Appendix 1

CASE SELECTION AND CODING

To reveal specific conditions that explain the appearance of opportunities for achieving climate adaptation, we conduct an archetype analysis of 26 selected case studies on water governance adaptation in river basins worldwide. The selection of these primary cases is based on the study of Oberlack and Eisenack (2018), where barriers to adaptation are thoroughly explored. This allows for examination of factors that enable adaptation opportunities in the context of already identified adaptation barriers. The studies were retrieved from the databases of Web of Science and Scopus so that the research is based on primary data and the articles are peer-reviewed. The final sample included primary studies on water governance adaptation in river basins worldwide from 20 scientific journals for the period of 1990-2015 (Table A1.1).

River basin	Reference
Watersheds in Washington State (USA)	Binder, L. C. W. 2006. Climate change and watershed planning in Washington state. *Journal of the American Water Resources Association* 42: 915–926
McKenzie River (USA)	Farley, K.A., C. Tague, and G.E. Grant. 2011. Vulnerability of water supply from the Oregon Cascades to changing climate: Linking science to users and policy. *Global Environmental Change* 21: 110–122
Yahara River (USA)	Gillon, S., E.G. Booth, and A.R. Rissman. 2015. Shifting drivers and static baselines in environmental governance: Challenges for improving and proving water quality outcomes. *Regional Environmental Change* 16: 759–775
Columbia River (USA)	Hamlet, A.F. 2011. Assessing water resources adaptive capacity to climate change impacts in the Pacific Northwest Region of North America. *Hydrology and Earth System Sciences* 15: 1427–1443
Susquehanna River (USA)	O'Connor, R.E., B. Yarnal, R. Neff, R. Bord, N. Wiefek, C. Reenock, R. Shudak, C.L. Jocoy, P. Pascals, and C.G. Knight. 1999. Weather and climate extremes, climate change, and planning: Views of Community Water System Managers in Pennsylvania's Susquehanna River Basin. *Journal of the American Water Resources Association* 35: 1411–1419
Bear river basin (USA)	Welsh, L.W., J. Endter-Wada, R. Downard, and K.M. Kettenring. 2013. Developing adaptive capacity to droughts: The rationality of locality. *Ecology and Society* 18: 7
Jaguaribe-Banabuiu Basin, Itajai Basin (Brazil) and Watersheds in Arizona and Georgia (USA)	Kirchhoff, C.J., M.C. Lemos, and N.L. Engle. 2013. What influences climate information use in water management? The role of boundary organizations and governance regimes in Brazil and the U.S. *Environmental Science & Policy* 26: 6–18
Colorado River (Mexico, USA)	Pulwarty, R.S., and T.S. Melis. 2001. Climate extremes and adaptive management on the Colorado River: Lessons from the

	1997–1998 ENSO event. *Journal of Environmental Management* 63: 307–324
Arizona-Sonora region (Mexico, USA)	Wilder, M., C.A. Scott, N.P. Pablos, R.G. Varady, G.M. Garfin, and J. McEvoy. 2010. Adapting across boundaries: climate change, social learning, and resilience in the U.S.–Mexico border region. *Annals of the Association of American Geographers* 100: 917–928
Colorado River (Mexico, USA) and Guadiana River (Portugal, Spain)	Pulwarty, R.S., and R. Maia. 2015. Adaptation Challenges in Complex Rivers Around the World: The Guadiana and the Colorado Basins. *Water Resources Management* 29: 273–293.
Southern Saskatchewan (Canada)	Hurlbert, M., H. Diaz, D.R. Corkal, and J. Warren. 2009. Climate change and water governance in Saskatchewan, Canada. *International Journal of Climate Change Strategies and Management* 1: 118–132
Okanagan (Canada)	Shepherd, P., J. Tansey, and H. Dowlatabadi. 2006. Context Matters: What Shapes Adaptation to Water Stress in the Okanagan? *Climatic Change* 78: 31–62
Columbia River (Canada, USA)	Cosens, B.A., and M.K. Williams. 2012. Resilience and Water Governance: Adaptive Governance in the Columbia River Basin. *Ecology and Society* 17: 3
Southern Saskatchewan (Canada) and Elqui (Chile)	Hurlbert, M.A., and H. Diaz. 2013. Water Governance in Chile and Canada: A Comparison of Adaptive Characteristics. *Ecology and Society* 18: 61-83
Mendoza (Argentina) and Oldman River (Canada)	Hurlbert, M.A., and E. Montana. 2015. Dimensions of Adaptive Water Governance and Drought in Argentina and Canada. *Journal of Sustainable Development* 8: 120-137
18 river basins in Brazil	Engle, N.L., and M.C. Lemos. 2010. Unpacking governance: Building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change* 20: 4-13
Aconcagua River (Chile)	Hill-Clarvis; M. and Allan; A. (2014): Adaptive capacity in a Chilean context: A questionable model for Latin America. Environmental Science & Policy, 43, 78–90.
Aconcagua (Chile) and Rhone (CH)	Hill, M. 2013. Adaptive capacity of water governance: cases from the Alps and the Andes. *Mountain Research and Development* 33: 248–259
Guadiana River (Portugal, Spain)	Cots, F., J.D. Tàbara, D. McEvoy, S. Werners, and E. Roca. 2009. Cross-Border Organisations as an Adaptive Water Management Response to Climate Change: The Case of the Guadiana River Basin. *Environment and Planning C* 27: 876–893
Multiple rivers in Denmark	Larsen, S.V. 2011. Risk as a challenge in practice: Investigating climate change in water management. *Regional Environmental Change* 11: 111–122

Orange-Senqu River (Botswana, Lesotho, Namibia, South Africa)	Kistin, E.J., and P.J. Ashton. 2008. Adapting to Change in Transboundary Rivers: An Analysis of Treaty Flexibility on the Orange-Senqu River Basin. *International Journal of Water Resources Development* 24: 385–400
Catchments in northeast Queensland (Australia)	Boer, H. 2010. Policy options for, and constraints on, effective adaptation for rivers and wetlands in northeast Queensland. *Australasian Journal of Environmental Management* 17: 154–164
Murray-Darling Basin (Australia)	Pittock, J., and C.M. Finlayson. 2013. Climate change adaptation in the Murray-Darling Basin: Reducing resilience of wetlands with engineering. *Australian Journal of Water Resources* 12: 161-169
Murray-Darling Basin (Australia)	Wei, Y., J. Langford, I.R. Willett, S. Barlow, and C. Lyle. 2011. Is irrigated agriculture in the Murray Darling Basin well prepared to deal with reductions in water availability? *Global Environmental Change* 21: 906–916
Tweed River (Australia)	Singh-Peterson, L., S. Serrao-Neumann, F. Crick, and I. Sporne. 2013. Planning for climate change across borders: Insights from the Gold Coast (QLD) – Tweed (NSW) region. *Australian Planner* 50: 148–156
Elbe, Guadiana, Rhine, Nile, Orange, Amudarya	Krysanova, V., C. Dickens, J. Timmerman, C. Varela-Ortega, M. Schlüter, K. Roest, P. Huntjens, F. Jaspers, H. Buiteveld, E. Moreno, J. de Pedraza Carrera, R. Slámová, M. Martínková, L. Blanco, P. Esteve, K. Pringle, C. Pahl-Wostl, and P. Kabat. 2010. Cross-Comparison of Climate Change Adaptation Strategies Across Large River Basins in Europe, Africa and Asia. *Water Resources Management* 24: 4121–4160

Table A1.1 Primary case studies and river basins

Since selected case studies contain heterogenic data and contexts, we refer to archetype analysis. In such instance, this approach appears to be valuable in that it generates two extremes that one could run to by trying to identify some regularities: context-specificity and over-generalization. Archetypes are representative patterns of human-environmental interactions that are recurrently observed (Eisenack et al. 2006).

To identify interactions between various elements in adaptation situations coding methodology was used. Coding is a practical tool that is widely used for a qualitative analysis as it helps to systematically organize textual data. We coded text segments in the selected publications that describe situations, under which opportunities for adaptation emerge.

Development of codes for the present study on adaptation opportunities was based on the Ostrom's (2009) Social-Ecological Systems (SES) framework and on its modification for the climate adaptation context by Oberlack and Eisenack (2018). In most general terms, the SES framework encompasses outcomes (IO) in action situations framed by the core elements of the SES: resource systems (RS), resource units (RU), actors (A) and governance systems (GS) (Ostrom 2009). These elements or subsystems function within broader social-political-economic settings (S) and in the context of related ecological systems (ECO). The modification of the framework for the climate adaptation context involves the addition of the category "adaptation option" (AO) to characterize adaptation examined in a primary study. The elements introduced above represent first-tier categories in the SES framework. More detailed codes that include explanatory factors form second- and third-tier attributes of the adjusted SES framework (e.g. GS51 stakeholder participation, RS221 climate stimuli not (yet) experienced: flood).

Coding of the data from primary case studies was processed electronically with the use of the software MaxQDA. The segments of the case studies that proved to include explanatory factors form second- and third-tier attributes of the adjusted SES framework were systematically coded. This was done using at least one interaction attribute (IO) and at least another one from the remaining SES elements (RS, A, GS, S, or AO). Rationale for requiring at least one interaction attribute (IO) is that opportunities for adaptation were operationalized as an interaction attribute: whenever an interaction attribute is observed, an opportunity is observed as well. The interaction attribute represents thus the *outcome set* for the analysis of the data produced through the coding process.

If the interaction attribute represents the outcome set, the remaining attributes constitute the model inherent to each causal statement coded herewith. The model encapsulates the results of interactions documented in primary studies and is the unit of analysis. Therefore, similar to Oberlack (2017) and Oberlack and Eisenack (2018) our meta-analysis is "model-centered" (Rudel 2008). Rationale for focusing the analysis on models is the following: 1) models represent explicit statements, thus requiring less interpretation than the case as a whole; 2) although they represent a reduction of complexity, they were done by someone with case-level knowledge; and 3) they passed the peer-review process, which, with all its limitations, should guarantee a minimum degree of reliability.

The fact that our research aims at exploring opportunities for climate adaptation, which is yet an emerging concept and is less addressed in comparison to the concept of barriers to adaptation, requires a consideration of a wider unit of observation. This means that a pure causal statement where one factor or combination of factors lead to a particular outcome (see Oberlack 2017) does not allow to describe the whole situation, under which opportunities for achieving adaptation arise. This is why we discerningly deviate from the approach of pure „causal statements" as in Oberlack (2017) and Oberlack and Eisenack (2018) and consider models as „narratives" that describe how a particular enabling factor (e.g. provision of climate information) coupled with other factors (attributes from the SES framework) leads to adaptation to climate change. In this sense, models encapsulate the presence of adaptation due to provision of climate information (e.g. in contrast to adaptation due to institutional change) and other attributes that help to describe situations in which such adaptation emerge, which makes it possible to identify its nature (incremental vs transformational).

Some examples of how causal statements were identified and coded will help clarify how models came about. For a practical illustration we refer to the paper of Kirchhoff et al. (2013). The paper addresses the role of water governance regimes and boundary organizations in shaping climate information use. Kirchhoff et al. (2013) build their study on the analysis of data obtained from surveys of river basin councils' members and interviews with water and disaster managers in the United States and Brazil. In search of causal statements, we look for text segments in the paper that explicitly link the characteristics of a particular situation to specific opportunities for adaptation. By doing so, we pay a particular attention that such explanations are found in direct presentation of the results and do not refer to some theoretical observations of other authors mentioned in the paper, i.e. they are not part of the literature review. Once such causality was observed, it was coded upon the common vocabulary of attributes.

One of the models we found in the study of Kirchhoff et al. (2013) crystallized out of the following text passage: "*In Arizona, interviews with water managers working with CLIMAS*[1] *revealed they were sensitive to climatic conditions and to other issues that affect water availability. These managers recognized that climate variability, and to a lesser extent climate change, may put water resources at increased risk in the future, given population growth and competition for water resources. Their perception of the vulnerability of water resources to climatic risks coupled with their goal of providing reliable water supplies was an important motivator for sustaining interaction with CLIMAS to produce usable climate information.*" We interpreted and coded this passage as following:

- Actor characteristics (A): this text segment allows for coding several actors' characteristics, such as "awareness of climate impacts", "understanding climate stimulus", "quality commitment", "availability of and accessibility to climate information". We assign these codes according to the sense that water managers' awareness of climate impacts and the recognition of the resource vulnerability to such impacts combined with a willingness to provide a reliable water supply sensitized water managers to information-seeking behavior.
- Resource system characteristics (RS): from the text passage, it becomes clear that the resource system is affected by a concurrent stimulus, a stimulus that is not related to climate issues, such as population growth in this case, but can likewise cause or exacerbate a water stress problem. We code it as a "concurrent stimuli".
- Adaptation option (AO): in order to understand how climate change may affect the water supply reliability in the future, water managers were seeking for relevant information to inform decision-making. This behavior of actors resulted in collaboration with the boundary organization aiming to generate usable information and thus to integrate climate impacts into planning and management settings. This is why we coded this as "adaptation responses due to interaction with boundary organizations".
- Governance system characteristics (GS): Such collaboration on information production requires an efficient interaction between actors and scientists from the boundary organization in order to reconcile information supply with a concrete demand, which we code as "coordination of data and knowledge" and "science-management interface".
- Opportunity for climate adaptation (IO): in the selected text segment, we can observe how the constellation of various factors (based on the SES framework) enable climate adaptation through production and use of climate information in planning and decision-making. Therefore, we consider sustained interaction with boundary organization as an opportunity for climate adaptation as it results in integration of climate impacts into governance and management practices, thus addressing a common barrier of water managers' risk aversion or skepticism.

For another example of model's extraction we refer to the study of Wilder et al. (2010) on adaptation of water resources in the U.S.–Mexico border region. The paper argues for a transboundary approach to increase regional adaptive capacity across borders. The study thus considers several cases of innovation in the regional strategies that aim at reconciling transboundary divide (Wilder et al. 2010). One of such innovations is the creation of a

[1] The Climate Assessment for the Southwest, a boundary organization in Arizona.

transboundary assessment program that specifically tends to fill the gap in the scientific knowledge on groundwater resources in the region, and as a result has a high potential for improvements in sharing of climate information and its better integration into planning and decision-making practices. The following text segment of the article was considered as a model: "*An emerging initiative, the U.S.–Mexico Transboundary Aquifer Assessment Program (TAAP), seeks to overcome these institutional and water-resource challenges through binational collaboration. Authorized by U.S. federal law and funded by annual budget appropriations, TAAP is implemented by the U.S. Geological Survey and the state water resources research institutes of Arizona, New Mexico, and Texas, with collaboration from Mexican federal, state, and local counterparts as well as IBWC[2] and CILA[2]. (…) Over TAAP's brief lifetime, mutually defined priorities for Arizona's and Sonora's common Santa Cruz and San Pedro aquifers have been identified as vehicles for water for growth, adaptation to climate change, local aquifer-recharge programs, and institutional assessment of groundwater management asymmetries.*". We interpreted this model as following:

- Actor characteristics (A): we code the willingness of actors to collaborate on information sharing, thus improving information flow and building a shared vision in the region, as "homogeneous interests". We also interpret such initiative as a way towards "understanding of interdependencies" in the social-ecological system of concern. The exchange and use of information to address inter alia climate change translated into the code of "availability and accessibility of climate information".
- Governance system characteristics (GS): from the governance perspective, such collaboration explicitly results into effective coordination between the two parties; this is why we correspondingly code it as "horizontal coordination".
- Adaptation option (AO): adaptation responses in this case are due to "creation of joint initiatives" in order to address climatic pressures.
- Opportunity for climate adaptation (IO): the creation of the information-sharing program represents an opportunity for achieving adaptation since it prompts collaboration among actors that leads to improving information flows. As a result, it has potential to develop a more systematic integration of new, relevant information into planning and management practices.

The coding procedure was repeated twice. If the codes were changed while coding a new study, the already coded studies were re-examined, and if necessary were subjected to the coding procedure a third time. In this way, through a stepwise coding, a detailed codebook was inductively developed and refined. In the final round, all models were checked for the congruence with the final codebook. This translated to a data set of 83 models, 110 attributes that hold for them, spanning across five different SES elements, and 6 different outcomes. The corresponding codebook is reported below (Table A1.2).

Code		Interpretation
O	Outcome	
O1	Opportunity to adaptation is reported	A case study reports and explains an opportunity to climate change adaptation.
IO	Interaction outcome	

[2] International Boundary and Water Commissions in the US and Mexico

IO1	Enhancing climate information use	Enhancing the usability of relevant information in planning and management practices, necessary for responding to longer-term changes (intra-annual variability, evaluation of data on extremes and mean values, climate projections).
IO2	Adjusting government regulations	Changes in government regulations or institutional design.
IO3	Integration	Integrating various aspects (social, economic, climate, political, etc.) as well as all actors involved at different levels to prepare responsive actions to climate change adaptation.
IO4	Learning	Various social learning processes that help to address climate adaptation needs.
IO5	Collaboration and coordination	Involvement of the interested and affected stakeholders and/or agencies (building networks or coalitions) for the joint cooperation (information, knowledge and resources) to increase adaptive capacity.
IO6	Capacity building	Provision of information, water accounting and necessary resources either from government or from other institutions in order to favor adaptation.
A	Actors	
A1	Individual knowledge	
A11	Understanding climate stimulus	Actors understand how climate change may affect the resource system.
A12	Understanding SES	Actors have a good understanding of the system they operate in.
A13	Understanding interdependencies in a SES	Actors have a good understanding of interdependent elements of the system they operate in.
A14	Awareness of climate change impacts	Actors are aware about climate impacts or they have a perception to be exposed to climate them.
A2	Homogenous beliefs, interests and priorities	
A21	Homogeneous beliefs	Actors have homogeneous beliefs about climate change and its impacts.
A22	Interest in climate change	Interest in climate change of individual actors who perceive the vulnerability of the resource system towards climate impacts.
A23	Trust building among actors	All actors are pursuing cooperative strategies and common interests.
A24	Political (public) acceptability	Adaptation related actions do not conflict with political values.
A25	Quality commitment	A goal to provide a reliable water supply.
A26	Homogeneous interests	Development of homogeneous beliefs among actors as well as building a common vision.
A3	Access to material resources	Actors possess resources necessary for the adaptation process.

A31	Available financing	Actors have access to funding means.
A32	Increasing technical capacity	Actors are able to increase technical capacity to prepare adaptive responses to climate impacts.
A4	Access to information resources	
A41	Use of modelling tools	The use of modelling tools for predictions and analysis of climate impacts.
A42	Available data on climate change projections at the local scale	There is available data on climate change projections at the local scale.
A43	Information on the system and on climate events	The use of information on the system actors are operating in and on local climate events in decision-making.
A44	Provision and use of new/additional information	The use of new, updated/additional information on climate and/or climate impacts in decision-making.
A45	Use of information on past events	The use of information on past climate extreme events.
A46	Communication of information	Dissemination of relevant climate information and demonstration of climate impacts to managers in order to increase awareness about climate change.
A5	Staff resources	
A51	High professional staff	Professional managers show familiarity with climate variability and change, helping to bring climate impacts into decision-making process.
RS	Resource system	
RS1	Size and scale of a resource system	
RS11	A resource system is embedded in a larger water system	The examined resource system is a part of a larger system, which is relevant for analysis.
RS12	Upstream-downstream effects	A particular positioning of actors of the resource system that has implications for decision-making.
RS2	Stimuli and exposure	
RS21	Current climate stimuli	Current climate stimuli that affect the resource system.
RS211	Drought	
RS212	Flood	
RS213	High variability	
RS214	Low variability	
RS215	Other	
RS22	Climate stimuli not (yet) experienced	Expected climate stimuli in view of climate change.
RS221	Flood	
RS222	Drought	
RS223	Other	

RS3	Current state of a resource system	
RS31	Degradation of a system	The examined resource system is in a degraded condition.
RS32	Water pollution	Pollution of water resources is a critical issue and has impact on its quality.
RS4	Concurrent stimuli	The resource system is affected by a concurrent stimulus, e.g. development processes, population growth, etc.
GS	Governance system	
GS1	Scale of institutions	Temporal boundaries of institutional operation.
GS11	Continuity in formal capacity	Continuity in formal capacity after the planning process has been completed.
GS12	Change in administration	Changes in administration due to staff rotation (e.g. as a result of the elections).
GS2	Adaptiveness of institutions	The extent to which institutions are able to be changed.
GS21	Flexibility of institutions	Flexibility in procedures for institutional change.
GS22	Complex management system	Management or governance system is considered complex due to many actors involved in managing process.
GS23	Institutional learning	Learning process as a result of information and knowledge flow across all levels of government.
GS3	Social connectivity	Characteristics of institutionalised procedures (i.e. chains of actions, events and outcomes) and networks (i.e. connections between multiple positions and actors) that connect actors within and across tiers of social organisation.
GS31	Vertical coordination	Coordination between actors of the analysed resource system and other governance levels.
GS32	Horizontal coordination	Coordination between different departments of the same-level public organizations.
GS321	Coordination of data and knowledge	Coordination between actors/ different departments of public organizations at the same-level of decision-making for data and knowledge exchange.
GS322	Common efforts and resources	Coordination between actors/ different departments of public organizations at the same-level of decision-making for joint efforts and resources.
GS33	Top-down decision-making	Decision-making process is based on a hierarchical, top-down manner.
GS34	Decentralized governance system	The governance system is characterized as decentralized.

GS4	Rights and responsibilities	
GS41	Institutional incentives and priorities	
GS411	Long-term focus	Operational rules prompt long-term planning.
GS 412	Efficiency and conservation are included/prioritized	Adaptive needs of ecosystems are prioritised.
GS413	Rules based on historical hydrology	Operational rules are based on historic hydrologic conditions.
GS414	Updates	Regular updates of planning documentation.
GS42	Responsibilities	Attributes of position and choice rules that regulate the positions of participants and their actions associated to these positions.
GS421	Clear not-fragmented responsibilities/decision-making	Responsibilities are clear.
GS422	Fragmented responsibilities	There are multiple independent actors of decision-making that are not coordinated.
GS43	Property rights	
GS431	Secure property rights	Security of property rights is high.
GS431a	Secure property rights with fixed allocations	Security of property rights is high and they provide their holders with the right to a fixed amount of a resource (e.g. prior appropriation rule).
GS5	Actors	
GS51	Stakeholder participation	Eligibility of stakeholders to participate in decision-making.
GS52	Leadership	There is a strong leader in a stakeholder group that can influence decision-making process.
GS6	Social learning	Institutional attributes that shape how information, knowledge, values and preferences are constructed, communicated and accepted among participants.
GS61	Effective science-policy/science-management interface	The science-policy/science-management interface is effective in terms of social learning.
GS62	Institutional learning	Effective institutional learning, incl. learning process as a result of information and knowledge flow across all levels of government.
GS63	Learning from other examples	Learning from other examples or areas takes place.
GS64	Context specific	Social learning is based on the understanding of interdependencies of actors in SES.
GS65	Learning is based on past experiences	Learning is based on past experiences with climate variability.
GS66	Education of stakeholders	Communication with and education of stakeholders (and public).

GS7	Control	Type of control over the system's management and over the aggregate outcomes of an adaptation situation.
GS71	Centralized coordinated	Distribution of power and authority is well-coordinated under a hierarchical governance mode.
GS72	Polycentric	Distribution of power and authority among various well-coordinated centres.
AO	Adaptation Option	
AO1	Reactive adaptation	Fast responses that include prompt decisions in order to reduce the damage caused by climate extremes.
AO2	Adaptation responses complementary with	Adaptation responses are complementary with various management and planning acts/programs.
AO21	Nature conservation and management acts	
AO22	State planning/management acts	
AO23	Water allocation management	
AO24	Water conservation program	
AO25	Water agreements	
AO26	Adaptive management program	
AO3	Formation of institutional bodies	Adaptation requires formation of various types of institutional bodies for its planning and implementation.
AO31	Local watershed units	
AO32	Joint institutional arrangements	
AO33	Basin-based councils	
AO34	Interface organisations	

Table A1.2 Codebook

DATA PROCESSING: ARCHETYPE ANALYSIS USING R

Step 1: Definition of the outcome set

Each model extracted from the literature through the coding process described so far is linked to an outcome. Similarly, to all other SES elements above, interactions/opportunities (IO) are coded in a nested form. As a result, outcomes vary both in qualitative terms (IO1 vs. IO2 vs. IO3) and in terms of specificity (IO1 vs. IO11 vs. IO111). Furthermore, models vary in terms of how often they are observed, implying that some opportunities appear in a large number of models, whereas other ones appear more seldom. Finally, the nested nature of the SES framework implies that instances of e.g. IO111 are a subset of the instances of IO11, which in turn are a subset of IO1 – as for all remaining entries in the codebook.

Because of the qualitative difference between the various outcomes, each individual instance (IO1, IO12, etc.) is worth an analysis on its own account. This corresponds to running the algorithm described herewith with a different outcome set. Space and the specificity of the research focus of the paper do not allow for an analysis of all instances of opportunities observed. Since the concept of archetype implies reappearing phenomena, suitable outcomes are those that are frequently observed. Figure A1.1 below shows how frequently each instance of opportunity/driver is observed.

Given the distribution shown in Figure A1.1, IO1 ("the provision of climate information") seems the most feasible option: being observed in almost every other model (38 out of 83), it is specific enough to be qualitatively meaningful, yet it is generic enough to be observed in a large pool of models.

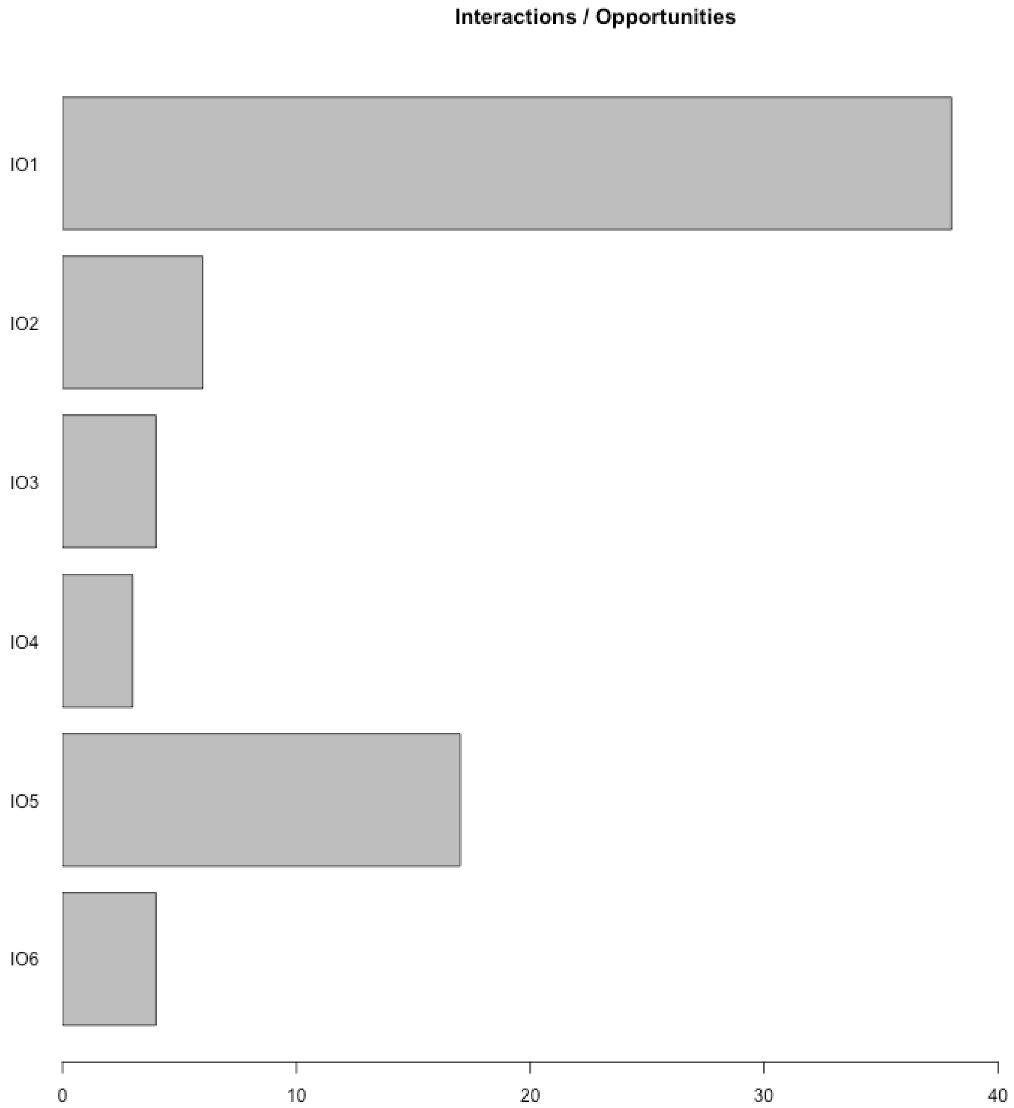

Figure A1.1: Number of models for each type of opportunity.

Step 2: identification of archetypes

To identify archetypical situations under which opportunities to adapt emerge, we processed the data on the models' attributes using R. We specifically wrote an algorithm that (ideally) computes all possible archetypes obtainable from the above mentioned 110 attributes, populates them with the available data, and tests whether the specific models identified by each archetype are consistently linked to the outcome set: IO1 or "enhancing the provision of climate information", the type of opportunity identified above.

Doing the above raises a few challenges. A key challenge is linked to computing all possible archetypes. The number of all possible combinations of 110 elements is the factorial of 110, which is in excess of 10^{178}. To express all theoretically possible archetypes alone is thus a computationally very intensive task – the more so if one also wants to verify which of the observed models is contained in each of them and link them to the outcome set. A more manageable task is instead to compute all possible archetypes that involve one (or no) attribute for each of those SES elements relevant for this study (RS, A, GS, S, and AO). Furthermore, attributes can be omitted if they are observed too seldom to appear in an archetype[3], or whether they are too general to be of interest. Eliminating such attributes further reduces the combinatorial space in which archetypes may potentially come about.

The above shortcuts produce a grand total of 53.312 computationally possible configurations of attributes. To obtain the corresponding models and test for the presence of IO1 programmatically is a feasible and rather straightforward task. That is however not a guarantee that the amount of relevant archetypes (those leading to IO1), will be in any way manageable. In order to achieve that, additional criteria are necessary. We have used a total of four, as detailed out below.

- The first of the four criteria corresponds to selecting those archetypes where IO1 is indeed *consistently observed*. Any given combination of SES elements (say: A131*GS21*AO3) yields a number of models which may or may not feature IO1 – for instance, some may feature IO2. In this first step, archetypes are retained if the models they yield *only* feature IO1. Please note that, while models featuring e.g. IO2 will lead the corresponding archetype to be discarded, models featuring more specific opportunities than IO1 (e.g. IO11 or IO123) will be retained. From an operational point of view, for each set of models identified by a particular archetype set-theoretic consistency as a sufficient condition for IO1 is calculated. Archetypes are retained if that consistency is 1.0, implying full consistency.

- Second and third, archetypes are required to feature in at least two models across at least two different papers. This two-fold requirement operationalizes the concept of archetypes as recurring patterns, taking into account that multiple models within the same archetypes may all come from the same publication and are thus only questionably "recurring". It is consistent with Oberlack and Eisenack (2018).

- Fourth, archetypes are selected based on their complexity, understood as the number of SES elements featuring therein. Specifically, archetypes are retained if they feature at least two different elements. We thus restrict the analysis to archetypes expressing the *combination* of *different* SES elements. Please note that this restriction has two

[3] By definition, an attribute observed only once cannot be observed in at least two models or papers. It thus cannot characterize an archetype, since archetypes need to be observed in at least two models from two different papers. More generally, the more seldom an attribute, the more unlikely it can appear in conjunction with other attributes. For the present analysis, the threshold has been set at three: attributes observed less than that were excluded from the analysis.

components: 1) that the *attributes* characterizing the archetypes must be more than one; and 2) that they must belong to different elements. As a result, archetypes made up of individual attributes are eliminated. Recall that archetypes are generated by computing all possible archetypes that involve one (*or no*) attribute for each SES element (RS, A, GS, S, or AO), which does not exclude archetypes encompassing a single attribute. Single-attribute archetypes, however, hardly fit the nature of archetypes as *patterns*. Leaving them out of the analysis is thus in order. Furthermore, archetypes encompassing more attributes from the same elements (e.g. GS12*GS15) *would* be eliminated as well. Such archetypes were not generated in the first place, though, as doing so would cause the number of potential archetypes to skyrocket. A mathematical proof is available here[4], but the reader can simply grasp this by comparing the amount of theoretically possible combinations of attributes (10^{178}) with the amount of archetypes obtained by combining one (or no) attribute for each individual SES element (53.312).

A first selection is then performed based on the four abovementioned criteria, leading to 15 relevant combinations of attributes. Although much more manageable, a similar selection of archetypes cannot ensure a meaningful diversity. The reader can easily grasp the issue by comparing a combination of attributes such as e.g. A13*GS21*AO31 with another one such as A131*GS21*AO3: both have the same degree of complexity, as they both involve three different SES elements; however, the former is more specific concerning adaptation outcomes (AO31 vs. AO3), whereas the latter is more specific concerning actor characteristics (A131 vs. A13).

What happens here is that any two combinations of attributes can be fundamentally similar, and increasing specificity on one hand can be off-set by decreasing specificity on another aspect of the archetype. These raises the question whether all archetypes characterized by a given selection of SES elements represent individually relevant archetypes, or whether they are better considered as variants of the same archetype, thus requiring further selection. The latter approach seems more meaningful in analytical terms, as it would ideally lead to results which are more parsimonious, and thus more amenable to theoretical interpretation.

In order ensure a degree of distinction between archetypes, these are first sorted lexicographically, based on complexity and, by equal complexity, by number of models. Based on that ranking, a last selection is performed, aiming at archetypes that, although different in terms of the attributes characterizing them, end up identifying the same set of models. Specifically, the selection process involves a pairwise comparison of archetypes, starting from the top ones and moving down the ranking. In each comparison, archetypes are eliminated if the models they encompass overlap beyond a certain threshold (50%). This means: if two archetypes overlap for more than 50 percent in terms of the models they identify, they are considered variants of the same archetype. In that case, the lower one in the ranking is eliminated. Note that, by proceeding in this way, individual models *can* be captured by different

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[4] Assume $y = a + b$, where $a > 1$ and $b > 1$. It follows that $!y = (a + b) * (a + b - 1) * (\dots)$, so that $!y > (a + b) * (a + b - 1)$, meaning $!y > a^2 + b^2 + 2ab - a - b$. That can be expressed as $!y > ab + k$, where $k = a^2 + b^2 + ab - a - b$. It follows that $k > 0$ because $a^2 + b^2 + ab > a + b$. Hence, $!y > ab + k$, hence $!y > ab$, q.e.d.

Note that cases where either a or b are either nil or simply smaller than one are out of scope here, as they would respectively represent an entirely empty set ($a = b = 0$), a single-attribute archetype ($a = 0$ or $b = 0$) non-integer or even negative amounts ($a < 1$ or $b < 1$).

archetypes. What the procedure does not allow is that archetypes identify *sets of models* that overlap beyond a certain threshold.

When the comparisons are completed, the archetypes left in the ranking meet all the conditions needed in order to qualify as archetypes: they are linked to a certain “outcome” (IO1); they represent sets of attributes; they are observed in multiple cases (here: models from different articles); multiple archetypes can be observed in individual cases, yet different archetypes encompass sets of cases that differ from one another. Additionally, their complexity (how many attributes) is chosen systematically, as a result of the process described above.

Based on the dataset at stake, the number of archetypes identified with the procedure described so far amounts to the following 6:

Archetype	ATs	Number of models	Papers	Models
Adaptation as collective action	AO32, A23, GS32	2	2	Kistin and Ashton 2008 (02), Wilder et al. 2010 (01)
Adaptation through local knowledge	AO31, A14	3	3	Binder 2006 (09), Hurlbert and Diaz 2013 (04), O´Connor et al. 1999 (02)
Adaptation “fit”	AO31, GS41	3	2	Binder 2006 (07), Binder 2006 (08), Hamlet 2011 (03)
Knowledge in context	AO31, A42	2	2	Binder 2006 (13), O´Connor et al. 1999 (01)
System evolution	RS21, GS411	2	2	Kirchhoff et al. 2013 (03), Pulwarty and Maia 2015 (03)
Learning	AC14, GS41	2	2	Boer 2010 (03), Farley et al. 2011 (05)

Table A1.3 Archetypes of opportunities for enhancing climate information use.

The attributes encompassed thereby are the following:

ID	Code	Label
18	AO31	local watershed units
19	AO32	joint institutional arrangements
38	RS21	current climate stimuli
74	A14	awareness of climate impacts

78	A23	trust building among actors
88	A42	available data on climate projections at the local scale
105	GS32	horizontal coordination
112	GS41	institutional incentives and priorities
113	GS411	long-term focus

Table A1.4 Attributes of archetypes.