Annex: Data, models, diagnostics, and statistical and technical information

To the Article "Germany's Energy and Climate Policy as an Ecology of Games" by Volker Schneider

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This Annex provides detailed background information on the empirical foundation and modelling approach of the study. It begins with an overview of the data collection process and a description of the dataset used for the analysis. This is followed by technical documentation of the Exponential Random Graph Models (ERGMs), including specifications of the basic, full, and reduced models. The Annex also presents Markov Chain Monte Carlo (MCMC) diagnostics and goodness-of-fit (GoF) plots to assess model convergence and robustness.

Collection of network data

Between August 2011 and October 2012, we interviewed 51 organizations active in German climate change discourse. Pre-test interviews with experts from climate institutes ensured that the questions were clear and accessible. For sampling, we applied a simplified version of Laumann and Knoke's (1987) boundary specification method, combining media analysis and snowball sampling. Initially, organizations were selected based on a media analysis which was also used fora discourse network analysis (Schneider & Ollmann, 2013). We listed all actors (national, foreign, or transnational) cited at least twice per year in newspaper articles on climate change between 2007 and 2010. This list was then expanded to include organizations identified as important at least twice during the interviews. National and transnational actors with a German presence were contacted for interviews. Seven organizations were added via snowball sampling. Foreign and transnational actors without a German office were not interviewed, but could be selected in the relational part of the study. Midway through the interviews, the list was reviewed and organizations identified as important fewer than twice were removed.

We interviewed one representative per organization, selecting the person responsible for climate change issues. If this individual couldn't be identified online, the public affairs manager was asked to nominate them. Most interviews were conducted face-to-face; when time constraints prevented this, they were done by phone or email. To secure participation, we assured full confidentiality—not only of individuals but also of their organizations. Therefore, neither organization names nor individual names appear in this study or in the diagrams.

Sample composition and response rate

Political and societal sectors	Sample size	Responses	Response rate
Ministries and governmental agencies	9	3	33%
Political parties	6	5	83%
Scientific institutes and bodies	15	14	93%
Firms and business associations	31	21	68%
Civil society organizations	9	8	89%
Sum	*70*	*51*	*73%*

Table 1 summarizes the sample composition and sectoral response rates. Most ministries declined to participate, though the key ministry for climate policy—the Federal Ministry for the Environment—was included. The German Liberal Party was the only political party that refused. Among business associations, three representing the energy and water sector did not participate, potentially distorting the data. However, this distortion is balanced somewhat, as non-responses came from both renewable and non-renewable sectors. Three non-responses among companies involved car manufacturers. Additionally, two organizations were excluded due to excessive missing data.

Data description

A total of 48 policy organizations were included in the analysis. Table A2 summarizes the networks, listing the number of vertices and edges, along with three key indices: density (actual vs possible ties), reciprocity (mutual ties in directed networks), and transitivity (closed vs connected triplets).

Summaries of network data

Networks	Vertices	Edges	Density	Reciprocity	Transitivity
Influence reputation	48	964	0.4273	0.4896	0.6347
Information received	48	660	0.2926	0.3091	0.5994
Information sent	48	429	0.1902	0.2145	0.5247
Collaboration	48	359	0.1591	0.3287	0.4721
Advice giving	48	197	0.0873	0.0711	0.4871

Network analytic statistical modelling was conducted using the R packages *sna* and *statnet* (Butts, 2008; Hunter et al., 2008). Some of the figures were visualized with visone (Brandes & Wagner, 2004), others were generated using the Python programming language. The code development was interactively supported with the assistance of ChatGPT (OpenAI), serving as a programming and troubleshooting aid to enhance the reproducibility and transparency of the graphical outputs.

ERGM model specifications

The following provides a detailed overview of the three ERGMs estimated for the analysis: a basic model, a full model, and a reduced model. All models share the same dependent variable, which captures mutually confirmed information exchange between actors within the climate–energy policy network. This binary outcome indicates whether a direct tie was mutually acknowledged by both actors involved.

The models progressively incorporate different types of covariates and structural dependencies. The basic model includes only the edges term, which serves as a baseline control for network density. The full model expands on this by including a set of endogenous network processes, such as mutuality (reciprocity of ties), indegree popularity (preference for well-connected actors), and triadic closure (tendency to form transitive or closed triads).

In addition, the full model includes edge covariates (edcov) capturing the similarity or presence of relational structures external to the confirmed information exchange network, namely: issue similarity, based on actors' positions in the issue space, collaboration ties, and advice relations. The reduced model is derived by systematically excluding statistically insignificant covariates from the full model to improve model parsimony while maintaining explanatory power.

For each model, we report the estimated coefficients along with their standard errors, providing insight into the direction, strength, and significance of each effect. We also include model fit diagnostics, such as MCMC convergence plots and GoF statistics, to evaluate the empirical adequacy of the models in reproducing key structural features of the observed network.

Basic, full, and reduced model (ERGM)

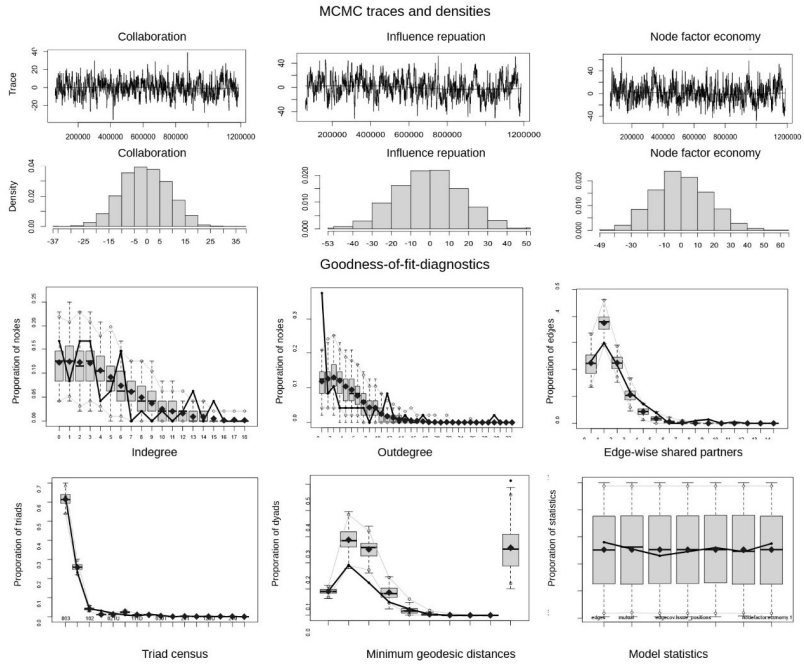
Variables/factors	**Basic**	**Full**	**Reduced**
Edges	-3.61 ***	-3.72 ***	-4.00 ***
	(0.24)	(0.36)	(0.29)
Mutual	1.40 ***	0.46	0.45
	(0.25)	(0.29)	(0.29)
edgecov.Issue_positions	0.17 ***	-0.00	-0.01
	(0.03)	(0.03)	(0.03)
gwideg.fixed.0.2 (indegree popularity)		-0.52	
		(0.50)	
gwesp.OTP.fixed.0.2 (clustering tendency/triangle closure)		1.04 ***	1.13 ***
		(0.16)	(0.14)
edgecov.Collaboration		0.51 **	0.48 **
		(0.18)	(0.17)
edgecov.Advice		-0.06	
		(0.23)	
edgecov.Influence_reputation		0.88 ***	0.88 ***
		(0.17)	(0.17)
nodematch.subsys (exchange within subsystems)		-0.09	
		(0.19)	
nodefactor.politics.1 (political actors)		-0.15	
		(0.11)	
nodefactor.economy.1 (economic actors)		-0.38 **	-0.31 **
		(0.15)	(0.12)
nodefactor.science.1 (scientific actors)		-0.06	
		(0.11)	
AIC	1334.33	1144.08	1137.87
BIC	1351.49	1212.73	1177.92
Log Likelihood	-664.16	-560.04	-561.94

A visual comparison of the three ERGM models is presented in Figure 4 using Leifeld's *plotreg*() function from the *texreg* package in R (Leifeld, 2013).

MCMC convergence plots and GoF diagnosis of reduced ERGM

To check convergence and robustness, MCMC diagnostics and GoF procedures and plots were applied, using subroutines in statnet. In the reduced model, MCMC diagnostics were generated for the three parameters estimated using stochastic simulation: collaboration, influence reputation, and economy (nodefactor). The trace and density plots show good convergence behaviour indicating a stable model varying stochastically around their respective value in the observed network.

The GoF diagnosis compares simulated networks to the observed network on degree distribution (indegree and outdegree), edgewise shared partners (triadic closure), triad census, and model statistics (summary of terms used). Each plot shows the observed statistic (black line) and the simulated range (grey envelope) based on the fitted model. The diagnosis shows a rather good fit since the black line falls, with few exceptions, within the grey envelope (simulated quantiles). In other words, the model adequately reproduces that network feature.



Measuring political mood and issue salience

The *Politbarometer* captures political mood through a representative survey asking: *"Which party would you vote for if federal elections were held next Sunday?"*

Issue salience is assessed using a specific open-ended question: *"In your opinion, what is currently the most important problem in Germany?"* The responses are subsequently coded into thematic categories (e.g., *"migration", "energy policy"*). The percentage of respondents mentioning each issue is reported, indicating how salient it is in public opinion at that time. Datasets are available on the website: https://www.forschungsgruppe.de/Umfragen/Politbarometer/. For methodological discussions on these survey strategies see Kaase (2003), Wlezien (2005), and recently Teney and Rupieper (2023).

Scoring procedure of the Climate Change Performance Index (CCPI)

The Climate Change Performance Index (CCPI), published annually by Germanwatch, the NewClimate Institute, and the Climate Action Network, evaluates and compares the climate policy performance of more than 60 countries responsible for over 90% of global GHG emissions. The index is based on standardized indicators grouped into four categories (weights in brackets): (1) GHG emissions (40%) including current emissions levels, trends, and targets. (2) Renewable energy (20%)—share and dynamics of renewables in energy production. (3) Energy use (20%)—per capita energy consumption and changes over time. (4) Climate policy (20%)—expert assessments of national and international climate policies.

Scores in each category are normalized and combined into an overall performance score. Countries are ranked accordingly, with the top three positions often left empty to signal that no country is currently on a pathway consistent with the Paris Agreement. The methodology is transparent and publicly available, and the index is widely used in policy analysis and scholarly research.

Use of AI-assisted tools

Parts of the writing and revision process for this article were supported by AI-based tools. DeepL was used for preliminary translation and phrasing support, particularly in earlier drafting stages. ChatGPT (OpenAI, 2024–2025 editions) was employed to assist with language refinement across the manuscript and for programming assistance. All content was critically reviewed, fact-checked, and revised by the author to ensure academic integrity and intellectual responsibility.

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