CHAPTER 5

Contracting and the Commons: Linking the Insights of Gary Libecap and Elinor Ostrom

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In 2009, Elinor Ostrom won the Noble memorial prize in economics sciences for, in the words of the prize committee, "demonstrating how local property can be successfully managed by local commons without any regulation by central authorities or privatization."[1] This account of Ostrom's contribution focuses on how her work presented a "third way" of governing the commons in direct contrast to the two solutions suggested by Garrett Hardin.[2] In critiquing Hardin's view, Ostrom studied many cases in which resource users, in the presence of weak, dysfunctional, or nonexistent governments, created resilient institutions to manage resource use. In these settings, she demonstrated that self-regulating common-pool resource (CPR) governance can take the place of other institutional arrangements more familiar to economists and political scientists.

Because many of Ostrom's groundbreaking findings emerged from studies of local, self-sustaining governance built on informal norms, economists have tended to view her work as less relevant to governance questions related to industrial resource use in developed countries where formal property rights, regulation, and contracts also play a role.[3] One clear exception is found in the

work of economist Gary Libecap, who examines settings where the ultimate governance structure is either a contract between resource users or the creation of new formal property rights. Libecap's approach treats the outcome of property right negotiations as a collective action problem, and in this chapter, we explore how his approach complements and extends Ostrom's work. We also explore key areas of divergence between Libecap, and property rights scholars generally, and the work of Ostrom and other commons scholars—unsurprising given Ostrom's skepticism of property right solutions as a panacea.[4]

Starting with Arthur Cecil Pigou, economists have analyzed natural and environmental resource problems against the benchmark of a social planner making optimal decisions.[5] In this view, idealized solutions are clear, and the realities of if, or how, they are implemented are a secondary concern. Ostrom and Libecap turn this on its head, studying as their primary research objective how users deal with factors that cause coordination and collective action problems, rather than treating these problems as obstacles to achieving some desired optimal outcome. Both Libecap and Ostrom see the world through the lens of collective action and individual incentives. While Ostrom and her colleagues looked broadly at collective governance, Libecap found parallels between CPR governance and collective action through formal contractual agreements: group characteristics, information problems, and the proportionality of resource distributions being key determinants of success. These results build on Ostrom's work and provide important insight into contemporary environmental and natural resource challenges, where the same factors that cause difficulties in collective action and coordination prevent the adoption of optimal regulatory solutions.[6]

In comparing Libecap and Ostrom, we acknowledge that both authors have large bodies of work grounded in the empirical realities of numerous cases. It is difficult to fully generalize each

author's work, and that is not our goal. Instead, we use an illustrative selection of their writings and those of related scholars to make two key arguments: (1) Ostrom's work is applicable to the study of property rights and regulation, as well as self-governing regimes; and (2) the type of property rights and contracting results Libecap discussed, under some circumstances, move resource users toward effective CPR governance. We first provide examples of how the study of collective action in the work of both authors yields important insights for both property rights and contracting. We then focus on one apparent area of divergence: Libecap's emphasis of the effectiveness of property rights in contrast to Ostrom's emphasis on trust. We argue that trust and clearly defined property rights serve similar functions in some cases, and that because of this they can be viewed as partial substitutes.

The chapter is organized as follows: Section 1 provides a framework for understanding collective action and the management of natural resources. In the subsequent sections 2–4, we examine similar empirical findings from both Libecap and Ostrom centered on group characteristics, information, and proportionality. In section 5 we discuss how contracting solutions might overcome some of the difficulties encountered in the self-organizing collective management Ostrom observed. Section 6 concludes with a discussion of the ongoing importance of Ostrom's work beyond the settings she studied.

1. Collective Action to Manage Common-Pool Resources

The common-pool resource problem, as traditionally viewed by economists, is a market failure. Specifically, there is an externality in consumption or production of the resource whereby one user's use imposes a cost on other users. The solution suggested by Pigou was to make each resource user liable for the damage caused to other users.[7] While taxes or other regulatory remedies could be potential solutions, the level of resource use that maxi-

mizes value could also be achieved by consolidating ownership under one individual or entity that could then optimize resource use. One obvious choice for such an entity is a central government, which could plan for optimal extraction and impose restrictions on users in order to achieve it.

This top-down prescription for resource management fails for several reasons, however, two of which appear to have motivated the work of Libecap and Ostrom. First, Ostrom takes exception to the idea that an existing overarching authority is necessary or sufficient for managing CPRs, suggesting that the users could themselves form the authority and might be able to do so more effectively.[8] Ostrom asks under what circumstances collective action will lead to successful, self-regulating CPRs.[9] Second, Libecap takes exception to the idea that a central government is interested in choosing resource use that maximizes aggregate value. Instead, he suggests that a government is made up of politicians who care about resource user constituencies as well as about the public's preferences.[10] Libecap asks under what circumstances resource users will act collectively to improve the management of their CPR.[11]

Both authors, upon questioning the standard economic conception of CPRs, arrive at a similar starting point for their analysis: users must find some way to coordinate when their individual interests are not aligned. To understand this problem, both authors pay particular attention to the work of Mancur Olson on collective action. In particular, they ask why users might successfully act collectively when Olson suggests there are significant barriers to action: "Unless the number of individuals is quite small, or unless there is coercion or some other special device to make individuals act in their common interest, *rational, self-interested individuals will not act to achieve their common or group interests*."[12]

In Libecap's framework, users attempt to change contracts or property rights to capture more value from the resource. The

question is whether individuals' expected rents are greater under open (or limited) access or under a contracting regime. Individuals will only agree to an assignment of formal property rights via a contractual arrangement if the expected value of their formal right is at least as great as their expected rents under the status quo, absent contracting.[13] When these conditions are not easily met, collective action is needed to develop an initial allocation of individual property rights or to reconfigure contracts such that each user is made as well off. If agreement is reached, contracts are enforced by an external authority. However, the initial collective action problem is still not easily solved.[14]

Ostrom and her colleagues often viewed CPR governance through the framework of social-dilemma games. If the games are one-shot or are repeated for a preset, finite number of rounds, agreements must be enforced by an outside authority.[15] Infinitely repeated social-dilemma games can support a variety of equilibria. However, the extent to which coordination allows resource users to solve the collective action problem articulated by Olson had not been addressed with systematic and rigorous analysis.[16] The problem articulated by Ostrom and her colleagues is determining what factors allow users to forgo selfish behavior in the present, instead taking actions that, although not immediately self-interested, would in the long run yield greater benefits.[17] When individuals exhibit reciprocity, forgoing gains in the short run to demonstrate cooperative intentions, they build trust and over time groups are able to establish long-term commitments to act in the group interest.[18] Often, a group establishes norms or rules, formal or informal, to govern the CPR, and this builds reciprocity into behavior to the point that selfish acts may be viewed distastefully or not considered.[19]

Acting consistently with their broader bottom-up approach to resource governance, both Libecap and Ostrom focused on how the characteristics of resources and of the groups themselves, as

well as external pressures, affect individual incentives by shaping benefits and costs. In many of the cases Ostrom studied, the group must find a way to enforce its choices for resource use, while Libecap's resource users rely on the state's contract enforcement capability once an agreement is reached. Although the institutions differ, the factors that lead to success or failure of the entire enterprise are similar. Ostrom's and Libecap's focus on individual incentives stands in contrast to models of optimal resource governance that measure efficiency in the aggregate without comparing the distribution of individual payoffs under alternative institutional arrangements.[20] Focusing on the users themselves yields generalizable results, because the same factors that cause the problem with managing the resource in the first place, such as resource complexity, lack of information, high costs, and divergences in user expectations and outcomes, prompt users to resist or otherwise foil top-down solutions.

Both Libecap and Ostrom embraced complexity and empirical observation, studying a wide variety of natural resources, cultures, and institutional settings. Yet taken in the aggregate, these many disparate settings yield common themes, both within and between their works. First, understanding how and why people in groups behave in particular ways is paramount to understanding whether they can solve a CPR problem. Success requires buy-in on a solution from many parties and identifying the problem or externality facing the group is a necessary, but not a sufficient, condition. Second, individual user costs and benefits matter, not just the aggregate outcome. User perceptions of these costs and benefits also matter, and information asymmetry and uncertainty can decrease the likelihood of success. Third, the relationship between costs and benefits matters. In Ostrom's work, this gets at the idea of fairness: unequal proportions of costs and benefits are likely to discourage collective action because individuals are not willing to contribute to the maintenance of a system that they

feel does not fairly distribute the gains of cooperation.[21] Libecap perceives proportionality as affecting bargaining, because users seeing similar proportions of costs to benefits are more likely to have their interests aligned.[22]

2. Group Characteristics

Both Libecap and Ostrom identify group characteristics as crucial to successful CPR management because users together must agree on a mutually beneficial set of rules and expectations for behavior. Based on earlier work on collective action, group size and heterogeneity are a focus for both authors.[23] With large groups, coordinating the bargaining process becomes more burdensome; large groups may increase the level of conflict and costs of arriving at acceptable allocation formulas.[24] Group heterogeneity can affect both the ability to make proportionate allocations and the information available to different users, as discussed above.

In the literature on collective action, no clear consensus has emerged on the effect of group size and heterogeneity. While increases in the number and heterogeneity of bargaining parties tend to increase the transaction costs of negotiation and make agreement less likely,[25] this is definitively not always the case.[26] Because both group size and heterogeneity may be endogenous to the collective action process, success may lead to larger and more heterogeneous groups, while less successful outcomes lead to fragmentation—smaller but more homogeneous groups.[27] Both authors acknowledge this issue and emphasize that the existence of large group sizes or high degrees of heterogeneity are not themselves the cause of the breakdown of collective action. Instead, it is the impact of these factors on variables that actually affect the expectation of the costs and benefits perceived by users. Both authors' work in this area is linked by a rigorous assessment of the key variables that explain perceived costs and benefits over a series of empirical cases.

2.1 Size

Libecap is explicit in his assessment of the issue of group size: "The greater the number of competing interest groups with a stake in the new definition of property rights, the more claims that must be addressed by politicians in building a consensus on institutional change."[28] It is more difficult to bring larger number of users to the bargaining table, have them all agree on the state of the resource and the nature of the problem, and create and enforce a solution. Large resource users internalize more of the rent dissipation, and if a large number of smaller users can free ride on any curtailment, large users are likely to impede agreements.[29] The necessity of including a large number of parties in a contracting situation is often indicative of a more complex and interconnected resource.

Ostrom argues that the key to understanding the role of aspects like group size lies in embracing the complexity of social-ecological systems;[30] in her social-ecological systems (SES) framework the number of users is one of nine traits of resource users that affect collective action, and all nine traits are interrelated. For this reason, Ostrom is more muted than Libecap in her assessment of group size: "The effect of the number of participants facing problems of creating and sustaining a self-governing enterprise is unclear." She continues, "Analyzing the conflict levels over a subtractable good and the transaction costs of arriving at acceptable allocation formulas, group size may well exacerbate the problems of self-governing systems."[31] Correlated factors make it difficult to directly assess the impact of group size. Small groups allow for more interactions and the ability to build trust, but may also decrease the resources available to mobilize and run the group.[32]

Political scientist Amy Poteete and Ostrom suggest that the relationships between group size and heterogeneity and collective action are not likely to be linear, although their examples suggest

that these nonlinearities may stem from correlated factors.[33] For instance, the size of a group might interact with other factors, such as the distribution of wealth: "Appropriators who possess more substantial economic and political assets may have similar interests to those with fewer assets or they may differ substantially on multiple attributes."[34] A large group's size might facilitate allowing enough wealthy individuals to lead the collective action endeavor to make it successful in situations where interests are aligned. Alternatively, where the interests of the wealthy diverge, the lack of repeated interactions and trust in large groups might lead to a breakdown in collective action.

This argument appears to be at odds with Libecap's assessment that large groups tend to increase both complexity and heterogeneity. One explanation for the divergence in views is that the groups studied by Ostrom may have been quite small or homogeneous (or both) relative to those studied by Libecap.[35] Alternatively, the correlation of size with other factors predicting success, including the overall gains from coordination, might limit consensus. Still, Libecap and co-author Steven Wiggins's argument that having few, large firms on an oil or gas field can allow for a rapid agreement is analogous to Ostrom's view that appropriators with substantial assets may facilitate agreement, if the total number of users is held small and constant.[36] Increasing the number of firms, Libecap argues, decreases the willingness of large firms to participate in an agreement that will allow small appropriators to continue to dissipate resource rents.[37]

2.2 Heterogeneity

It is clear in the work of both Libecap and Ostrom that group size and heterogeneity are linked, although the two authors conceive of group heterogeneity in slightly different ways, each aligning their approach to their conception of the collective action problem faced by resource users. Libecap views heterogeneity through the lens of transaction costs.[38] A group whose members face signifi-

cantly different potential benefits and costs from a proposed solution has higher costs of reaching agreement: "Even when there are aggregate net benefits from implementing management regimes . . . , not all parties perceive individual gains. Therefore, some may resist collective action."[39] A diverse set of economic interests, or more users generally, make finding a mutually acceptable agreement more difficult.

Production cost heterogeneity also affects collective action. During the New Deal, differences in cost structure limited the ability of industrial firms to lobby to enforce collusive policies, while agricultural producers represented by the American Farm Bureau Federation had uniform production costs and successfully retained collusive pricing policies.[40] However, even in agriculture, producer heterogeneity limited the scope for successful collective action, as exemplified by Florida and California citrus producers' inability to agree on effective prorationing rules.[41] Heterogeneity in user incentives, as a result of unequal revenue and cost share distributions, hinders oil and gas unitization agreements when revenue shares are not the same as cost shares, creating differential incentives to exploit the resources.[42]

Alternatively, Ostrom views heterogeneity primarily in terms of its effect on social cohesion and trust: "If groups coming from diverse cultural backgrounds share access to a common resource, the key question affecting the likelihood of self-organized solutions is whether the views of the multiple groups concerning the structure of the resource, authority, interpretation of rules, trust, and reciprocity differ or are similar."[43] In Ostrom's reckoning, trust in a CPR governance regime requires users to have a shared understanding of the world and of the resource system in particular. Heterogeneity can undermine trust when the views and norms held by users are not conducive to building such a shared understanding.

Despite Libecap and Ostrom's different conceptions of heterogeneity, their results are similar: they both find that when inter-

ests diverge, it is more difficult to reach a consensus. For example, differential abilities among fishers affect their willingness to organize with others, because those with high skill receive rents even under open access conditions and therefore require larger shares.[44] However, identifying heterogeneity in users is not a sufficient condition for identifying a potential breakdown in collective action. Ostrom discusses this example, but suggests that trust is key, because ongoing, repeated interactions among users help overcome the challenges that heterogeneity creates.[45] Studying forest user groups in Nepal, co-author George Varughese and Ostrom find that heterogeneity does pose a key challenge that can be overcome with innovative institutional arrangements.[46]

3. Information Problems

Although Ostrom's original design principles focused on institutional characteristics rather than resource characteristics, her later development of the social-ecological systems framework also incorporated resource characteristics.[47] Within the context of the framework, Ostrom continuously emphasized users' ability to observe and understand the resource as critical to successful CPR management:

> Characteristics of CPRs affect the problems of devising governance regimes. These attributes include the size and carrying capacity of the resource system, the measurability of the resource, the temporal and spatial availability of resource flows, the amount of storage in the system, whether resources move (like water, wildlife, and most fish) or are stationary (like trees and medicinal plants), how fast resources regenerate, and how various harvesting technologies affect patterns of regeneration. . . . It is relatively easy to

> estimate the number and size of trees in a forest and allocate their use accordingly, but it is much more difficult to assess migratory fish stocks and available irrigation water in a system without storage capacity.[48]

Broadly, the challenges that these resource characteristics pose for collective action could be summarized as "information problems" that limit users' ability to understand and predict resource characteristics with sufficient certainty to develop institutions for governance.

Economists have long appreciated the role of information in affecting coordination,[49] and Ostrom explicitly incorporated economic reasoning in her explanation of how information problems affect individuals' willingness to cooperatively develop governance regimes. Drawing on economists Harold Demsetz, Douglass North, and others, Ostrom argues,

> Whether the users themselves are able to overcome the higher level dilemmas they face in bearing the cost of designing, testing, and modifying governance systems depends on the benefits they perceive to result from a change as well as the expected costs of negotiating, monitoring, and enforcing these rules. . . . Perceived benefits are greater when the resource reliably generates valuable products for the users. . . . Perceived costs are higher when the resource is large and complex, users lack a common understanding of resource dynamics, and users have substantially diverse interests.[50]

Ostrom also appreciated that information problems and perceptions about benefits and costs could stymie government-based solutions and formal property rights as well as informal systems for CPR management Criticizing economists and other political scientists for their focus on aggregates in the search for global optima, she focused instead on how local knowledge would affect users' incentives to pursue one form of governance or another. This approach emphasizes the importance of local over "highly aggregated" information about resource stocks in shaping incentives for individuals to solve collective action problems either informally or through the political process, which Ostrom treated as endogenous.[51]

Like Ostrom, Libecap studied the effects of information about resource stocks on individuals' perceived benefits and costs from contracting to solve common-pool problems. Rights-based policy reforms that appear to be Pareto-improving may nevertheless be unacceptable to a majority of resource users, preventing reform.[52] Hence, economists' focus on statistical aggregates (macro-level Pareto improvements) causes them to overlook the important local information that determines whether individual users will actually support a particular institution.

A particularly salient example of the similarities between Ostrom's discussion of information and Libecap's findings is the study of common-pool problems in oil production. In many areas of the United States, rights to subsurface resources were conveyed to landowners when land was first privatized. Conventional oil reservoirs can span thousands of acres, whereas most land parcels were 160 to 320 acres initially. This gave rise to a common-pool problem whereby many landowners could access the same underground oil reservoir but were unable to exclude one another due to the migratory nature of the oil.[53] Libecap's study of this common-pool problem and the associated regulatory and contractual

solutions relied heavily on the role of asymmetric and imperfect information about resource stocks—Ostrom's "local knowledge."

Wiggins and Libecap study the effect of imperfect and asymmetric information on contractual solutions to the common-pool problem in seven oil fields.[54] Unitization—the "obvious" contractual solution—involves the formation of a single production unit, which turns over production of the reservoir to a single firm. All the potential users then share the revenues from efficient extraction of oil. The solution is Pareto-improving in the sense that it improves the total rents from oil production relative to competitive extraction. Oil field unitization is conceptually very similar to the CPRs studied by Ostrom in that users must come to a collective agreement about how to manage the resource and distribute the associated benefits. The primary distinction between unitization and an informal CPR regime is that unitization agreements are enforced via formal contracts rather than informal norms and social sanctioning.

Despite the aggregate efficiency gains of joint management, voluntary unitization is somewhat rare, and this is the problem Wiggins and Libecap seek to understand.[55] Contractual solutions that improve aggregate efficiency can nevertheless fail if individuals do not agree to the allocation of shares of net revenue under the unitized contract. Disagreement about these shares—based on parties' limited and differential information about the value of subsurface deposits—is what causes contracts to fail. Though oil can migrate through a reservoir, there is considerable heterogeneity in the productivity of different locations across a given reservoir, but these differential productivities are not observable by all firms. Hence, when firms come to the table, they each have limited information about the productive capacity of all other firms.

Using data from trade journals about the potential unitization of seven oil fields, Wiggins and Libecap study how firms' limited information about subsurface oil reservoirs influences unitization

outcomes.[56] Their findings are consistent with their predictions, and with those of Ostrom:[57] they find that unitization is much less likely to occur in oil fields where there is considerable heterogeneity in resource productivity, which makes the information held by individual users more asymmetric. They also find that individual firms that face greater uncertainty about their productivity choose to delay joining units longer because the benefits of unitization relative to open access are less clear when future productivity is hard to forecast.

Libecap's finding that information problems stymie contractual solutions to common-pool problems can be paired with another assertion from Ostrom's work: the same information problems that limit contractual solutions also pose challenges for regulators.[58] Libecap and Wiggins study regulatory responses to common-pool losses in oil reservoirs in Oklahoma, Texas, and Wyoming. The crux of their argument is that the same users that prefer common-pool competition to unitization will also lobby to prevent regulation because they stand to gain from doing so. Libecap and Wiggins find policy on federal lands in Wyoming to be more effective than policy on state lands because federal policy requires unitization before oil field exploration, when all parties are equally uncertain about the resource and there is no local knowledge available.[59] In this setting, firms are less likely to oppose unitization. By contrast, unitization in Oklahoma and Texas can occur only after fields have been developed, at which point certain firms' local information gives them strong incentives to resist unitizing and to resist regulation.

Again, Libecap's approach mirrors Ostrom's emphasis on individual users and their incentives rather than on aggregates. And Libecap and Wiggins explicitly treat regulatory outcomes as endogenous to the information problem, in the same manner called for by Ostrom.[60] Information problems are an especially important arena for treating policymakers as endogenous because poli-

cymakers are likely to suffer from the same information problems as resource users. Rather than conclude with pessimism regarding the prospect of effectively governing resources fraught with uncertainty and variability, Libecap and Ostrom both propose that the government should invest in information provision to alleviate the problem. For Libecap, this takes the form of lowering transaction costs,[61] whereas for Ostrom it takes the form of "technological infrastructure" that makes resources less difficult to monitor.[62]

4. Proportionality

Given the challenges of group size, heterogeneity, and imperfect information identified in the previous two sections, how can users design enduring agreements? Both Libecap and Ostrom, examining different resources and institutional settings, find that the proportional allocation of costs and benefit shares is key to ongoing resource management success.

Both authors measure success as the extent to which the value of the resource is maximized. In one example, Ostrom and colleague Roy Gardner examine irrigation ditch management in Nepal, where effective management means a high level of irrigation utilization: more land over more of the year under cultivation.[63] In another example, Libecap and legal scholar Henry Smith look at oil and gas unit management, where effective management means coordinated extraction over time to maximize the amount of the resource extracted.[64] In both settings, costs are incurred separately from benefits and the authors find that when costs are not proportional to benefits, management institutions are less successful.

In Nepal, the key cost is ditch maintenance, which must be performed to ensure that water diversions and deliveries are effective. By allocating these cleanup costs in the form of labor to all users along the ditch, water deliveries are proportionally assigned. Users near the head of the canal are in an advantageous position

to extract more water, but agree to a proportional share because they need the labor of others along the canal. When the Nepalese government implemented engineering improvements that made bearing costs to clear the canal unnecessary, the proportional relationship between costs and benefits was disrupted. Users in advantageous positions took advantage by diverting excess water, and overall irrigation utilization decreased dramatically.

In oil and gas extraction, multiple parties may have leasing rights to drill on a particular field, but maximizing extraction requires coordination. The Prudhoe Bay field in Alaska is characterized by a gas cap and an oil rim, which means the natural gas creates pressure in the middle of the formation. As long as the gas is left in the field, oil is driven out of wells at the rim. However, in the creation of the Prudhoe Bay unit agreement, costs and benefits of total field production were not allocated proportionally across all owners because oil and gas revenues and costs were separated. Gas owners then favored increased gas production, increasing the costs of oil extraction and decreasing the ultimate recovery of oil. Conversely, oil owners favored forgoing gas production and using the gas instead as an injectant to further increase oil production. A lack of proportional distribution of benefits and costs led to disagreement among resource users, and ultimately to aggregate losses.[65]

A key empirical finding of both authors is that different settings, even of the same resource, can lead to different rules of proportionality. In examining the Philippine *zanjera* irrigation organizations, Ostrom builds on the work of economist Robert Siy to look at allocation rules for a system requiring considerable manual labor to maintain.[66] Alternative water allocation schemes could increase water use efficiency, as was observed in Nepal,[67] but the use of the water requires large investments of labor by contributing users, and by allocating water in proportion to labor, the system is able to deliver efficiencies in the cost of maintaining

infrastructure. Likewise, the allocation of proportional shares of oil and gas production works generally, but breaks down on the subset of formations requiring multiple phases because the proportionality condition is only met within, but not across, phases.[68]

The principle of proportionality laid out by both authors relies on specific knowledge of the characteristics of the resource being managed. In both cases above, understanding the behavior of the resource—the unidirectional flow of water and the forced flow of oil—is critical to understanding why one set of allocation rules is proportional and another is not. Gardner and his colleagues suggest that these lessons can be applied broadly, citing the Montreal Protocol as an example of how a large, global CPR can be managed via proportional cutbacks, and suggesting that failures can be linked to too-large cutbacks or asymmetries in payoffs.[69]

5. Self-Organizing Collective Management and Contracting

Thus far, this chapter has focused on similarities in the conditions for successful resolution of common-pool resource management challenges that Ostrom and Libecap highlighted. Libecap generally focused on formal contracts, contrasting with much of Ostrom's work, which focused on informal governance in settings where such contracts were not available or enforceable owing to absent, weak, or dysfunctional governments. In this section we compare Ostrom's and Libecap's analysis of coordination challenges in the governance of surface water systems, which both authors studied extensively. Their work suggests that, at least in this case, informal institutions and formal property rights serve a similar function, and can be viewed as substitutes.

Irrigation infrastructure—canals, ditches, dams, and reservoirs used to store and convey water to where it is most useful—require large up-front capital costs but entail very low marginal costs once constructed.[70] However, the benefits of infrastructure projects often take time to materialize, particularly in agriculture.

This presents a problem for individual irrigators seeking to develop diversion and storage infrastructure in settings where there is limited access to credit, such as on the nineteenth-century American frontier and in the developing world today.[71]

One way for individuals to overcome high up-front costs is to pool their capital and invest jointly in building larger diversion canals, which can then feed smaller ditches for each individual user. This cost-sharing approach can facilitate the construction of larger, more efficient ditches than would be possible via individual investment.[72] We briefly discussed in the prior section the case of irrigation in Nepal. Once a ditch is constructed, potential users of the ditch face an asymmetric commons dilemma: those closer to the diversion point (head-enders) can access the water before those at the opposite end of the ditch (tail-enders). Because the fixed investment costs are already sunk and the marginal costs of diversion are low, head-enders have an incentive to divert all or most of the water once a ditch has been constructed.[73] Recognizing this potential problem, tail-enders will be unwilling to invest in the first place, creating a classic collective action problem in which all parties would be better off with joint investment, but it is not individually rational for parties to invest.

Ostrom focused on constraints on opportunistic behavior by head-enders that could enable collective action, especially the use of labor and allocation rules. In systems where ex post maintenance labor was critical, rules were more likely to be followed.[74] In the Spanish *huertas*, allocation rules and norms of mutual enforcement made monitoring less costly—the rotational nature of the allocation gave farmers an incentive and ability to monitor others' behavior as they prepared for their own deliveries.[75] In the context of the American frontier, Ostrom emphasized the ability of the Mormon church to serve as a coordinating institution for supporting communal ditch building. The church was able to effectively limit entry by outsiders and link labor and water al-

locations via construction activities, while also providing strong social sanctions for potential unauthorized diversions after ditch building was complete.[76]

The Nepalese irrigation systems, the *huertas*, and Mormon villages all consisted of homogeneous groups of users with shared cultural backgrounds that facilitated cooperation, either through organizing joint labor or through providing common sanctioning mechanisms.[77] Ostrom emphasized the importance of these shared values by contrasting successes in both the Nepalese and Mormon cases to examples in each setting where the government attempted and failed to solve the same collective action problems in developing irrigation works.[78] In both cases, the government lacked local knowledge and failed to prevent opportunistic behavior by irrigators. Thus, while the government could solve the problem of financing infrastructure, it struggled to resolve collective action problems ex post in the absence of formal property rights.

Libecap's work on the evolution of property rights to resources on the American frontier emphasized a different solution to the same collective action problem. In the context of irrigation development on the frontier, Ostrom's and Libecap's predictions about the role of information problems, the characteristics of the resource, and the scope for formal government management were identical. But where Ostrom emphasized the importance of informal coordinating institutions, economist Bryan Leonard and Libecap, emphasizes the importance of formal property rights to water in solving the collective action problems of infrastructure development.[79] The property right institution in this case is the prior appropriation doctrine, which defined property rights to water on a first-come, first-served basis and allowed water rights to be separated from land ownership. Prior appropriation also entailed priority-based allocation of water during droughts so users with more senior claims had preferential access to water.

Leonard and Libecap characterize the collective action problem of ditch construction exactly as Ostrom did,[80] building their economic framework directly upon Ostrom and Gardner's.[81] However, they focus on the role that priority-based allocation played in enabling users to write contracts to share the costs of ditch construction—a secure property right to water ex post reduced the risk of opportunistic behavior and aligned incentives ex ante. Hence, Ostrom and Leonard and Libecap present two very different solutions to the same collective action problem.[82]

Leonard and Libecap argue that social sanctioning and limits to entry associated with the Mormon church and emphasized by Ostrom were the exception rather than the norm on the western frontier.[83] The successful irrigation systems described by Ostrom may simply not have been feasible for many western communities where a large number of new settlers from diverse cultural and institutional backgrounds were arriving.[84] These settlers lacked a common set of shared social norms to facilitate sanctioning, and there was no way to predict how many irrigators might show up in the future. Under these conditions, a formal property right to water provided the security necessary to facilitate contracting rather than informal coordination. Moreover, the benefits associated with prior appropriation rights (greater ditch investment, higher crop income per acre) were lower in areas of Colorado dominated by Mormon settlement and other preexisting irrigation institutions, suggesting that formal property rights and informal norms were in fact both solving a similar collective action problem based on the broader institutional constraints.[85]

6. Conclusion

The preceding examples and discussion serve to illustrate the congruence between the collective action problems faced by users attempting to define property rights and the collective action problems facing users creating self-enforcing governance insti-

tutions. We emphasize three ways in which collective action to contract and collective action to form self-organizing governance institutions are similar: (1) larger and more heterogeneous groups potentially increase the difficulty of collective action, but these challenges can be overcome; (2) information problems associated with the resource and with local knowledge limit collective action; and (3) proportional allocations of benefits and costs aid in successful collective action. Given these similarities, it is natural to ask what differentiates the settings that lead to self-organizing CPR management and those that lead to contracting. To conclude this chapter, we discuss how further research can provide insight into this question. This is especially relevant in applying the lessons of Ostrom, Libecap, and other authors to the improved management of natural and environmental resources.

One question is whether *access* to formal contracts is the only factor that distinguishes the emergence of a formal contract or property right from self-organizing governance. Key cases, and economic intuition, suggest that the relative costs and benefits of different institutions would play an important role. The availability of contracting may lower the cost of collective action but not eliminate the adoption of alternative institutional forms. Where property rights are expensive to enforce, as in the management of groundwater, institutions that look more like self-organizing governance emerge.[86] Groundwater users in Kansas petitioned the state to receive the ability to manage their common-pool groundwater according to local rules and customs.[87] These sorts of hybrid systems where formal and informal institutions exist concurrently are exhibited in Colorado, where users collectively adopted pumping taxes;[88] in Nebraska, where more formal market exchanges were adopted;[89] and in Kansas, where users voluntarily adopted pumping restrictions.[90] In these cases, state laws or state-enforced contracts provide a viable and low-cost end point to collective action to solve CPR problems.

More research is needed to better characterize the conditions under which self-sustaining CPR governance occurs and where contracts and property rights are viable substitutes. For instance, what factors would lead to successful self-organizing CPR governance in countries with strong property rights and a viable court system? This question is key if changes in policy or knowledge can allow for the adoption of alternative, more successful institutional forms. Ostrom suggests one of the problems is the teaching of scientific management of natural resources in a way that suggests central governments impose uniform regulations that fit textbook solutons: "National governmental agencies are frequently unsuccessful in their efforts to design effective and uniform sets of rules to regulate important common-pool resources across a broad domain."[91] Because alternative, successful institutions might exist, it becomes imperative to understand when centralized control, property rights or contracting, or self-organizing institutions are likely to be successful.

This type of analysis is equally relevant to understanding emerging CPR problems. Three areas where Ostrom's insight into self-enforcing CPR management are potentially valuable are global carbon dioxide emissions, the arctic, and outer space. The melting of the arctic ice cap has opened many potential fossil fuel deposits to extraction in an area where several large and wealthy countries all claim extraction rights. Mineral resources in outer space offer a similar, if currently hypothetical, scenario. More pressing is the problem of global climate change. These situations might seem to be scaled-up versions of a classic CPR. However, the institutional features Ostrom emphasized—such as group cohesion and long-evolved, shared norms—are unlikely to play a large role in governance of the global climate, the arctic, or outer space. Applying the findings of this chapter to these settings, however, reveals essential components of the structure of collective action problems in general, highlighting the need for institu-

tions that perform specific functions (e.g., enforcement, sharing of benefits and costs).

Libecap brings together several empirical examples to illustrate factors that affect the success of collective action in managing CPRs of varying scales.[92] In pointing out the collective action problems inherent in property rights formation, his work points to the fallacy of viewing Ostrom only as a "third-way" alternative to government ownership or privatization. Instead, he applies Ostrom's insights about collective action to the study of the success or failure of private property and government regulation. This chapter offers one example of how researchers can build on Ostrom's legacy by bringing the lessons from her work to new institutional and resource settings by examining resource governance empirically and carefully. As Ostrom suggests,

> As an institutionalist studying empirical phenomena, I presume that individuals try to solve problems as effectively as they can. . . . It is my responsibility as a scientist to ascertain what problem individuals are trying to solve and what factors help or hinder them in these efforts.[93]

This drive to understand how resource users try to solve problems, and when they are successful, is the common thread woven through the work of both Gary Libecap and Elinor Ostrom.

219 Pennington, 34.

220 Ostrom, *Governing the Commons*.

221 Julian L. Simon, *The Ultimate Resource 2* (1981; repr., Princeton, NJ: Princeton University Press, 1996), available at http://www.juliansimon.org/writings/Ultimate_Resource/.

CHAPTER 5. "CONTRACTING AND THE COMMONS: LINKING THE INSIGHTS OF GARY LIBECAP AND ELINOR OSTROM"

1 "Elinor Ostrom: Facts," Nobel Prize (website), accessed December 18, 2019, https://www.nobelprize.org/prizes/economic-sciences/2009/ostrom/facts/.

2 Garrett Hardin, "The Tragedy of the Commons," *Science* 162, no. 3859 (December 1968): 1243–48.

3 This is a broad generalization. However, in the ten years since Ostrom won the Nobel prize, we find only a few citations of her work in the *American Economic Review* (21), the *Journal of Political Economy* (4), and the *Quarterly Journal of Economics* (2), and most of these citations are related to her development or behavioral work and not to the management of environmental or natural resource problems. The view that more complex resource problems are beyond Ostrom's framework is summarized by Robert Stavins and Gary Libecap, although both authors argue, as we do here, for the relevance of Ostrom's work in this context. Robert N. Stavins, "The Problem of the Commons: Still Unsettled after 100 Years," *American Economic Review* 101, no. 1 (2011): 81–108; Gary D. Libecap, "Addressing Global Environmental Externalities: Transaction Costs Considerations," *Journal of Economic Literature* 52, no. 2 (2014): 424–79.

4 Elinor Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action* (Cambridge: Cambridge University Press, 1990); Elinor Ostrom, Marco A. Janssen, and John M. Anderies, "Going beyond Panaceas," *Proceedings of the National Academy of Sciences* 104, no. 39 (2007): 15176–78.

5 Arthur Cecil Pigou, *The Economics of Welfare* (MacMillan and Co: Londo1932).

6 See, for example, Gary D. Libecap and Steven N. Wiggins, "The Influence of Private Contractual Failure on Regulation: The Case of Oil Field Unitization," *Journal of Political Economy* 93, no. 4 (1985): 690–714.

7 Pigou, *Economics of Welfare*.

8 Ostrom, *Governing the Commons*, 21.

9 Ostrom, 14.

10 Ronald N. Johnson and Gary D. Libecap, *The Federal Civil Service System and the Problem of Bureaucracy: The Economics and Politics of Institutional Change* (Chicago: University of Chicago Press, 1994), 163; Gary D. Libecap, *Contracting for Property Rights* (Cambridge: Cambridge University Press, 1989), 22.

11 Libecap, *Contracting for Property Rights*, 27.

12 Mancur Olson, *The Logic of Collective Action: Public Goods and the Theory of Groups* (Cambridge, MA: Harvard University Press, 1965), 2. Italics in original.

13 Libecap, *Contracting for Property Rights*, 74.

14 See, for example, Libecap and Wiggins, "Influence of Private Contractual Failure."

15 Ostrom, Elinor. "Toward a behavioral theory linking trust, reciprocity, and reputation." *Trust and reciprocity: Interdisciplinary lessons from experimental research* 6 (2003): 19-79.

16 Ostrom, 22.

17 See, for example, Elinor Ostrom, Roy Gardner, and James Walker, *Rules, Games, and Common-Pool Resources* (Ann Arbor: University of Michigan Press, 1994), 198.

18 Ostrom, Gardner, and Walker, *Rules, Games, and Common-Pool Resources*, 215.

19 Ostrom, *Governing the Commons*, 35.

20 See, for example, H. Scott Gordon. "The Economic Theory Of A Common-Property Resource: The Fishery'." *The Journal of Political Economy* 62, no. 2 (1954): 124-142;
Jonathan M. Karpoff, "Suboptimal Controls in Common Resource Management: The Case of the Fishery," *Journal of Political Economy* 95, no. 1 (1987): 179–94; Frances R. Homans and James E. Wilen, "Markets and Rent Dissipation in Regulated Open Access Fisheries," *Journal of Environmental Economics and Management* 49, no. 2 (2005): 381–404.

21 Elinor Ostrom, "Collective Action and the Evolution of Social Norms," *Journal of Economic Perspectives* 14, no. 3 (2000): 150.

22 Gary D. Libecap and James L. Smith, "The Self-Enforcing Provisions of Oil and Gas Unit Operating Agreements: Theory and Evidence," *Journal of Law, Economics, and Organization* 15, no. 2 (1999): 526–48.

23 Olson, *Logic of Collective Action; Baland, Jean-Marie, and Jean-Philippe Platteau. Halting degradation of natural resources: is there a role for rural communities?. Food & Agriculture Org., 1996..*

24 Andrew B. Ayres, Eric C. Edwards, and Gary D. Libecap, "How Transaction Costs Obstruct Collective Action: The Case of California's Groundwater," *Journal of Environmental Economics and Management* 91 (2018): 46–65; Ostrom 2014.

25 Olson, *Logic of Collective Action*; Gary D. Libecap, "Distributional Issues in Contracting for Property Rights," *Journal of Institutional and Theoretical Economics (JITE) / Zeitschrift für die gesamte Staatswissenschaft* 145, no. 1 (1989): 6–24; Ostrom, *Governing the Commons*; Bhim Adhikari and Jon C. Lovett, "Transaction Costs and Community-Based Natural Resource Management in Nepal," *Journal of Environmental Management* 78, no. 1 (2006): 5–15; Lore M. Ruttan, "Economic Heterogeneity and the Commons: Effects on Collective Action and Collective Goods Provisioning," *World Development* 36, no. 5 (May 2008): 969–85.

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27 Ayres, Edwards, and Libecap, "How Transaction Costs Obstruct Collective Action"; Amy R. Poteete and Elinor Ostrom, "Heterogeneity, Group Size and Collective Action: The Role of Institutions in Forest Management," *Development and Change* 35, no. 3 (2004): 435–61.

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29 Gary D. Libecap and Steven N. Wiggins, "Contractual Responses to the Common Pool: Prorationing of Crude Oil Production," *American Economic Review* 74, no. 1 (1984): 87–98.

30 Elinor Ostrom, "A Diagnostic Approach for Going beyond Panaceas," *Proceedings of the National Academy of Sciences* 104, no. 39 (2007): 15181–87.

31 Elinor Ostrom, "Reformulating the Commons," *Ambiente & Sociedade* 10 (2002): 13.

32 Poteete and Ostrom, "Heterogeneity, Group Size and Collective Action."

33 Poteete and Ostrom, "Heterogeneity, Group Size and Collective Action."

34 Ostrom, "Reformulating the Commons," 14.

35 A notable exception is Ostrom's study of Spanish *huertas*, which sometimes contained in excess of ten thousand users. However, the *huertas* are still marked by the homogeneity of the participants. Ostrom, *Governing the Commons*.

36 Libecap and Wiggins, "Contractual Responses"; Ostrom, "Reformulating the Commons, " 14.

37 Libecap and Wiggins, "Contractual Responses."

38 Libecap, *Contracting for Property Rights.*

39 Ayres, Edwards, and Libecap, "How Transaction Costs Obstruct Collective Action."

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43 Ostrom, "Reformulating the Commons," 14.

44 Ronald N. Johnson and Gary D. Libecap, "Contracting Problems and Regulation: The Case of the Fishery," *American Economic Review* 72, no. 5 (1982): 1005–22.

45 Elinor Ostrom, "Self-Governance and Forest Resources," in *Terracotta Reader: A Market Approach to the Environment*, ed. Parth J. Shah and Vidisha Maitra (New Delhi: Academic Foundation, 2005), 9; Marco A. Janssen and Elinor Ostrom, "Adoption of a New Regulation for the Governance of Common-Pool Resources by a Heterogeneous Population," in *Inequality, Cooperation, and Environmental Sustainability*, ed. Jean-Marie Baland, Pranab Bardhan, and Samuel Bowles (New York: Russell Sage Foundation and Princeton University Press, 2007).

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51 Thomas Dietz, Elinor Ostrom, and Paul C. Stern, "The Struggle to Govern the Commons," *Science* 302, no. 5652 (2003): 1907–12; Elinor Ostrom, "Beyond markets and states: polycentric governance of complex economic systems." *American economic review* 100, no. 3 (2010): 641-72.

52 Steven N. Wiggins and Gary D. Libecap, "Presence of Imperfect Information," *American Economic Review* 75, no. 3 (1985): 368–85; Johnson and Libecap, "Contracting Problems and Regulation"; Bryan Leonard and Gary D. Libecap, "Collective Action by Contract: Prior Appropriation and the Development of Irrigation in the Western United States," *Journal of Law and Economics* 62, no. 1 (2019): 67–115.

53 Libecap and Wiggins, "Contractual Responses."

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55 Wiggins and Libecap, "Presence of Imperfect Information."

56 Wiggins and Libecap, "Presence of Imperfect Information."

57 Ostrom, "Diagnostic Approach."

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59 Libecap and Wiggins, "Influence of Private Contractual Failure."

60 Ostrom, Elinor. "Beyond markets and states: polycentric governance of complex economic systems." *American economic review* 100, no. 3 (2010): 641-72.

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63 Elinor Ostrom and Roy Gardner, "Coping with Asymmetries in the Commons: Self-Governing Irrigation Systems Can Work," *Journal of Economic Perspectives* 7, no. 4 (1993): 93–112.

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66 Ostrom, *Governing the Commons*, 87; Robert Y. Siy Jr., *Community Resource Management: Lessons from the Zanjera* (Rome: Food and Agricultural Organization of the United Nations, 1982).

67 Ostrom and Gardner, "Coping with Asymmetries."

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Libecap, Gary D. "Institutional path dependence in climate adaptation: Coman's" Some unsettled problems of irrigation"." *American Economic Review* 101, no. 1 (2011): 64-80;
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71 Hanemann, Sustainable Irrigation.

72 Leonard and Libecap, "Collective Action by Contract."

73 Ostrom and Gardner, "Coping with Asymmetries."

74 Ostrom and Gardner, "Coping with Asymmetries."

75 Ostrom, *Governing the Commons*.

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77 Ostrom, *Governing the Commons*; Ostrom, "Reflections on 'Some Unsettled Problems'"; Ostrom and Gardner, "Coping with Asymmetries."

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80 Leonard and Libecap, "Collective Action by Contract."

81 Ostrom and Gardner, "Coping with Asymmetries."

82 Ostrom, "Reflections on 'Some Unsettled Problems'"; Leonard and Libecap, "Collective Action by Contract."

83 Ostrom, "Reflections on 'Some Unsettled Problems.'"

84 Ostrom, "Reflections on 'Some Unsettled Problems.'"

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91 Ostrom, "Coping with Tragedies of the Commons," 495.

92 Libecap, "Addressing Global Environmental Externalities."

93 Ostrom, *Governing the Commons*, 25.

CHAPTER 6. "THE ENVIRONMENTAL BENEFITS OF LONG-DISTANCE TRADE: INSIGHTS FROM THE HISTORY OF BY-PRODUCT DEVELOPMENT"

1 Garrett Hardin, "The Tragedy of the Commons," *Science* 162, no. 3859 (December 1968): 1244.

2 Elinor Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action* (Cambridge: Cambridge University Press, 1990); Elinor Ostrom, *Understanding Institutional Diversity* (Princeton, NJ: Princeton University Press, 2005); Elinor Ostrom, "Beyond Markets and States: Polycentric Governance of Complex Economic Systems," *American Economic Review* 100, no. 3 (June 2010): 641–72.

3 Among the few exceptions to CPR management case studies being confined to economically marginal areas is water management in the context of a rapidly growing population, increased manufacturing, and agricultural demand in the United States. In the US water management case, technological innovations and adaptations moved beyond traditional practices and technologies. Elinor