35</b><br>(0.08)  |                        | <b>0.26</b><br>(0.11)  |
| Similarity Topics        | 0.11<br>(0.08)         | 0.11<br>(0.09)         | 0.06<br>(0.09)         | 0.07<br>(0.09)         | 0.15<br>(0.12)         | 0.12<br>(0.11)         |
| Similarity Methods       | <b>−0.23</b><br>(0.09) | <b>−0.24</b><br>(0.09) | <b>−0.21</b><br>(0.09) | <b>−0.22</b><br>(0.09) | −0.15<br>(0.11)        | −0.14<br>(0.11)        |
| Similarity Size          | 0.03<br>(0.02)         | 0.03<br>(0.02)         | <b>0.05</b><br>(0.02)  | <b>0.05</b><br>(0.02)  | 0.03<br>(0.03)         | 0.02<br>(0.03)         |
| Similarity Experience    | 0.01<br>(0.03)         | 0.02<br>(0.03)         | 0.01<br>(0.03)         | 0.01<br>(0.03)         | −0.02<br>(0.03)        | −0.02<br>(0.03)        |
| Similarity Forum         | <b>0.30</b><br>(0.08)  | <b>0.31</b><br>(0.08)  | <b>0.27</b><br>(0.08)  | <b>0.29</b><br>(0.08)  | <b>0.23</b><br>(0.10)  | <b>0.22</b><br>(0.11)  |
| Edges                    | <b>−6.19</b><br>(0.24) | <b>−6.68</b><br>(0.26) | <b>−5.98</b><br>(0.22) | <b>−6.61</b><br>(0.24) | <b>−6.13</b><br>(0.25) | <b>−6.82</b><br>(0.27) |
| Reciprocity              | <b>4.26</b><br>(0.19)  | <b>4.26</b><br>(0.19)  | <b>4.20</b><br>(0.22)  | <b>4.22</b><br>(0.21)  | <b>4.66</b><br>(0.26)  | <b>4.66</b><br>(0.26)  |
| Triadic closure (GWESP)  | <b>1.08</b><br>(0.12)  | <b>1.07</b><br>(0.12)  | <b>1.04</b><br>(0.10)  | <b>1.04</b><br>(0.10)  | <b>0.81</b><br>(0.09)  | <b>0.82</b><br>(0.09)  |
| Triadic closure (GWDSP)  | 0.00<br>(0.01)         | 0.00<br>(0.01)         | 0.01<br>(0.01)         | 0.01<br>(0.01)         | 0.02<br>(0.01)         | <b>0.02</b><br>(0.00)  |
| Academia Out             | <b>0.44</b><br>(0.21)  | <b>0.59</b><br>(0.22)  | <b>0.44</b><br>(0.21)  | <b>1.18</b><br>(0.21)  | −0.32<br>(0.31)        | −0.15<br>(0.31)        |
| Academia In              | −0.22<br>(0.22)        | −0.08<br>(0.22)        | −0.22<br>(0.22)        | <b>−0.71</b><br>(0.22) | 0.55<br>(0.29)         | <b>0.75</b><br>(0.30)  |
| NGO Out                  | −0.30<br>(0.19)        | −0.19<br>(0.19)        | −0.30<br>(0.19)        | −0.13<br>(0.19)        | −0.04<br>(0.28)        | 0.13<br>(0.27)         |
| NGO In                   | 0.17<br>(0.19)         | 0.17<br>(0.19)         | 0.17<br>(0.19)         | 0.15<br>(0.19)         | 0.08<br>(0.24)         | 0.24<br>(0.27)         |
| Government Out           | −0.35<br>(0.21)        | −0.21<br>(0.20)        | −0.35<br>(0.21)        | <b>−0.70</b><br>(0.21) | 0.51<br>(0.29)         | <b>0.74</b><br>(0.28)  |
| Government In            | 0.26<br>(0.20)         | <b>0.42</b><br>(0.20)  | 0.26<br>(0.20)         | <b>0.81</b><br>(0.20)  | −0.34<br>(0.29)        | −0.17<br>(0.28)        |
| Size Out                 | −0.04<br>(0.04)        | −0.04<br>(0.04)        | 0.00<br>(0.04)         | 0.00<br>(0.04)         | −0.07<br>(0.05)        | −0.07<br>(0.05)        |
| Size In                  | <b>0.10</b><br>(0.04)  | <b>0.10</b><br>(0.04)  | 0.00<br>(0.04)         | 0.04<br>(0.04)         | 0.09<br>(0.05)         | 0.09<br>(0.05)         |
| Experience Out           | 0.11<br>(0.06)         | 0.11<br>(0.06)         | 0.01<br>(0.06)         | 0.01<br>(0.06)         | 0.11<br>(0.07)         | 0.12<br>(0.07)         |
| Experience In            | −0.05<br>(0.06)        | −0.05<br>(0.06)        | 0.04<br>(0.06)         | 0.04<br>(0.06)         | −0.06<br>(0.07)        | −0.06<br>(0.07)        |
| Sum Methods Out          | <b>0.09</b><br>(0.04)  | <b>0.09</b><br>(0.04)  | 0.03<br>(0.04)         | 0.03<br>(0.04)         | <b>0.11</b><br>(0.05)  | <b>0.10</b><br>(0.05)  |
| Sum Methods In           | 0.03<br>(0.04)         | 0.03<br>(0.04)         | 0.05<br>(0.04)         | 0.06<br>(0.04)         | −0.01<br>(0.05)        | −0.01<br>(0.05)        |
| Sum Topics Out           | −0.02<br>(0.03)        | 0.02<br>(0.03)         | 0.00<br>(0.03)         | 0.00<br>(0.03)         | −0.00<br>(0.04)        | 0.00<br>(0.04)         |
| Sum Topics In            | 0.05<br>(0.03)         | 0.05<br>(0.03)         | 0.05<br>(0.03)         | 0.04<br>(0.03)         | 0.02<br>(0.04)         | 0.02<br>(0.04)         |
| Form Memberships Out     | 0.10<br>(0.05)         | 0.10<br>(0.05)         | <b>0.14</b><br>(0.05)  | 0.13<br>(0.05)         | 0.07<br>(0.06)         | 0.07<br>(0.06)         |
| Forum Memberships In     | −0.01<br>(0.05)        | −0.05<br>(0.05)        | −0.09<br>(0.05)        | −0.09<br>(0.05)        | −0.03<br>(0.07)        | −0.03<br>(0.07)        |
| AIC                      | 2818.70                | 2821.61                | 2818.70                | 2545.97                | 1812.46                | 1814.93                |
| BIC                      | 2987.99                | 3003.91                | 2987.99                | 2728.28                | 1981.75                | 1997.24                |
| Log Likelihood           | −1383.35               | −1382.81               | −1383.35               | −1244.99               | −880.23                | −879.47                |

Bold value indicates the significance of  $p < 0.05$

influencing actors' information exchange, but not for all actor dimensions. Results are mostly robust in subsequent models in Table 2 (columns 4–7) that show results for separate models for either technical or political information exchange only.

First, we see positive and significant results for organizational type homophily and forum homophily. Actors that are of the same type and actors that attend the same forums tend to exchange information among their peers more than with other actors that are dissimilar to them with respect to these dimensions. The size of effects, i.e., the probability of

observing a tie can be obtained by calculating the exponential function of effects.<sup>5</sup> Thus, for example, the probability of a general information exchange tie between two actors increases by 60% ( $\exp(0.41)/(1 + \exp$

<sup>5</sup> The size of effects can only be interpreted assuming that all other covariate values are the same, that is, that the rest of the network is fixed (conditional log-odds). For more detailed explanations, see 75. Goodreau SM, Handcock MS, Hunter DR, Butts CT, Morris M: **A statnet Tutorial**. *Journal of statistical software* 2008, 24:1.

(0.41)) = 0.60) if two actors are of the same type, as compared to two actors not of the same type. The second model additionally provides more specific results with respect to actor types and shows that type homophily is a significant driver of all types of information exchange for government and academic actors, while NGOs show homophily only with respect to general information exchange.<sup>6</sup>

Second, the different levels of experience, actors' size, and actors' topical profile do not seem to significantly affect information exchange, nor general nor specifically political or technical information exchange. There is a small exception with respect to actors' size and a specific type of information. We observe a weak positive effect of actors' similar size on their tendency to exchange technical information. Overall, however, for the three dimensions of experience, size and topics, both mechanisms of homophily and heterophily seem to equal each other out.

Third, we also observe tendencies of heterophily in the information exchange network around SDG implementation. General as well as technical information exchange happens more between actors with different methodological foci, as compared to actors that have a similar methodological portfolio. For example, the probability of a general information exchange tie between two actors decreases by 44% with each point of similarity between two actors' methodological portfolio.

## 5. Discussion

Our findings partially support our expectation that homophily is an important mechanism in networks of actors involved in SDG implementation. Also as expected, we observe differences across these dimensions with respect to how strongly homophily or heterophily structure the information exchange network. Actors tend to form information exchange network ties to others that are similar in terms of their organizational type and the forums they participate in. By contrast, homophily is not a relevant network mechanism related to actors' size, actors' experience in the domain of SDG 6, actors' topical focus. For the dimension of actors' methodological profile model results indicate that actors do actually "mix", that is, exchange of information happens across boundaries rather than within boundaries.

The result that actors with different methodological foci tend to exchange information more than those with the same methodological profile suggests that there exist great opportunities for developing interdisciplinary projects. Actor networks' potential to integrate different methodological profiles such as policy, engineering or research is one of the reasons why both the UN in SDG 17 (UN, 2015), as well as the academic literature on sustainability governance (O'Connor et al., 2016; UN, 2015; Barzola et al., 2019; Kamphof and Melissen, 2018; Hoff, 2018; Pärli and Fischer, 2020; Messerli et al., 2019a) emphasize the importance of diverse actor networks. For example, an actor operating in the field of advocacy could benefit from exchanging information with researchers to gain evidence for their advocacy work, while vice versa the researchers may benefit from the reach of the organization. The observation of heterophily with respect to methodological foci suggests that actors are looking for information exchange partners that complement their own methodological focus, and that they do so rather pragmatically and based on their specific project needs. In the open questions of the survey one actor explained:

*"Communication and information exchange between organisations is based on the need and the feeling that it is beneficial to program activities." (actor from civil society, 2018).*

In contrast, interacting with actors of a different organizational type and with affiliations to different forums seems more difficult for actors. Clustering of organizational types due to homophily is a frequent

mechanism in social networks in general (Henry and Dietz, 2011; Scott and Ulibarri, 2019; McPherson et al., 2001). Different organizational types often have diverse and sometimes opposing goals, dissimilar organizational structures and professional languages, different sets of knowledge, and fulfill different functions in the governance system, making coordination across them challenging (Huxham et al., 2000; Edelenbos et al., 2011). One often mentioned difficulty was for example the integration of the private sector, as exemplified by the following statements from our open survey questions:

*"Private sector and the world in which the SDGs are created are different worlds with not much links." (actor from private sector, 2018).*

*"Aligning the business agenda with the SDG agenda is a challenge for us." (actor from private sector, 2018).*

The lack of integration of the private sector in global sustainability governance and the resulting missed opportunities has already been emphasized in the literature (Abbott, 2012). Beyond the private sector, the importance of functioning information exchange systems, especially for the integration of research result, has been emphasized by an interview partner working in science:

*"We can work with nodes of the network, but not with all of them. We need to be sure that we communicate with one good node, who then distributes our information further. That does not work that well yet." (Scientist, 2018).*

Thus, diverse network structures across different types of actors are crucial for whether information reaches a variety of actors or stays within a given circle (Bodin and Crona, 2009). Related to that, another interview partner from civil society mentioned the importance of collaborative projects involving scientists and practitioners. Such projects, as discussed in the literature (Schneider et al., 2019; Fritz et al., 2019; Norström et al., 2020), create opportunities for strengthening the networks between research and other types of actors.

Most generally, a lack of integration across different types of actors could thus be a bottleneck to effective SDG implementation. Indeed, the participation of a wide range of actors, including the private sector but also research, has been described as a crucial element of SDG implementation on the national level (Biermann et al., 2017; Meuleman and Niestroy, 2015; Glass and Newig, 2019), and sustainability governance more generally.

Another option to foster information exchange networks that include a diversity of actors are forums. Our results suggest that joint forum participation is a crucial factor influencing information exchange. Being affiliated to the same forum creates more opportunities for actors to exchange information, among other things (Pärli and Fischer, 2020; Fischer and Leifeld, 2015). Contrarily, it is also possible that those actors who already exchange information join the same forums, suggesting that causality between joint forum membership and information exchange could run in both directions. Yet, all interviewees emphasized the importance of forums for information exchange. The experts see the different forums as a place for establishing contacts especially beyond their topical focus and organizational type. The example of the forum SWP which specifically targets the integration of the private sectors shows that forums might also be a useful tool to shape information exchange networks.

One expert even described forums as allowing people to learn how to communicate with people from other backgrounds. According to this interviewee, scientists who regularly attended meetings of forums would thereby be more apt to discuss issues with people from public administration, the private sector or NGOs. Another interviewee described forums as places where, thanks to the different backgrounds of the participants, many perspectives and different ways of problem-solving convene. The interviewee described such exchange as highly positive as it enhances the productivity and may lead to innovative new ways of addressing problems. The same interviewee also specifically mentioned

<sup>6</sup> An additional model, not shown here, shows that there is no homophily among private actors (when using NGO as a reference category).

the role of the forum SDSN, which is not directly related to water but to the implementation of the Agenda 2030 in general and thus connects highly diverse actors. Thus, the observed homophily regarding participation in the same forums might, according to our qualitative data, facilitate and foster information exchange between different actors in terms of organizational type or topical focus. Forums thus greatly contribute to actor networks, but they might also run the risk of creating separate spaces where subsets of actors exchange, but not mix. Regarding sustainability governance and the potential benefits of heterophilous actors interactions (O'Connor et al., 2016; UN, 2015; Barzola et al., 2019; Kamphof and Melissen, 2018; Hoff, 2018; Pärli and Fischer, 2020; Messerli et al., 2019a), our results also show that information is exchanged within but not across forums.

Actors with different size, different levels of experience, and focusing on different topics within and related to SDG 6 neither show specific tendencies to heterophily nor to homophily. The latter suggests that some cross-sectoral exchange is happening with respect to different topics, but actors do not explicitly reach out to others with different topical foci. Mixing different topical foci is important, as the literature has repeatedly assessed how different SDGs are strongly interconnected and potential synergies and trade-offs exist across them (Messerli et al., 2019a; Pham-Truffert et al., 2020; Griggs et al., 2017; Nilsson et al., 2018; Messerli et al., 2019b). An interviewee working in public administration described this problem as a thematic gap. She implied that the Swiss actors working on the implementation of the SDG 6 were divided and exchange between different topics was still missing. Another interviewee mentioned that the implementation of the SDG 6 requires all involved actors to have a holistic understanding of the water cycle, as otherwise, the connections between the different sub goals might be neglected.<sup>7</sup> This is in line with the already mentioned statement from an actor emphasizing that information exchange increases once organizations feel the need of such an exchange for their program activities. However, interviewees from public administration and civil society stated that while the need to bridge topics is still high, fragmentation has reduced over the last years. This could help to increase policy coherence related to SDG implementation (Biermann et al., 2017; Meuleman and Niestroy, 2015; Glass and Newig, 2019). Furthermore, collaborative approaches bridging science and practice might facilitate the exchange across subgoals and thus overall SDG implementation, as they are not only aiming to bridge researchers and non-academic actors but also integrate several disciplines to tackle interconnected problems (Bixler et al., 2019).

## 6. Conclusions

This article studies how mechanisms of homophily and heterophily influence sustainability and network governance in the context of SDG implementation. More specifically, we analyze networks of information exchange between Swiss actors in implementing the SDG 6 in the global South. Our analysis has focused on important sub-structures within networks related to homophily (that is, actors having network ties with actors similar to them) or heterophily (that is, actors having ties with actors dissimilar to them). Homophily and heterophily have important theoretical implications for (global) sustainability governance. Heterophilous network relations among actors dissimilar to each other can be associated with cross-sectoral coordination, claimed to be pivotal for SDG implementation, and network governance of sustainable

development, more generally (Biermann et al., 2017; Kanie and Biermann, 2017; Hoff, 2018; Berkes, 2002). Yet, the relation studies in this analysis, information exchange, is a mere precondition for these further outcomes (Keast et al., 2007; Margerum, 2008).

This study contributes to the literature on network governance by highlighting that both homophily and heterophily can be present with respect to different actor dimensions (Henry and Dietz, 2011; Leifeld and Schneider, 2012; Scott and Ulibarri, 2019). In the context of (global) sustainability governance, such a network perspective provides one angle to understanding the complexities of SDG implementation in relation to extraterritorial responsibilities of industrialized countries, as well as to the implementation of SDG 17 focusing on collaborative partnerships among many different actors (UN, 2015). Overall, we find that it is easier for actors to exchange with others that are similar in terms of organizational type and forum participation. Especially actor type homophily could represent a bottleneck for efficient SDG implementation, and is a major impediment to achieving SDG 17 on actor partnerships. However, we also find that actors tend to exchange information with others that are different to them in terms of methodological focus. This heterophily with respect to methods indicates great opportunities for actors to, e.g., learn from others (Bennett and Howlett, 1992), and implement interdisciplinary projects for SDG implementation.

Our result regarding forums is especially interesting. In line with our qualitative data as well as the literature on forums (Fischer and Leifeld, 2015; Maag and Fischer, 2018), we find that shared forums increase chances of information exchange. However, forums also present an opportunity for exchange between different actors, e.g. between government, academia and civil society (Maag and Fischer, 2018), or with different ideas and goals. That is, whereas actors in the same forum tend to exchange information, the fact that forums include a diversity of actors could still support information exchange across actors that differ on other dimensions, such as their organizational type or topical portfolio. Of course, a full understanding of the functioning of these forums should be pursued in further research, and include answering questions such as why actors participate in these forums (Olivier and Berardo, 2021), how these “collaboration spaces” work (Fischer and Leifeld, 2015), and how they contribute to the implementation of SDGs (Pärli and Fischer, 2020) and (global) sustainability governance.

The case of Switzerland is likely to be representative of industrialized countries of the global North with an extraterritorial responsibility, and is a typical case of collaborative and network governance. We thus expect that empirical results with respect to actor collaboration would tend towards the same directions also in other, comparable country contexts. Furthermore, related to the Swiss case context, Switzerland has lots of professional and scientific expertise in the water sector. Yet, the current literature on the use of evidence in decision-making suspects that the involved actors might not share the produced evidence sufficiently (Hering, 2016; Crewe and Young, 2002).

Based on our findings, we suggest the following recommendations to actors involved in the implementation of the SDG 6 in countries of the global South. First, studies and tools presenting the interconnectedness of the SDGs are likely worthwhile to raise awareness and to trigger actors to think outside of their core competencies. Second, we encourage actors involved in sustainability governance as well as researchers studying related processes to consider different dimensions such as organizational type, methodological focus, size or methodological focus when thinking about the costs and benefits of information exchange with others. Third, we propose to give more emphasis to information exchange across sectors. Supporting forums, collaborative approaches bridging science and practice, as well as specific funding schemes for cross-sectoral projects, considering the increased time resources, could support that actors combine their agendas across different dimensions and combine different types of expertise.

<sup>7</sup> “The SDG 6 requires a holistic understanding of the water cycle and the will to act on its whole, which is not understood by many stakeholders. Combining a public health and environmental health perspectives is a challenging task, often overseen because of too narrow focus of interventions. Generally speaking, the sector also suffers from too many stakeholders lacking the most basic understanding of the relations between surface and groundwater as well as the link between land use and water quantity or quality.”



**Declaration of Competing Interest**

None.

**Acknowledgements**

We thank the two anonymous reviewers for their helpful inputs.

**Appendix 1****Table A1**  
Actors' list.

| Actor  | Type           |
|--|----------------|
| Eawag - Department Sanitation and Solid Waste for Development                        | Academia       |
| Eawag - Department for Environmental Social Sciences                                 | Academia       |
| Eawag - Department Process Engineering   | Academia       |
| Eawag - Department Urban Water Management  | Academia       |
| Eawag - Department Environmental Microbiology  | Academia       |
| Eawag - Department Water Resources and Drinking Water                                | Academia       |
| ETHZ - Institute of Biogeochemistry and Pollutant Dynamics                           | Academia       |
| University of Neuchatel - Centre for Hydrology and Geomethric (CHYN)                 | Academia       |
| SUPSI - Centre for Development and Cooperation                                       | Academia       |
| University of Berne - Center for Development and Environment (CDE)                   | Academia       |
| HAFL - International Agriculture and Rural Development                               | Academia       |
| HAFL -Sustainability and Ecosystems  | Academia       |
| University of Geneva - Platform for International Water Law                          | Academia       |
| University of Basel - Swiss Tropical and Public Health Institute                     | Academia       |
| State Secretariat for Economic Affairs (SECO) - Economic Cooperation and Development | Government     |
| Federal Office for Agriculture (FOA) - International Affaires                        | Government     |
| Swiss Agency for Development and Cooperation (SDC) - Global Programme Water          | Government     |
| SDC - Global Programme Climate Change  | Government     |
| SDC - Global Cooperation   | Government     |
| SDC - South Cooperation  | Government     |
| SDC - Cooperation with Eastern Europe  | Government     |
| SDC - Humanitarian Aid and SHA   | Government     |
| Swiss Cooperation Office Islamabad   | Government     |
| Swiss Cooperation Office Tanzania  | Government     |
| Swiss Cooperation Office Uzbekistan  | Government     |
| Swiss Cooperation Office Tajikistan  | Government     |
| Swiss Cooperation Office Kyrgyzstan  | Government     |
| Swiss Cooperation Office Ukraine   | Government     |
| Swiss Cooperation Office Macedonia   | Government     |
| Swiss Cooperation Office Kosovo  | Government     |
| Programme Office Colombia  | Government     |
| Swiss Cooperation Office Libanon   | Government     |
| Antenna Technologies   | NGO            |
| Seecon   | NGO            |
| HEKS   | NGO            |
| Sanakvo Foundation   | NGO            |
| Solar Pump Association Switzerland   | NGO            |
| Swiss Red Cross  | NGO            |
| SwissWaterKiosk  | NGO            |
| World Vision   | NGO            |
| WWF Switzerland  | NGO            |
| Terre des hommes   | NGO            |
| Aquasis Solutions  | NGO            |
| Waterpreneurs  | NGO            |
| Skat Consulting Ltd.   | NGO            |
| Biovision  | NGO            |
| The Gold Standard Foundation   | NGO            |
| Fastenopfer  | NGO            |
| Solidar Suisse   | NGO            |
| Wasser für Wasser  | NGO            |
| Vivamos Mejor  | NGO            |
| Tearfund   | NGO            |
| Fairmed  | NGO            |
| Morija   | NGO            |
| Nouvelle Planète   | NGO            |
| SolidarMed   | NGO            |
| Stiftung Green Ethiopia  | NGO            |
| Autark Engineering   | Private Sector |
| ECOPSIS  | Private Sector |
| EBP Schweiz  | Private Sector |
| Hydrosolutions Ltd   | Private Sector |
| Swiss Bluetec Bridge   | Private Sector |
| South Pole Group   | Private Sector |
| Swiss Fresh Water  | Private Sector |
| Odermatt & Brockmann   | Private Sector |
| Aqua-4D® Water solutions   | Private Sector |

(continued on next page)

**Table A1** (continued)

| Actor                     | Type           |
|---------------------------|----------------|
| Swiss Toilet Organization | Private Sector |
| Geberit                   | Private Sector |
| Nestle                    | Private Sector |
| CSD Engineers             | Private Sector |
| Georg Fischer             | Private Sector |

## Appendix 2

### Exponential Random Graph Modeling

Exponential Random Graph Models (ERGM) (Robins et al., 2007) allow for statistical inference on network data. Observations on networks cannot be assumed to be non-independent, as the structural properties of the network in which two actors are embedded might influence whether they share a network tie or not (Leifeld and Schneider, 2012; Cranmer and Desmarais, 2011; Fischer and Sciarini, 2014; Gerber et al., 2013). Normal regression models do not take this dependency into account and do erroneously attribute explanatory power to exogenous variables (Cranmer and Desmarais, 2011). The dependent variable of an ERGM is a single observation on the whole network (Cranmer and Desmarais, 2011). The structure of this whole network is then modeled given actor-level variables (node covariates), dyadic variables (edge covariates), and endogenous network structures. The latter correspond to effects of network structures on the network itself, i.e. actors' tendency to reciprocate ties or close triangles. The model then assesses the probability of observing the given network compared to all other networks that could have been observed. ERGMs rely on Markov Chain Monte Carlo Maximum Likelihood (MCMC-MLE), given that the computation of the exact maximum likelihood is too demanding (Cranmer and Desmarais, 2011).

## Appendix 3

**Table A2**ERGM results with sub-categories,  $p < 0.05$ .

|                               | Topics                        | Forums                        |
|-------------------------------|-------------------------------|-------------------------------|
| Same Actor Type               | <b>0.40</b><br><b>(0.06)</b>  | <b>0.41</b><br><b>(0.06)</b>  |
| Similarity Size               | 0.03<br>(0.02)                | 0.03<br>(0.02)                |
| Similarity Experience         | 0.01<br>(0.03)                | 0.00<br>(0.03)                |
| Similarity Methods            | <b>-0.23</b><br><b>(0.09)</b> | <b>-0.24</b><br><b>(0.09)</b> |
| Similarity Topics             |                               | 0.11<br>(0.08)                |
| Both Drinking Water           | <b>0.18</b><br><b>(0.07)</b>  |                               |
| Both Sanitation & Hygiene     | -0.05<br>(0.07)               |                               |
| Both Water Quality            | 0.03<br>(0.07)                |                               |
| Both Water Use Efficiency     | 0.07<br>(0.06)                |                               |
| Both IWRM                     | 0.08<br>(0.06)                |                               |
| Both Water-Related Ecosystems | -0.03<br>(0.06)               |                               |
| Both Water & Agriculture      | <b>0.18</b><br><b>(0.06)</b>  |                               |
| Similarity Forum              | <b>0.30</b><br><b>(0.08)</b>  |                               |
| Both ResEau                   |                               | <b>0.15</b><br><b>(0.06)</b>  |
| Both SDSN                     |                               | <b>0.18</b><br><b>(0.06)</b>  |
| Both AGUASAN                  |                               | 0.02<br>(0.07)                |
| Edges                         | <b>-6.37</b><br><b>(0.26)</b> | <b>-6.40</b><br><b>(0.24)</b> |
| Reciprocity                   | <b>4.25</b><br><b>(0.19)</b>  | <b>4.26</b><br><b>(0.19)</b>  |
| Triadic closure (GWESP)       | <b>1.09</b><br><b>(0.12)</b>  | <b>1.11</b><br><b>(0.12)</b>  |
| Triadic closure (GWDSP)       | 0.01<br>(0.01)                | 0.01<br>(0.01)                |
| Academia Out                  | <b>0.43</b><br><b>(0.21)</b>  | <b>0.42</b><br><b>(0.21)</b>  |
| Academia In                   | -0.24                         | -0.24                         |

(continued on next page)

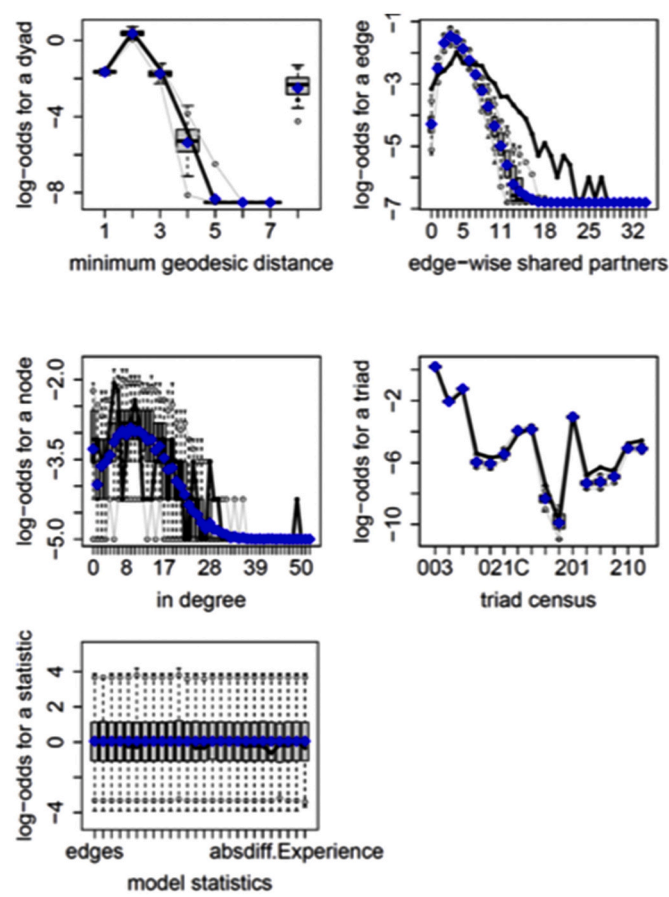
**Table A2** (*continued*)

|                      | Topics        | Forums        |
|----------------------|---------------|---------------|
|                      | (0.22)        | (0.22)        |
| NGO Out              | −0.30         | −0.33         |
|                      | (0.19)        | (0.19)        |
| NGO In               | 0.17          | 0.15          |
|                      | (0.19)        | (0.19)        |
| Government Out       | −0.37         | −0.38         |
|                      | (0.21)        | (0.21)        |
| Government In        | 0.25          | 0.25          |
|                      | (0.21)        | (0.21)        |
| Size Out             | −0.05         | −0.05         |
|                      | (0.04)        | (0.04)        |
| Size In              | <b>0.11</b>   | <b>0.10</b>   |
|                      | <b>(0.04)</b> | <b>(0.04)</b> |
| Experience Out       | 0.11          | 0.10          |
|                      | (0.06)        | (0.06)        |
| Experience In        | −0.05         | −0.06         |
|                      | (0.06)        | (0.06)        |
| Sum Methods Out      | <b>0.09</b>   | <b>0.08</b>   |
|                      | <b>(0.04)</b> | <b>(0.04)</b> |
| Sum Methods In       | 0.03          | 0.02          |
|                      | (0.04)        | (0.04)        |
| Sum Topics Out       | −0.01         | −0.02         |
|                      | (0.03)        | (0.03)        |
| Sum Topics In        | 0.06          | 0.05          |
|                      | (0.03)        | (0.03)        |
| Form Memberships Out | 0.10          | <b>0.18</b>   |
|                      | (0.05)        | <b>(0.05)</b> |
| Forum Memberships In | −0.05         | 0.02          |
|                      | (0.05)        | (0.05)        |
| AIC                  | 2811.82       | 2821.48       |
| BIC                  | 3020.18       | 3003.80       |
| Log Likelihood       | −1373.91      | −1382.74      |

Bold value indicates the significance of  $p < 0.05$

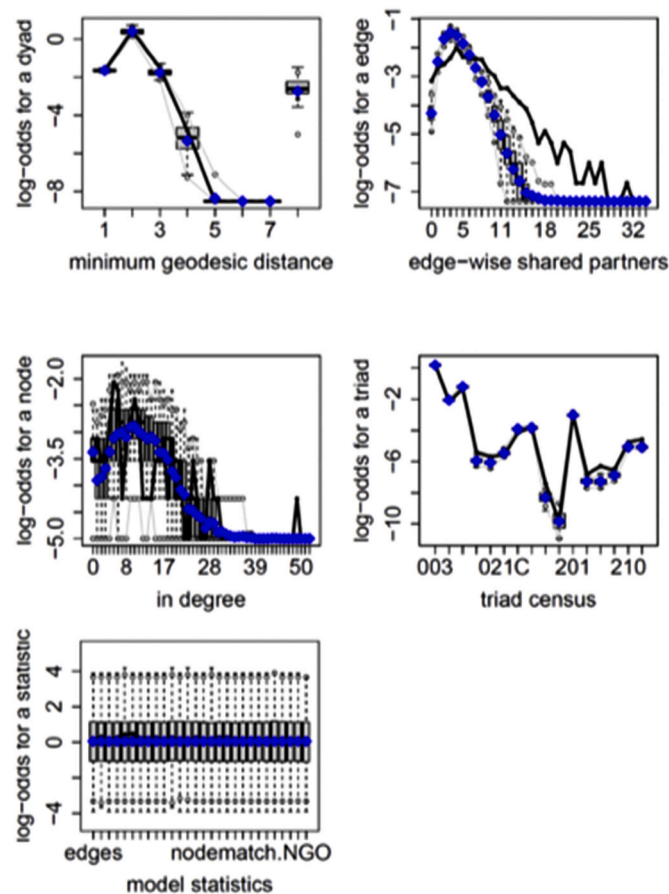
#### Appendix 4

*Goodness of fit model “all ties 1”*



Goodness of fit model “all ties 2”





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