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The Role of Cross-Scale Institutional Linkages in Common Pool Resource Management: Assessing Interstate River Compacts*

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This article extends the Institutional Analysis and Development Framework's seminal research on common pool resource (CPR) management in new directions by exploring how the design principles of robust and enduring CPR management, initially proposed by Elinor Ostrom in 1990, can be used to measure and assess cross-scale institutional linkages. This study examines data from 14 interstate river basin compacts in the western United States to identify the types of linkages established in these interstate settings, the factors that contribute to the emergence of diverse types of linkages around these shared resources, and how different types of linkages perform. Using Ostrom's CPR design principles to operationalize and measure linkages, the study shows that diverse types of cross-scale linkages were created under the 14 interstate compacts, with linkages related to monitoring found to be particularly prevalent. The types and diversity of linkages can largely be explained by the conditions under which compacts emerged and the water management issues states jointly face. In applying the evaluative criteria operationalized by the CPR design principles, this research further shows that the monitoring and collective choice linkages created by compacts tend to be of higher quality, while enforcement and conflict resolution linkages appeared to be of the lowest quality. In addition to developing the IAD literature on CPR management, these findings offer critical insights for assessing the capacity of interstate river basin compacts in the western United States to manage shared resources successfully, as well as insights for what types of institutional investments may be needed for enhanced resource governance.

KEY WORDS: cross-scale institutional linkages, institutional analysis and development, common pool resource theory, interstate compacts, water resource management

New Directions for IAD Literature on Common Pool Resources

Scholars working within the Institutional Analysis and Development (IAD) Framework have developed a vigorous and extensive body of literature on the

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management of common pool resources (CPRs), such as fisheries, forests, and water resources, which has sought to characterize the types of institutional arrangements that support robust and enduring CPRs (E. Ostrom, 1990, 2001, 2007; E. Ostrom, Gardner, & Walker, 1994; Poteete, Janssen, & Ostrom, 2010). The defining characteristics of CPRs, costly exclusion and rivalry in use of resource units, create management challenges; individual resource users may not perceive any benefits of maintaining or limiting their use of the resource, which can lead to problems of over appropriation and resource degradation (E. Ostrom, 1990; E. Ostrom et al., 1994). In examining the factors that allow communities to avert these dilemmas, studies of CPR management pay particular attention to the institutional design principles in Elinor Ostrom's (1990) seminal book *Governing the Commons*—seminal not only for developing a theory of common pool resource management but also for demonstrating the applicability of institutional analysis to the study of the commons (see Appendix 1 for a complete list of the eight design principles). As many CPR management studies have focused on locally managed CPR settings, a critical area of research is to understand the governance of larger scale CPRs, by analyzing "relationships among multiple levels of these complex systems" (E. Ostrom, 2009, p. 420). That is, what types of institutional design features avert CPR dilemmas when resources, organizations, and resource users cross multiple scales or boundaries?

A few scholars have begun to tackle these questions, arguing that linkages across scales are associated with more successful CPR governance in complex systems (Berkes, 2002; Young, 2002). Generally speaking, a *linkage* may be defined as a point of interaction or cooperation between two or more actors or collective bodies, such as organizations or units of government. These linkages may be established through institutions, which can include shared rules and strategies, or regularized patterns of interaction, creating functional interdependencies between different actors, or collective bodies (Young).[1] *Cross-scale* institutional linkages therefore connect actors or collective bodies that function at different scales or levels of social organization or political jurisdiction. For CPR management, such linkages are thought to enhance the capacity of actors with distinct jurisdictional or organizational boundaries to simultaneously address problems or dilemmas in managing the CPR that may cross or overlap those boundaries.

While increasing attention has been given to cross-scale linkages in CPR governance, some key questions have not been fully explored in this literature, such as: (i) How can the potential types of cross-scale linkages that are likely to be important within CPR settings be defined and measured? (ii) Why do actors invest in particular types of cross-scale linkages? (iii) How can we assess the quality of different cross-scale linkages for CPR management? These questions are addressed by utilizing E. Ostrom's (1990) design principles to measure and assess cross-scale linkages within the context of interstate river basins in the western United States. Probing these questions not only contributes to a better understanding of the governance of CPRs that cross multiple scales of decision making, it also shows IAD scholars how some of the seminal work in the literature can be applied to explore emerging issues in the field.

Cross-Scale Linkages

The concept and importance of linking organizations and governance units across scales is not new to CPR scholars. Ostrom's (1990) seminal work explicitly recognized that when CPRs are part of larger systems, the organizations that govern them are more successful when they are linked in a nested fashion. "Nestedness," was defined as "appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities . . . organized at multiple layers" (E. Ostrom, 1990, p. 90). As the focus of this research was on local decision-making bodies, implicit in the definition was that nestedness involved linking action situations at smaller scales, such as local CPR user groups, with those at larger scales, such as state or national-level government bodies.

Within the CPR literature, and the broader IAD literature, linked or nested systems also appear under the rubric of "polycentricity," which describes those settings where multiple, independent decision-makers or jurisdictions have overlapping authority (V. Ostrom, Tiebout, & Warren, 1961) and thus "multiple opportunities by which participants can forge or dissolve links among different collective entities" (McGinnis, 1999). Polycentricity, which can also describe federalist systems of government, affords opportunities for units of government to work together toward a particular end, while the individual units involved still maintain their own identities, rights, and authorities (Elazar, 1987). This creates opportunities for actions to locate at the most appropriate scale among the actors at hand (Baer & Marando, 2001), or for actors to reorganize as needed around shared issues (Schulz, 2007). The concept of polycentricity has been applied to studies of CPRs and social ecological systems to describe the relationships and linkages that arise among the different actors, users, and resources in such systems (Andereis, Janssen, & Ostrom, 2004; Schulz) and the outcomes that these relationships produce (Andersson & Ostrom, 2008).

In addition to the CPR literature that looks at nestedness and polycentricity, various scholars have recognized the role of cross-scale linkages in transboundary natural resource management. Different terms than "linkages" are often used, but they all underscore the concept of cross-scale connections across or between actors, organizations, or collective bodies that have distinct scales or scopes of authority. Terms include "co-management" (Adger, Brown, & Tomkins, 2006; Berkes, 2002; Carlsson & Berkes, 2005; Pinkerton, Wilson, Nielsen, & Degnbol, 2003; Wilson, Ahmed, Siar, & Kanagaratnam, 2006), "institutional interplay" (Young, 2002, 2006), and "boundary organizations" (Cash & Moser, 2000). Young (2002) sees these linkages as being exhibited through interactions and "functional interdependencies" between organizational actors at different scales, focusing on common substantive problems. Berkes similarly recognizes that linkages across actors or organizations operating at distinct scales involves addressing issues or problems simultaneously, or in coordination (e.g., through co-management) among those actors, versus management that occurs at multiple scales isolated from one another. Actors at different scales may share similar functions or responsibilities, but those functions and responsibilities may not be tied together in any formal means through shared rules, strategies, or actions unless there is a formal linkage established.

Using CPR Theory to Identify Types of Linkages

Given the diversity of concepts associated with cross-scale linkages, one challenge facing scholars in the CPR field is deciding which types of linkages should be the focus of analysis.[2]

We build on the approach of Andereis et al. (2004), who recognize the potential application of Ostrom's design principles for analyzing the robustness of complex social-ecological systems. Here we suggest that the design principles can be used as a theoretically grounded typology of cross-scale linkages. As shown in Appendix 1, the CPR design principles offer a well-established set of factors known to be important in the performance of local CPR institutions. Additionally, the eighth design principle of "nestedness" highlights the cross-scale applicability of the design principles. This principle suggests that the multiple layers of nested enterprises need to be established around the tasks or governance activities identified in the other design principles (E. Ostrom, 1990). *Types* of cross-scale linkages can be identified and measured around the actions identified within the CPR design principles, namely the establishment of boundaries around a CPR, appropriation and provision activities, collective choice activities, monitoring and enforcement, and conflict resolution. Moreover, as suggested by our definition of cross-scale linkages, the "linkage" is indicated by a formal rule, strategy, or regularized action that establishes interdependencies among two distinct actors around these different tasks. Using the CPR design principles as a typology therefore provides a starting point for identifying and measuring the presence and diversity of different linkages within CPR systems.

Using CPR Theory to Identify Quality of Linkages

How linkages complement or conflict with one another, or their "quality," is also important. As Berkes (2002, 2007) has repeatedly pointed out, the ties between actors or organizations at different scales may be complementary and productive, but they may also be conflictual and counter-productive. Ostrom's design principles point to measures of quality. Are boundaries of the resource and of the resources users clearly defined? Are provision and appropriation rules congruent with local conditions? Are monitors held accountable? Are sanctions graduated and are conflict resolution mechanisms *easily accessible*? Design principle seven points to another measure of quality—"minimal recognition of rights to organize" (E. Ostrom, 1990, p. 90). Recognition by larger-level organizations can help local communities establish rules that are more likely to be effective and enforced, and can enable and support local capacity (Andersson & Ostrom, 2008; Berkes, 2002), compared with those settings where cross-scale linkages allow for the dominance of one organizational arena over another (Young, 2006).

Thus, within each of the design principles, criteria are available to assess the quality of linkages, and ultimately shed light on the strength or performance of linkages (Berkes, 2002; Lebel, Garden, & Imamura, 2005).

Study Setting and Methods

The unit of analysis is the interstate river basin "compact." Interstate river basin compacts, which are provided for under the U.S. Constitution, allow states to develop, adopt, and enter into agreements with one another for the purposes of allocating or managing interstate rivers. Most interstate river compacts were created in the early to mid twentieth century as a way to mitigate conflicts over competing demands for water between states, as well as support the provision of water supply infrastructure that would be shared between states. In general, the expectations of states entering into compacts were that this mechanism would allow them to jointly provide for the efficient use and equitable apportionment of the water from shared rivers while promoting "interstate comity."[3] Through the compact agreements, states have established linkages at the "constitutional" level—constitutional in that they set rules for the powers and authorities of the member states around interstate water use and management.

The various rules identified in these constitutional-level agreements create functional interdependencies between the states that we define as cross-scale linkages. These linkages vary greatly across the basins. They may include linkages that are formed through the rules establishing compact boundaries, the rules requiring or authorizing members to engage in collective choice activities, such as compact administration, as well as rules for the allocation and provision of water resources, monitoring, enforcement, and conflict resolution. Compact rules may also authorize the states to devise additional collective choice rules, beyond what is stated in the compact agreement, to specify or clarify their joint responsibilities for monitoring, administering, and enforcing the compact, as well as resolving conflict. In effect, through the linkages established under compacts, or through the decisions and rules of their collective choice bodies, states create a "regional-level" organization that defines capabilities and limitations of member governments, prescribes ways to make and enforce rules, and defines a geographical boundary within which the compact applies (Schlager & Blomquist, 2008). This new institutional arrangement in turn provides opportunities for states to invest in linkages between the regional level government and its member states or water users within states, or between the regional government and the federal government. Thus, compacts are institutional arrangements, common to the U.S. federal system, that allow for multiple types of horizontal and vertical linkages.

The data for this paper come from a larger study comparing the structure, governance, and performance of interstate compacts in 14 basins in the western United States, shown in Figure 1. These 14 compacts involve the population of western state-to-state compacts that deal with water allocation and have been ratified by their member states and Congress. Compacts with more than three states, or where the federal government plays a central role in the administration of the compact, were not part of this study, thus excluding the Colorado River and Upper Colorado River Compacts. Our focus is on compacts that involve only western states, versus eastern states, because it allows us to control for the legal setting governing rights to water and climatic conditions, which differ dramatically between the East

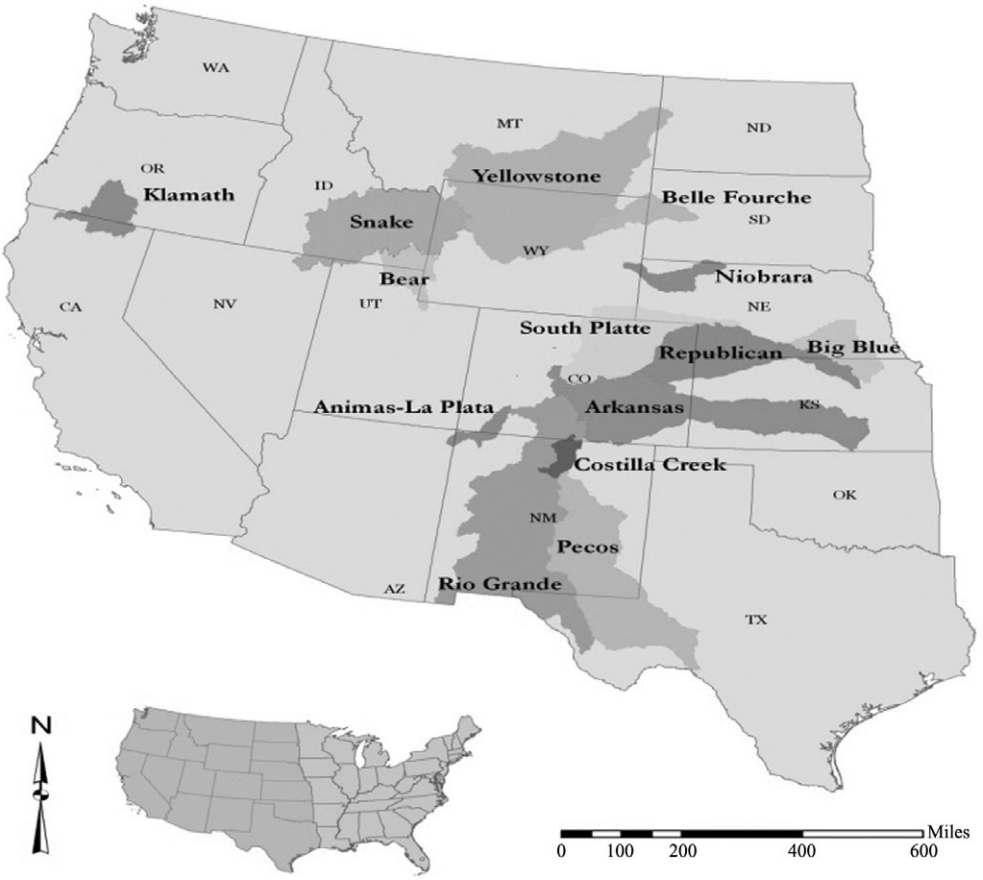

Figure 1. State-to-State Interstate River Compacts in the West.

and West.[4] Thus, compacts that involve both western and eastern states, such as the Red River Compact, are not included in this population.

Although water scarcity is common across the basins in which these compacts were signed, they do vary in terms of supply and demand settings (shown in Appendix 2). Basins in the more arid, desert Southwest, such as the Pecos or La Plata, typically have less streamflow, measured by the river's discharge passing through key measurement gauges, compared with basins further north or east, such as the Yellowstone or the Big Blue, where there is more precipitation. These conditions lead to different water management challenges—with those whose supplies are limited relative to demand, such as the Arkansas River, more likely to confront CPR problems and conflicts than those that are wetter and face fewer demands, such as the upper Snake River. As a result, these conditions may play a role in the types and quality of linkages states establish through their compacts.

Our analysis begins with an examination of the types of linkages established by the compacts' "constitutions." The compact constitutions are the sets of rules that the states enter into and sign (via the compact agreements), which recognize and

establish who is authorized to participate in the compacts, as well as the authorized, required, or forbidden actions that the members may collectively take (E. Ostrom, 2005). The typology of the CPR design principles is used to operationalize and measure the different linkages that are exhibited through these constitutional agreements. To measure these linkages, we developed a coding form for the constitutional-level rules[5] which poses a set of questions around the presence and types of boundary rules, the types of appropriation and provision rules, who is authorized to participate in collective choice decisions, and what rules the states agree to for monitoring, enforcement, and conflict resolution. Coders read the full text of each compact agreement as the data source for coding the compact rules. These rules then provided the indicators of the presence of the different types of CPR linkages: including "boundary" linkages (design principle one) if the rules delineated the joint membership of states around the watershed; allocation and provision linkages (design principle two), if the rules clarified the shared role of states in allocation and provision; collective choice linkages (design principle three), if the states are required to engage in shared collective choice activities; monitoring, enforcement, and conflict resolution linkages (design principles four, five, and six), if the rules establish explicit actions required by the states to jointly engage in these activities.

Second, we coded linkages devised by the states through the collective choice and operational actions undertaken by their appointed compact administrators or commissions. Collective choice actions are the rules and strategies that states jointly devise as they decide how to administer their constitutional rules (E. Ostrom, 2005). Like the constitutional rules, we devised a collective choice coding form that includes a set of questions on the rules and regularized actions of the collective choice body, such as who participates in decisions, who conducts monitoring, and how members enforce rules and resolve conflicts. Operational actions are those day-to-day actions of administering and implementing their collective choice decisions (Ostrom). The operational coding form asks questions about the type of information used in compact administration and how it is used, as well as the patterns of interaction and compliance by the member states. The sources of data for the collective choice and operational actions were the official meeting minutes and annual report that were available for the compacts, starting from the year of compact inception, going through 2005. These documents were read in their entirety by a coder and used as the basis for coding the collective choice and operational actions. After coding these actions, we then identified which of these actions represented the types of linkages suggested by the design principles. For example, at the operational level, the member states may engage in diverse types of monitoring (e.g., monitoring surface water flows, monitoring water quality, and accounting for water use). Each of these different monitoring actions was then coded as a monitoring "type" of linkage.

As the primary sources of data for this study are the compact "constitutions" (or signed agreements), along with their collective choice and operational actions identified in their meeting minutes and annual reports, the linkages we identified are largely horizontal (between the states). However, through these data sources we also identified some vertical linkages between the compact commissions and either local

water users or federal government actors.[6] We summarize the number of different types of linkages per compact, as identified from our document coding, in the section that follows. Additionally, we describe some of the likely factors shaping why some compacts invest in more diverse cross-scale linkages than others. We look at data on the impetus for each compact, which came from reading and coding documents from the meetings of appointed representatives who negotiated the compacts, as well as data on the water supply and demand conditions in the basin.[7]

Our coded data on the collective choice and operational activities of the states participating in the compact also provide information for measuring the "quality," or performance, of linkages. As previously discussed, we operationalize our indicators of quality for each linkage according to the criteria implied by the CPR design principles, such as how "well-defined" the boundary linkages are (design principle one). Rather than measuring quality *ex ante*, we argue that measuring the quality of a linkage requires the linkage be tested, or used, in practice to determine how well it works. Unlike our measures for the presence of linkages, our coded data, however, do not provide quantifiable indicators of quality. Instead, we describe linkage quality from a qualitative perspective, according to the CPR design principle criteria, based on our data on the types of actions and interactions states have undertaken over time.

Types and Numbers of Compact Linkages Using CPR Theory

The linkages created through compacts vary by type and number per compact. Many of these linkages are formed through the compact constitutions, but most compacts also establish additional linkages via their collective choice and operational activities over time. The constitutional level linkages provide the starting point for structuring state-to-state interactions in the interstate water management arena.

Constitutional Level Linkages

As Table 1 shows, the most common type of linkage created under compact constitutions is a boundary linkage. From the coded constitutions, the first indicator of a boundary linkage is whether compacts define the boundaries of the watershed and the actors subject to the compact. The second indicator is whether the compact also defines boundaries of sub-basins in the compact. Nearly all of the compacts define boundaries of the watershed and the actors that states will jointly govern. Over half the compacts also have boundaries explicitly defined around sub-basins. Not surprisingly, those that do not recognize sub-basins tend to be the smaller watersheds like the Belle Fourche or Upper Snake, but this is not always the case, as evidenced by the Costilla Creek (a small watershed that is part of the larger Rio Grande).

Two indicators of allocation linkages were also identified under the compact constitutions. First is whether a compact quantifies allocation rules for the member states. Only two compacts, the Klamath and the Upper Niobrara, do not quantify how much water different states receive. The Klamath, rather than quantifying how much each state may appropriate, says that water will be allocated according to a

Table 1. Linkages Established through Interstate Compacts' Constitutional Rules

Compacts	Boundary	Allocation	Provision	Collective Choice	Monitoring	Enforce	Conflict Resolution
Arkansas	2	2	1	3	2	1	1
Bear	2	2	1	2	0	1	0
Belle Fourche	1	1	0	1	1	0	1
Big Blue	2	2	1	3	1	0	0
Costilla Creek	2	1	1	1	2	0	0
Klamath	2	0	1	2	1	1	1
La Plata	1	1	0	1	1	0	0
Pecos	1	1	1	2	2	0	0
Republican	2	2	0	1	2	0	1
Rio Grande	2	2	0	2	2	0	0
Snake	1	1	0	1	1	0	1
South Platte	2	1	0	0	1	0	0
Upper Niobrara	2	1	0	1	1	0	0
Yellowstone	2	2	1	2	1	0	1
Sum of Linkages	24	19	7	22	18	3	6

basin-wide system of prior appropriation (leaving it up to the individual states to quantify who has priority for water), while also restricting any out-of-basins transfers of water. The Upper Niobrara, on the other hand, places restrictions on when water storage can occur, as well as the rules under which direct flows can be regulated in certain stretches of the basin. This type of rule relates to the second indicator of allocation linkages, which is whether compacts specify distinct rules for different sub-boundaries of the watershed, which we find in 6 of the 14 compacts. Unlike allocation linkages, however, provision linkages are less common. The only indicator of provision linkages identified in our coding of compacts was whether the states must collectively support the financing of the administration of compacts, which is identified in half of the compacts.[8]

The collective choice linkages include the number of different types of representatives identified in the compact constitution. Among compacts the range of "types" of representatives includes state-level representatives, federal representatives, and water user representatives. Only two compacts explicitly establish all three types of linkages in their constitutions, the Arkansas and the Big Blue. Five compacts have two linkages, where the constitutional rules identify both state level and federal level representatives. Six compacts identify only one linkage through the representative from each state who participates in compact administration. A couple of these compacts, such as the Costilla Creek and Belle Fourche, although they do not include a federal representative on the commission, do note that federal agencies "shall collaborate" with the commission "for proper administration" of the compact. The only compact with no linkages formed around collective choice mechanisms is the South Platte. This means that the compact does not establish a formal collective choice mechanism that links the states together around joint decision making and administration. The states then must administer the shared allocation rules stated under the compact independently through their own agencies. It is, of course, possible for the

states to engage in more informal linkages if they communicate and discuss the compact, but such linkages were not available from the data used in this study.

The monitoring linkages indicate whether the compact requires states to (i) engage in monitoring or (ii) engage in accounting of water use. Monitoring focuses on measuring stream flows and water diversions, whereas accounting compares water diverted to water allocated. While accounting is required in only five of the 14 compacts, streamflow monitoring is explicitly required among all compacts except one. The Bear does not explicitly require monitoring, although the collective choice mechanism has broad authority to administer the compact, which does include monitoring, as we will see in the monitoring linkages identified through the collective choice rules and actions.

The last two linkages deal with issues of sanctioning (or more broadly "enforcement" as envisioned by design principle eight) and conflict resolution. In our study, enforcement is by far the weakest of the different linkages. No compacts establish penalties or sanctions for rule violation. Only three identify who must enforce the compact—e.g., the compact commission or member states: the Arkansas, Bear, and Klamath. Six compacts involve some sort of rule that links conflict resolution mechanisms among the states at the compact scale.

Linkages Established Through Collective Choice and Operational Actions

As states work together over time to implement their shared authority established at the constitutional level, they may decide to invest in additional linkages through the decisions and actions of their collective choice bodies, or compact administrators, shown in Table 2. In a few cases, like the Belle Fourche, the constitutional level linkages are far more extensive than the linkages established by the states' collective choice or operational actions. On the other hand, some compacts,

Table 2. Linkages Established through Interstate Compacts' Collective Choice Bodies

Compact	Boundary	Allocation	Provision	Collective Choice	Monitoring	Enforce	Conflict Resolution
Arkansas	0	2	1	3	4	0	0
Bear	0	1	1	3	5	0	0
Belle Fourche	0	0	0	0	1	0	0
Big Blue	0	2	1	2	3	0	0
Costilla	0	1	1	2	4	0	0
Klamath	0	0	1	1.5	3	0	0
La Plata	0	1	0	0.5	4	0	0
Pecos	0	1	1	2	5	0	0
Republican	0	2	0	2	0	0	1
Rio Grande	0	2	1	1	1	0	0
Snake	0	0	0	0.5	0	0	0
South Platte	0	1	0	0	1	0	0
Upper Niobrara	0	0	0	0	0	0	0
Yellowstone	0	0	1	1	2	0	1
Sum of Linkages	0	13	8	18.5	33	0	2

like the La Plata, start with limited linkages and build from there. Others that start out with substantial linkages, such as the Arkansas and Bear, continue to invest in linkages over time.

The most common type of linkage that compact administrators have invested in involves monitoring rules or activities. In coding compacts, we identified five possible indicators of monitoring linkages through the collective choice or operational activities of administrators. These include (i) monitoring of basin streamflows through a compact's collective choice body, (ii) monitoring through gauges of states or federal agencies, (iii) monitoring of water quality, (iv) exchanging or sharing of information from states or water users with compact administration, and (v) involving local watermasters in monitoring water withdrawals. For instance, the Bear River compact, which has no formal or explicit requirement in the compact constitution for monitoring or accounting, through its operational activities has created links to federal water supply monitoring, to state and local entities that share information on basin conditions with the compact commission, and to watermasters in the member states, who provide daily accounting information on water use. Other compacts, like the South Platte, simply keep track of streamflows through state or federal surface water gauges but do not establish additional compact gauges or other forms of monitoring actions.

With the exception of monitoring, many of the linkages established by collective choice bodies are fairly limited. This can be explained by the fact that some compacts, despite having formally authorized linkages through the compact constitution, do not have active collective choice bodies. For collective choice linkages, we measured whether compacts have active, inactive, or occasionally active commissions as one indicator. Additionally, we have indicators as to whether local water users actively participate as members of the commission, and whether local citizens participate in meetings. Thus, some compacts do have some degree of collective choice linkage, but it may be that the collective choice body only occasionally meets (which would be coded as a 0.5 instead of a 1 for active collective choice bodies).

The establishment of additional allocation linkages, particularly by those compacts with active commissions, is fairly common. The two indicators of allocation linkages are whether rules are actively administered and/or whether member states take special actions, internally within the state, to administer the compact. Some compacts, like the La Plata, may not have a commission that regularly meets, but the states still administer the streamflow allocation rules established under the compact constitution. The Yellowstone, on the other hand, has an active commission, but has not had to actively administer the allocation rules because streamflows have generally been adequate for all users to meet their needs without imposing interstate restrictions. Unlike allocation rules, however, only those states with an active commission were identified as having provision linkages through the actions of the collective choice bodies, measured as contributions by states toward a compact budget.

Enforcement and conflict resolution linkages between states, as exhibited by the rules and actions of compact collective choice bodies, are even fewer than those linkages identified by the constitutional rules. No compacts have established new

rules or linkages around sanctions or enforcement. Only two compacts have established linkages for conflict resolution. The Republican created an arbitration mechanism that was not specified in its compact, whereas the Yellowstone modified its conflict resolution procedure that was established in the compact through new rules established by the compact commission.

Variation in Linkage Diversity across Compacts

Before moving on to assess the quality of the different linkages, it is important to consider why certain states form more diverse sets of linkages. As previously noted, western compacts were developed in relatively arid watersheds where states commonly engaged in interstate water disputes prior to signing the compacts. Table 3 notes that eight of the compacts faced conflicts prior to signing these agreements. Additionally, when many compacts were signed, periods of either drought or flooding had precipitated negotiations, which further coincided with the federal government proposing to build large-scale water projects to help address water storage and flood control needs.

Among those nine compacts that started out with relatively high numbers of linkages (e.g., more than seven linkages), six faced at least two of the three issues that precipitated the compacts (conflicts; drought or flooding; water projects). Recognition of the extent of the different challenges that the states jointly faced may therefore explain efforts to establish a more diverse set of linkages. Three compacts with relatively high numbers of linkages at the outset, the Big Blue, Costilla, and Klamath, each only faced one of these issues. Thus other factors may certainly play a role in fostering linkages. In the Klamath, while conflicts between states were not an issue, both states were concerned that the upper portion of the basin would be diverted for

Table 3. Comparing Issues Facing Compacts and Linkage Diversity

Compact and Date Signed	Supply Relative to Demand	Issues When Compact Was Signed	Constitutional Linkages	Collective Choice and Operational Linkages
Arkansas 1942	Low	Conflicts; flooding; water project	13	10
Bear 1958, 1980	Low	Conflicts; drought; proposed water project	10	10
Belle Fourche 1943	Moderate	None	6	1
Big Blue 1971	Moderate	Proposed water project	9	8
Costilla 1944, 1963	Low	Conflicts	7	8
Klamath 1956	High	Proposed water project	8	5.5
La Plata 1922	Low	Conflicts	2	5.5
Pecos 1949	Low	Conflicts; floods; water project	7	9
Republican 1943	Low	Drought; floods; water project	8	5
Rio Grande 1938	Moderate	Conflicts; water project	8	5
Snake 1949	High	Conflicts; drought; water project	5	0.5
S. Platte 1923	Low	Conflicts	4	2
U. Niobrara 1963	Low	None	4	0
Yellowstone 1950	Moderate	Drought; water project	9	5

use in southern California, which combined with a proposal to build new hydroelectric dams in the 1950s, led to the creation of the compact in 1959. The Costilla is the smallest of the watersheds but also one where the river crosses state lines multiple times, perhaps fostering greater incentives for linkages. The Big Blue compact was the latest compact to emerge on the scene, suggesting perhaps some learning or at least awareness of the diverse ways in which compacts could be structured. Those compacts that have fewer constitutional level linkages all faced either none or only one of these challenges, with the exception of the Upper Snake. Notably, the Snake has one of the lowest water demands relative to supply compared with the other compacts.

Inter-state disputes, drought events, and concerns over reservoir development did not immediately disappear following the creation of these five compacts (Schlager & Heikkila, 2009). Investments in linkages to address these challenges have clearly been made by the collective choice bodies, particularly in monitoring linkages. The member states to the Pecos compact, for instance, were embroiled in a Supreme Court case in the 1970s and 1980s over New Mexico's ability to supply adequate flows to Texas. In settling the dispute, the Pecos compact invested in new monitoring and enforcement mechanisms, including enhanced modeling of the basin. New Mexico has also established additional allocation linkages through various water management strategies that allow it to better meet compact commitments—groundwater regulation, purchase and retirement of farmland, and water rights leasing.

In fact, all of the compacts that developed more diverse sets of linkages (between eight to ten) through collective choice and operational activities, which include the Pecos, started with more diverse constitutional linkages (seven or more), shown in Table 3. Similar to the Pecos, the Arkansas, Bear, and Costilla, not only had established high levels of constitutional linkages, but also continued to face conflicts after entering into their compact agreements (Schlager & Heikkila, 2009). The Big Blue, however, has not faced conflicts in the basin, but has continued to develop relatively extensive linkages at the collective choice and operational levels after establishing diverse constitutional linkages. These linkages have focused on addressing water quality problems, an issue recognized in the compact. The commission has addressed water quality issues primarily by developing monitoring linkages.

It is unclear if more diverse types of constitutional linkages are a sufficient condition for creating more collective choice and operational linkages. Four basins that started with more diverse sets of constitutional linkages (Klamath, Republican, Rio Grande, and Yellowstone) only established more moderate levels of linkages (around five each). It could be argued that the need for new linkages was not perceived to be as great in at least three of the four cases (Klamath, Rio Grande, and Yellowstone), which have moderate to high levels of water supplies relative to demand. Additionally, since one cannot judge the quality of linkages based on "numbers," it is possible that the linkages they did create have been sufficient to meet their shared water management needs—an issue we explore in the next section.

Among those five compacts that started with less diverse sets of linkages at the constitutional level (less than seven), none have created extensive sets of linkages at the collective choice or operational levels. The lack of diversity at both levels can largely be explained by the lack of serious water management issues in these five basins. The Upper Snake is the only case among this group that faced conflicts (albeit relatively "low level" conflicts), drought, and water project development prior to entering into the compact. Yet, it is also a fairly water rich basin and no major water management challenges between the states have since arisen, which may explain why the linkages are less diverse. Two of these five, the La Plata the South Platte, are the oldest compacts, signed in the early 1920s. Both faced some low level interstate disputes prior to compact negotiations. Yet neither encountered the added challenges of droughts and floods and expanded storage needs as those compacts with more diverse constitutional linkages and the South Platte, at least, has faced no serious interstate conflicts over compact administration since the compact was signed (Schlager & Heikkila, 2009). The La Plata, however, is actually the only compact in this group to create moderate levels of linkages through its collective choice body (five). Given that the La Plata has confronted some interstate tensions over the administration and compliance with the compact (Schlager & Heikkila), it is not surprising that the collective choice body has attempted to invest in new linkages. Neither the Belle Fourche (signed in 1943), nor the Upper Niobrara (signed in 1962), confronted any serious water management challenges when they were signed, nor have any conflicts or problems facing the states emerged since then.

Assessing the Quality of Compact Linkages

Numbers and types of linkages are an important starting point for understanding the effects of the larger institutional context on CPR governance, but in order to assess how these linkages matter for CPR governance, we have to consider their quality. Theoretically, high quality linkages can be considered indicators of robust CPR governance, but as previously noted few scholars have explored what "quality" means in practice. For this analysis, our goal is to provide the groundwork for identifying and evaluating the quality of linkages by qualitatively studying how the linkages have played out in practice and how they compare to the quality "criteria" embedded in the CPR design principles. In doing so, we provide some insights as to how these linkages have been successful (or not) in supporting the administration and performance of interstate water governance over time.[9]

"Well-defined" Boundaries

With respect to boundary linkages, the CPR design principles suggest that their quality can be measured by how "well-defined" they are around both the resource and resource users. *Ex ante*, relatively well-defined boundaries of the resource and the resource users are a hallmark of interstate river compacts. Most compacts contain sections in which water boundaries and user boundaries are

defined. The Yellowstone defines the following terms: Yellowstone River Basin, Yellowstone River System, tributary, and interstate tributaries. Like most compacts, it further pinpoints the precise geographic location of the different watershed units and scales that are identified in the compact boundaries. About the only compact that does not explicitly define boundaries is the La Plata. Rather it simply states, "The waters of the La Plata River are hereby equitably apportioned . . ." (La Plata River Compact, 1923).

The boundaries of the La Plata Compact have never been contested; however, the boundaries of other compacts have been. In practice, the boundaries of some compacts have turned out not to be as well defined as they appeared on paper. This has particularly been the case in relation to compacts in which groundwater pumping has begun to affect surface water flows, primarily in the Arkansas, the Pecos, and the Republican. In each case, as groundwater pumping in the upstream state increasingly depleted surface flows, downstream states started to question the boundaries of the compacts, arguing that groundwater was included within the compact. Even though the compacts did not explicitly mention groundwater, in each case the U.S. Supreme Court agreed with the downstream states, and compact boundaries were re-drawn accordingly. Another problem that has come up in the Yellowstone River compact is around the clarity of the boundaries of the water users governed by the compact. Montana has argued that compact rules should protect water users in the state who had rights at the time the compact was signed from the effects of water development in Wyoming (the upstream state) after the compact was signed, but Wyoming has disagreed. This argument has been one of the claims used by Montana in a recent Supreme Court case against Wyoming. In other words, incomplete boundary linkages in these cases point to areas where interstate water administration and governance may be challenged.

"Well Matched" Appropriation and Provision Rules

As noted above, all compacts have linkages established around appropriation rules (i.e., water allocation rules), which the design principles suggest should be "well matched" to CPR conditions. Evidence of mismatch comes from looking at the problems states encounter in administering these rules over time. In only two instances have compact allocation rules been persistently problematic. In the Pecos, the water allocation rule was based on a set of assumptions about relationships between inflows and outflows at different points on the river that in practice turned out to be fundamentally flawed. Consequently, the states could not determine the amount of water New Mexico should deliver to Texas. New Mexico and Texas struggled for almost two decades to make the "model" work before Texas finally brought a case before the Supreme Court to develop a workable water allocation rule. In the Arkansas, the water allocation rule for river flows (which excluded reservoir water) was vague, stating the waters of the river "shall not be materially depleted" (Arkansas River Compact, 1949). Over time the states of Colorado and Kansas began arguing over the meaning of material depletion, with Kansas eventually filing a suit before the Supreme Court for a determination.

The only other case where a mismatch between allocation rules and conditions of the resource has been an issue is on Costilla Creek, but the issue was addressed within the first year of its operation. New Mexico water users complained to the Compact commission that the compact's irrigation season rules did not match their irrigation season and that they should be allowed to take water before May 15. Without amending the compact's water allocation rules, the commission agreed with the irrigators, and but for very dry years, irrigators are allowed to irrigate, if they choose, before May 15. Notably, such mismatches between the physical setting and the rules governing the timing of water use may become more problematic with the onset of climate change as snowmelt and spring runoff in these river basins may start earlier (Schlager & Heikkila, 2011).

Provision linkages similarly require that they be well matched to the conditions of the basin to be of high quality. Since interstate river compacts provide very limited constitutional-level rules around "provision," assessing the quality of these linkages is challenging. The only indicator of provision linkages at the constitutional level was whether states were required to fund compact administration. One indirect measure of quality could be whether the funding has been adequate to deal with the basin-level challenges or administrative needs of the compact. We have examined in our data coding whether any of the states have been in arrears for funding or whether other states have failed to fully fund the compact. None of the compacts that have active funding and support from states have encountered this problem. In addition to those seven compacts that have provision linkages established in the constitution, the Rio Grande has actively established provision linkages through its collective choice body. Therefore, all eight of those compacts that actively fund their compacts have not exhibited any quality problems.

One reason why mismatches in provision and allocation linkages have not been more common may be the collective choice bodies, or governing commissions. Compact commissions have the authority to engage in rule making and may regularly devise and revise rules to better match them to the setting. To assess the quality of the collective choice linkages for those that do have commissions, design principle three indicates that those affected by the operational rules should actively participate in modifying them. Compact rules affect two levels of actors. Most directly they affect the state governments, particularly their water agencies, which make commitments to each other to manage water to meet the requirements of the compact. Representatives from state water agencies are in fact the dominant representative on compact commissions and arguably meet this quality criterion. Yet compacts also indirectly affect water users as these state officials must regulate the actions of their water users to comply with the compact. While all of the compacts with active commissions allow water users to attend meetings and voice their opinions, only three compacts (Arkansas, Bear, and Big Blue) allow for water users, namely farmers, to participate on the collective choice body—with only the Bear permitting these members to vote. Thus, the quality of the collective choice linkages is arguably high for these three compacts. Further evidence of this quality comes from the fact that all three of these compacts ranked high on the number of linkages created by their collective choice and operational activities (Table 2).

Accountable Monitoring

Compared with the other types of linkages, monitoring is the only linkage that can be evaluated across all compacts. The indicator of "quality" monitoring posited by the CPR design principle is whether the monitors are accountable to the "appropriators." In the context of compacts, creating monitoring systems that are accountable to the member states and the water users (or appropriators) they represent means developing transparent monitoring that can be trusted, particularly by downstream states who may be suspicious of the activities of upstream states. While all compacts monitor, the degree to which monitoring is transparent varies by compact. In practice, the most common type of monitoring is through stream gauges, which all compacts use. Some obtain that data from state-sponsored gauges, while most compacts also tap into federal stream flow gauges (from the U.S. Geological Service), which may enhance transparency. A few compacts even work with local watermasters who provide accounting information on local water use and diversions to complement streamflow monitoring.

What is being monitored may also be as important as "who" is monitoring. State line flow data is the absolute minimal type of monitoring that a commission may engage in, and provides the least amount of information to downstream states. States can include gauges from multiple locations in the basin, can monitor both groundwater and surface water, or may also rely on hydrologic models to complement the stream gauges as a source of monitoring and information about the basin. How monitoring information is made available to member states and to water users—e.g., through joint annual reports—also provides indicators of the quality of monitoring. Compacts that are doing only the bare minimum of monitoring—for instance with stream gauges at the state line and not with multiple monitoring sources (Belle Fourche, Klamath, Snake, Upper Niobrara)—may not be as high quality as those states that either (i) use more extensive sources or (ii) are monitoring more types of information.

Those compacts that go beyond the minimum stream flow monitoring, or that go beyond active sharing of that information between states, either employ a commission-based hydrologic model or work with basin watermasters. Five compacts have invested in such comprehensive monitoring systems. Two, the Arkansas and the Republican, have developed hydrologic models that incorporate both groundwater and surface water diversions to account for river flows. The models require considerable amounts of water use data, which provides a measure of transparency to the downstream state concerning actions of the upstream state. Three, the Bear, Costilla Creek, and Pecos, have watermasters at the commission level. Each watermaster relates to their commission in a different way. In the case of the Bear, the watermaster works with and coordinates the watermasters of each of the states to ensure that water rights are administered in accordance with compact requirements. The Costilla Creek watermaster administers water rights in New Mexico, ensuring New Mexico water users abide by compact requirements. The Pecos watermaster is the water accountant for the commission. The states provide him water data and he "runs" the water model, which determines whether New Mexico is in compliance.

The monitoring linkages in these basins therefore indicate greater capacity on the part of the states to jointly engage in shared governance of the resource.

Little Enforcement

The final two types of linkages, sanctions (or more generally enforcement), and conflict resolution, are the least developed linkages among the compacts. In turn, the compacts raise a number of issues that may suggest modifications to the principles. As no compacts through their constitutions provide for sanctions, and states themselves have not sanctioned each other, sanctions cannot be considered "graduated" according to the design principles. Enforcement of compacts has occurred in practice, but it tends to be through vertical linkages. For instance, if a state violates the allocation rules of a compact, the commission may request that the violating state enforce the compact. To do that, the violating state must directly pursue enforcement through its own administrative processes, which can directly regulate or restrict the actions of water users. States have mixed incentives to enforce compact requirements against their water users. Reducing the water allocation of one's own users to benefit the users of another state is an action that states are reluctant to take with any enthusiasm. Furthermore, states have often allocated rights to more water than what is available, either in the river or under the compact. Thus, water users may have a water right that has been granted by the state but its use would violate the compact. For states to actively administer compact allocation rules among their water users (vertically) sometimes requires state to state (horizontal) enforcement first. However, states may have veto power over one another and if states try to enforce compacts horizontally (i.e., through the commission) they may find the other state refuses to comply. The result of these challenges has been that states rely on the enforcement powers of the U.S. Supreme Court, another vertical linkage, which has original jurisdiction over disputes among states. Five compacts have been enforced by the Supreme Court and a sixth is in process.

"Low Cost" Conflict Resolution

Conflict resolution is tightly coupled with enforcement. In the context of compacts, conflicts most commonly arise when states disagree over rule violations. As envisaged by design principle six, access to "low cost" conflict resolution would be the criterion for assessing the quality of conflict resolution linkages. As noted above in the discussion of linkages, only a handful of compacts have built in conflict resolution mechanisms, which might be considered "low cost," and for the most part, they have not been used by states to settle conflicts in practice. Three compacts that have these mechanisms established in the constitution—the Belle Fourche, Klamath, and the Snake have never confronted conflicts between the two states that required the use of these mechanisms. The other three—the Arkansas, Republican, and Yellowstone have found it difficult to employ these mechanisms in practice. For example, the Arkansas Compact provides for a binding arbitration mechanism. States may access it by a unanimous vote. The one instance in which Colorado and

Kansas discussed using arbitration, they could not agree on the issues they wanted the arbitrator to decide upon and thus no unanimous vote was possible. The Yellowstone confronted a similar issue. In the end, both compacts went to the Supreme Court to settle their differences. In contrast, the Republican compact commission adopted a nonbinding arbitration mechanism that any single state could call upon to assist in settling conflicts. Kansas requested arbitration with Nebraska, the two states selected an arbitrator who heard their cases and issued decisions. Since the decisions are nonbinding, Nebraska and Kansas rejected all but one. Only that one decision will go into effect. The other issues are likely to be litigated before the Supreme Court.

Therefore, in practice, the mechanisms for conflict resolution used by compact members, regardless of whether they have an "alternative" conflict resolution mechanism established, are compact commissions, i.e., the collective choice body, and the U.S. Supreme Court (Schlager & Heikkila, 2009). Although the Supreme Court is certainly higher cost than resolving a conflict collectively at the level of the commission, it may be an appropriate alternative conflict resolution venue for certain types of conflicts. Many water conflicts involve complex issues, competing demands, uncertain science, and debates over unclear rules. They also deal with resources that are vital to states' economies and livelihoods. Thus, the Supreme Court may be the best available alternative for particular conflicts. To assess which conflict resolution mechanism is most appropriate requires an understanding of each individual conflict, the issues at hand, and the capacity of alternative mechanisms to address that conflict.

Conclusion

Conceptualizing common pool resource systems as social ecological systems brings cross-scale linkages into sharp relief. As E. Ostrom (2007) notes, in quoting from Holland, common pool resource dilemmas, as well as critical feedbacks cross time and space, contribute to the behavior of cross-scale social-ecological systems. The challenge then is how to identify and measure, in a systematic and theoretically grounded way, the linkages across scales, in particular, how to identify and measure those that are institutionally grounded.

Numerous scholars have wrestled with the challenge, pointing to both types of linkages and their quality; however, no consensus is emerging on how best to untangle and study cross-scale linkages. In this paper, we have taken a different approach to identifying and measuring cross-scale linkages. We used E. Ostrom's (1990) design principles, originally devised to account for the persistence of self-governing arrangements around common pool resources. The advantages of using the design principles as a means of organizing and measuring linkages are several. First, the principles provide clearly defined actions or tasks that numerous empirical studies have demonstrated to be critical in accounting for success and failure in local level common pool resource governance. Thus, using the principles to identify types of linkages and measures of their quality directly ties the

study of cross-scale linkages into a well developed body of theory that can then be extended to the study of organizations operating across scales.

Second, using the design principles to organize the study of linkages allows for an important conversation to take place around the concepts embodied in the principles. One unfortunate way in which the principles came to be used was as a static checklist to mechanistically assess common pool resource cases. One cannot simply measure robustness of CPR settings in a cross-scale context by checking off all "types" of linkages. Rather, the types and quality of the linkages have to be assessed by examining rules in form, exhibited by the rules in the constitutions of the compacts, and rules in use, exhibited by the operationalization and implementation of the constitutional rules.

The creators of the compacts' constitutions established linkages that readily fit the design principle categories, with more extensive types of linkages emerging in those basins where states faced more severe challenges around water management, such as conflicts over water allocation, extreme weather events, or developing water storage projects. In turn, those with more constitutional level linkages tend to have more linkages established by collective choice bodies. Compacts that face fewer water management challenges made fewer investments in linkages. Finally, some types of linkages have proved to be more common than others, notably allocation rules, collective choice decision-making rules, and monitoring.

Monitoring linkages and collective choice decision-making linkages, relative to other types of linkages, are where we see greater "quality" across the board. Those compacts having particularly high quality linkages around monitoring and collective choice decision making, such as the Arkansas, Bear, and Costilla, are also those compacts that have over time developed more diverse sets of linkages at both the constitutional level and collective choice level. For instance, members of the Bear and Costilla compacts revised the constitutions of the compacts to better match water allocation rules to the physical setting of the river basins.

We were able to identify fewer "quality" linkages around enforcement and conflict resolution, at least as the CPR principles define quality. There are limits to the way these quality criteria may apply in the cross-scale context. In particular, the criteria do not focus enough attention on vertical linkages. In the compacts, monitoring, enforcement, and conflict resolution linkages may appear more commonly through vertical linkages with states linking to local water users or to the federal government than through horizontal linkages.

The CPR design principles worked well in identifying critical cross-scale linkages and they provided an excellent starting point for measuring the quality of the linkages; however, additional work remains to be done to better account for the challenges posed by studying institutional linkages across scales. First, further developing the actions and the measures of quality found in the design principles is necessary. In particular, monitoring, sanctioning or enforcement, and conflict resolution need additional consideration and development. While "low cost" may be a desirable feature of a conflict resolution mechanism, it must always be asked in a comparative fashion. A U.S. Supreme Court case between states over water

typically costs tens of millions of dollars and stretches out over a decade or more. Is that low cost? It depends on what the feasible alternatives are.

Second, the design principle actions could be further developed and incorporated within the framework for analyzing a social–ecological system (E. Ostrom, 2007). As Ostrom argues these systems are partially decomposable systems made up of separable subsystems that operate both independently and interactively. By incorporating another class of variables—types of cross-scale linkages—that allow researchers to identify the pathways or links by which separable subsystems interact, the current framework would provide much needed guidance to analysts on how to attend to more than one separable subsystem at one time.

Through our efforts to measure and evaluate cross-scale linkages, our study of interstate compacts will continue to provide a valuable case setting. Future work on interstate river compacts could include a more in-depth examination of vertical linkages, as well as an examination of the intersection of vertical and horizontal linkages to study polycentric linkages around river basins. Moreover, assessing how these linkages have evolved, at what points in time, and in relation to what forces, will further help refine this theory. Finally, a more detailed assessment of how these linkages relate to the ability of compacts to effectively manage water over time will further our understanding of the importance of cross-scale linkages.

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Notes

1. By viewing linkages through formal rules, shared strategies, or regularized patterns of interaction, we focus on more formalized institutional linkages, versus those that may be created through informal communication patterns or networks between actors within different organizations.
2. For instance, Carlsson and Berkes (2005) propose a more inductive approach, advising analysts to first identify key management tasks associated with governing a social-ecological system and then identify who is engaged with those tasks and at what levels. In contrast, Cash et al. (2006), posit a conceptual classification of seven scales, such as jurisdictional, and management, and various levels, or positions, on each scale. For instance, the jurisdictional scale is divided in the following levels: intergovernmental, national, provincial, and localities. Cash et al. (2006) urge analysts to carefully identify and understand which scales and levels they are working at in studying these systems.
3. Most compacts contain a statement similar to this one from the Arkansas River Compact (1949), "The major purposes of this compact are to provide for the most efficient use of the waters of the Snake River for multiple purposes; to provide for equitable division of such waters; to remove causes of present and future controversies; to promote interstate comity . . ."
4. As the western United States is relatively arid, the legal institutions that have emerged to allocate water in the West are markedly different from the East. Western states allocate water using the doctrine of prior appropriation—meaning those citizens who put water to beneficial use first have the priority to use flows during times of scarcity.

5. These coding forms were adapted from the original coding forms used for the CPR studies published by Ostrom (1990) in *Governing the Commons*. We pre-tested the forms and checked for inter-coder reliability on an interstate river compact that was not part of the study population, the Red River Compact. The coding forms developed for this study are available from the authors.
6. In addition, the relations and linkages between state governments and water users, or vertical linkages, affect the operation of compact governing bodies and compliance with water allocation rules, which we examine in a companion paper.
7. We use data on streamflow conditions in these basins from USGS station gauges and data on the population and percent of agricultural water use in the counties overlying the basin, using U.S. Census sources.
8. We note that this measure does not fit the typical type of "provision" rule as envisioned in CPR theory, which emphasizes those rules that require CPR maintenance and enhancement. None of the compacts have such rules. Therefore, we draw upon a broader definition of provision, from literature on the water industry and public economies that stresses financial contributions.
9. In this analysis we do not explore the correlation between the quality of linkages and ecological indicators of CPR "robustness." We recognize this as a fruitful area for future research.

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Appendix 1

Eight Design Principles from *Governing the Commons* (E. Ostrom, 1990, p. 90)

1. *Boundaries* that are clearly defined around the resource users and the resource.
2. *Appropriation and provision rules* that are well-matched to local conditions.
3. *Collective choice arrangement*, where most individuals affected by the operational rules can participate in modifying the rules.
4. *Monitoring* by individuals who actively audit CPR conditions, and who are accountable to appropriators.
5. *Graduated sanctions* (or enforcement) for appropriators who violate rules.
6. *Conflict-resolution mechanisms* in low-cost local arenas.
7. *Recognition of rights to organize* by external governmental authorities.
8. *Potentially nested enterprises* (if part of a larger institution/system), of appropriation, provision, monitoring, enforcement, and conflict resolution.

Appendix 2

Basin Supply and Demand Conditions for 14 Interstate Rivers Governed by Compacts

Basin	Average Annual Discharge* at key gauges (acre-feet)	Irrigated Acres** (1,000)	Population**
Arkansas (Upper)			
Headwaters	52		
Stateline	134	2,770	2,130,611
Bear			
Upper	140		
Central	136		
Lower	184	1,007	539,998
Belle Fourche			
Upper	16,600		
Stateline	62,455	105	157,200
Big Blue			
Headwaters	281,082		
Stateline	607,919		
Little Blue			
Headwaters	101,205		
Stateline	358,982	2,260	638,237
Costilla Creek			
Above dam	8,160		
Mouth	10,940	289	345,099
Klamath (Upper)			
Upstream tributary	544,000		
Near stateline	1,178,500	556	310,207
La Plata			
Upstream—	31,576		
Stateline	25,066	169	184,572
Pecos			
Headwaters	83,436		
Stateline	105,500	676	764,846
Republican			
Upstream	72,758		
Stateline	116,267	2,559	327,072
Rio Grande			
Headwaters	646,028		
Stateline	717,371	1,121	2,022,727
Snake (Upper)			
Headwaters	3,285,600		
Near stateline (below dam)	4,692,400	1,411	287,029
South Platte			
Headwaters	15,744		
Sateline	383,808	1,849	3,705,843
Upper Niobrara			
Headwaters	2,700		
State line	10,000	844	98,104

Appendix 2 Continued

Basin	Average Annual Discharge* at key gauges (acre-feet)	Irrigated Acres** (1,000)	Population**
Yellowstone			
Clarks' Fork			
Upstream	676,062		
Downstream	745,581		
Big Horn			
Upstream	1,177,900		
Downstream	2,677,126		
Tongue			
Upstream	128,292		
Downstream	292,171		
Powder			
Upstream	145,017		
Downstream	407,242	1,138	614,400

*Data is from USGS stream flow gauges.

**Data is from 2000 Census and USGS Estimate Water Use, calculated for all counties overlying the basin. Areas may extend beyond the boundaries governed by the interstate compact.