Unequal Irrigators:
Heterogeneity and Commons Management in Large-Scale Multivariate Research

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[Abstract]

Despite impressive advances in our understanding of the factors conducive to successful management on the commons, there remains considerable confusion about the effect of heterogeneity among the resource users. Perspectives on this issue fall into two camps. The first, pioneered by Olson (1965), and subsequently formalized in the theory of public goods, holds that inequality favors collective action. The second view, closely associated with the field-study literature, insists that heterogeneities hamper collective action. This chapter synthesizes recent theoretical and empirical research on this issue to clarify the arguments made by both camps. A first task is to provide a taxonomy of the relevant types of heterogeneity. We argue

that economic inequality (fundamentally, unequal distribution of wealth) comprises many types of heterogeneity and is likely closely correlated with other forms of heterogeneity. Some heterogeneities affect resource-users' behavior by influencing the incentives toward cooperation; others act through their effect on social norms and sanctions that can help enforce collective agreements. "Olson effects" are theoretically plausible when there are important non-convexities in the collective good in question (maintenance of infrastructure, restraint in harvesting, institutional supply). Nevertheless, when these conditions are not met, more recent theoretical literature confirms the field-study view that inequality can harm the prospects for collective action on the commons. In particular, some of the theoretical research identifies a U-shaped relationship between inequality and cooperation or collective action, suggesting that both schools of thought are in part correct.

The chapter argues that a principal innovation of the research agenda in the last fifteen years is the emergence of a number of multivariate analyses of resource-using communities based on large numbers of surveys of such systems. We synthesize a group of such studies of irrigation systems, including three large-scale studies in Nepal, southern India, and central Mexico. Among our conclusions are the following. First, there is a confirmation of the case-study literature's conclusion that heterogeneity, however it might be measured, has a negative impact on cooperation on the commons in these irrigation cases. Heterogeneity tends to have a discernable negative effect, or no effect at all. Second, the evidence is consistent with the hypothesis that heterogeneity weakens the effect of social norms and sanctions to enforce cooperative behavior and collective agreements. Third, however, controlling for this social heterogeneity, there is an independent, and largely negative, effect of economic heterogeneity *per se*. This conclusion underscores the importance of economic mechanisms, based on the differential incentives to cooperate created by the distribution of wealth or income, distinct from social norms. Moreover, while economic theory cannot predict whether "Olson effects" will predominate, the empirical evidence for irrigators is that they do not. Fourth, there is evidence that heterogeneity affects system performance both directly, and indirectly via its effect on the institutions adopted by an irrigating community. Inequality might affect the degree to which irrigators follow the rules, but it also affects the type of rules chosen, and not all rules are equally conducive to good performance.

We close with a consideration of the extent to which these empirical regularities can be generalized to other types of commons.

[Introduction]

Common-pool resources play a decisive role in determining the livelihood of the rural poor (Jodha, 1986, 1990), and local environmental conditions. The last fifteen years of research have clearly demonstrated the importance of institutional form to the performance of commons-using communities; the notion that such situations should always be viewed within the framework of the "Tragedy of the Commons" has been decisively dispelled. Nevertheless, much remains to be understood and synthesized. Among these unsettled questions is the following: what is the impact of heterogeneity among the users of a community-based natural resource? Many field studies of the commons have addressed this question, although generally only tangentially. Nevertheless, the only consensus that emerges from the multidisciplinary empirical literature is that the relationship between heterogeneity and commons use and management is complicated. Recent theoretical research in economics has clarified some of the complicated mechanisms that link inequality and commons outcomes, and we will consider much of the case-study literature in the light of this economic work. This survey article identifies the most important types of heterogeneity, the commons outcomes that they might affect, and the mechanisms that link the two.[1]

The principal task of this chapter is to survey large-scale surveys of locally-managed irrigation systems as an empirical illustration of the relationship between heterogeneity and success in managing the commons. Until recently, most studies of community-based irrigation (like most studies of common-pool resource systems generally) focused on one or two systems. We have learned a great deal from these case studies, but they do not permit generalizations about the relationship between heterogeneity and commons management. If one village with a high level of inequality also has a relatively successful management regime for its irrigation system, it is difficult to deduce from that a general relationship between heterogeneity and management. In statistical terms, the case studies do not have the degrees of freedom necessary to discern relationships among the institutions of governance, various dimensions of performance, and the structural characteristics of resource-using communities. More recently, a small number of studies has sought to complement the case-study approach with information culled from relatively large numbers of resource-using systems. This chapter is unique in this volume in that it gives pride of place to this large-scale multivariate research, rather than other forms of empirical inquiry (e.g. laboratory experiments or anthropological case studies). More specifically will synthesize lessons learned from a subset of these studies focused on irrigation systems.

The empirical context for our chapter, thus, is the poor hydraulic economy: peasant water users in conditions of low-income rural sectors. The unit of analysis is the resource-using group, of which heterogeneity is a characteristic.[2]

[Heterogeneity]

Irrigators, or users of some other common-pool resource, may be heterogeneous in economic, social, cultural, or other dimensions. There are many relevant types of economic inequality alone. These variants of economic heterogeneity include: inequality in wealth or income among the members of a resource-using group; inequalities in the sacrifices community members make in cooperating with commons-management regimes; inequalities in the benefits they derive from such regimes; and inequalities in outside earnings opportunities ("exit options"). There are other kinds of disparities that may have economic consequences, and those in turn affect cooperation. For example, locational differences, to the extent that they are not already reflected in land-holding or wealth differences, might not be adequately taken into account if one considers only wealth inequality. Head-end and tail-end farmers in irrigation systems face different incentives to cooperate (Bardhan, 1984:215; Ostrom, 1994), as do fishers with access to more or less productive fishing spots (Berkes, 1986). For irrigators, long-run locational advantages and disadvantages will be capitalized into land values if land markets work reasonably well. Thus, the head-end/tail-end inequality is another version of wealth inequality.[3] Of course, in many parts of the world, land markets notoriously do not work reasonably well. Even if head-end/tail-end differences are perfectly captured in land values, such locational differences provide strategic opportunities that are not normally available simply as a result of wealth differences. Head-end farmers, poor or not, get the water first. Similarly, differences in ability or efficiency in resource extraction will affect cooperative behavior (Johnson and Libecap, 1982). These differences in many cases will be closely correlated with wealth: fishers with more gear will have lower unit costs of harvesting. Differences in what economists call *rate of time preference* – essentially differences among resource users in the degree to which they consider the future in their current extraction activities (Ostrom, 1990:*passim*) – will lead to differential impatience among commons users in making short-run sacrifices for resource conservation.

Ethnic heterogeneity such as differences in language or caste among irrigators will also affect cooperative behavior.[4] An irrigating community may be socially heterogeneous if its users come from various villages. Of course, in many cases, ethnic or social heterogeneity will be correlated with economic heterogeneity, as certain castes or ethnic groups are also more likely to be richer or poorer than other groups. Nevertheless, these non-economic types of heterogeneity potentially have effects independent of the economic heterogeneity with which they are correlated.

Other types of inequality or heterogeneity are measured by state variables like trust or social cohesion – the absence of which Baland and Platteau (1995) called *cultural heterogeneity*. Generally, shared values or interpretations of social problems – cultural homogeneity – can facilitate cooperation in the use of the commons. It is conceivable that cultural homogeneity and pronounced economic heterogeneity coexist in a stable relationship. For example, highly unequal agrarian societies might sometimes exhibit widespread adherence to a hierarchical ideology that facilitates monitoring and enforcement of cooperative agreements.[5]

Cultural heterogeneity exists, then, when there is more than one community of interpretation or community of shared values, among the members of a group. This can overlap with ethnic or social or locational heterogeneity, but need not. The experimental social-psychology literature reviewed by Kopelman et al. (this volume) demonstrates the critical importance of the relative shares of "prosocial" and "proself" individuals in a group. This division could exist in the absence of other types of differentiation.[6] A related type of difference arises in the game-theoretic context of Falk et al. (this volume) which allows for the possibility that some players have a preference for reciprocity or equity.

The sources of heterogeneity considered in this chapter do not pretend to exhaust the possibilities for differentiation. One type of heterogeneity not considered here is different uses of the resource. In the western United States, this conflict pits residential water users against agricultural ones. In agrarian economies, an ever-present, and arguably the most important, dimension of heterogeneity is gender. For water users, Meinzen-Dick and Jackson (1996) argue that differentiation by gender and by type of use overlap substantially: in many cases, women need water for cleaning and cooking, while men need it to irrigate cash crops.[7]

Why is heterogeneity important? Generally speaking, if we can discern empirical regularities that link inequality to better or worse commons outcomes, then this has consequences for asset-redistribution policies like land reform, and for poverty-alleviation and development programs that target communities based on the level of inequality. For example, where policy-makers contemplate turning over the management of public irrigation assets to local communities, special types of assistance could be called for where irrigators are especially heterogeneous.

How does heterogeneity affect commons outcomes? The answer depends on which "commons outcomes" we mean. There are many of those: the success with which a community of resource users conserves a resource system (whether through a formal regulatory regime, or through social norms that prevail even in a community with no explicit resource-using rules); the success with which a community crafts rules for managing the commons (what Ostrom (1990) referred to as the problem of *institutional supply*); the success with which a community monitors and enforces its regulatory regime; the success with which a community resolves conflicts and modifies the regulatory regime in response to changes in social and environmental conditions. Broadly, theoretical and case-study research has tended to diverge into two camps: those studies that find a positive role for heterogeneity, and those that point out a negative role. For the moment, let us restrict attention to economic inequality – which, as we argued above, is actually quite broad and inclusive – and look more closely at the inequality-is-good and inequality-is-bad schools of thought.

That inequality may favor provision of collective goods can justifiably be called "Olson effects". Mancur Olson (1965:34), in a classic hypothesis, explained the effect this way:

> In smaller groups marked by considerable degrees of inequality – that is, in groups of members of unequal "size" or extent of interest in the collective good – there is the greatest likelihood that a collective good will be provided; for the greater the interest in the collective good of any single member, the greater the likelihood that that member will get such a significant proportion of the total benefit from the collective good that he will gain from seeing that the good is provided, even if he has to pay all of the cost himself.

Restraint in resource exploitation and cooperation with maintenance efforts (e.g., fire-prevention measures in community forests or canal-cleaning in irrigation systems) are approximately public goods: one villager's actions provide benefits to most or all other members of the community. In such settings a dominant player might "internalize" a sufficiently large share of the collective good he provides. Thus Olson's hypothesis suggests that inequality is beneficial to successful commons management.[8]

The Olson effect makes sense if, for example, each farmer in a community-managed irrigation system is responsible for cleaning the portion of the common canal network that passes through his or her land *and* if the amount of canal passing through one's land is proportional to one's land-holding size. Then an irrigator's payoff from canal cleaning is larger, the larger is his or her land-holding wealth. This is the case in Leach's (1961) account of collective duties known as *rajakariya* or "king's work" in the pre-independence Ceylonese village of Pul Eliya. Large landowners might provide canal-cleaning effort even if no other irrigators follow suit. In such a case, the smaller, non-cooperative irrigators free-ride on the effort of the large player.[9]

Olson effects are also likely if there are large fixed costs involved in setting up a commons-management regime. These costs might be material, such as the building of fences around pasturelands, or the construction of irrigation canals. Such start-up costs also involve the organizational effort to collectively mobilize a community of resource users. Vaidyanathan (1986) illustrates the historical importance of local élites in promoting the emergence of irrigation-management regimes in India, China, and Japan. Ruttan and Borgheroff Mulder's (1999) model of pastoralists illustrates the conditions under which the wealthier players choose to coerce the poorer players into conserving. Powerful élites in Vaidyanathan's history are successful in part because they centralize decision-making power as much as they command material wealth. Heterogeneity in *decision-making power*, considered by McCay (this volume), is another relevant dimension of inequality.

Large start-up costs of this type are an example of *non-convexities* in the production technology.[10] Roughly speaking, benefits from collective action are a non-convex function of the effort provided to produce those benefits if there is a threshold level of aggregate effort that must be supplied before *any* benefits are realized. As effort increases beyond the threshold, however, benefits to the group begin to increase. Irrigation, for example, provides no benefit until the expense of building a dam or a canal (or both), or drilling a tubewell, has been undertaken; but thereafter added effort systematically increases crop yields. In this setting, wealthier farmers may be able to mobilize the capital necessary to build the dam or install the tubewell. Non-convexities also exist if there is a threshold stock of the resource (e.g., fish or pasture) below which regeneration is impossible. Baland and Platteau (1997) confirm the theoretical possibility of this Olson effect when there are such non-convexities. Widening inequality in this setting can lead to discrete jumps in cooperative actions (e.g., maintenance effort or restraint in resource use) by the wealthier players. But they show that this result depends critically on assumptions about the characteristics of the resource-using technology.

Not everyone agrees, of course, that inequality is good for successful management of the commons. The case-study literature in particular is replete with examples of the harmful effects of inequality. This is not necessarily inconsistent with Olson. It is easy to imagine irrigation systems wherein the canal length passing through one's parcel is not proportional to one's parcel size, or commons where there are no significant non-convexities. In such cases, the Olson effect need not hold. Indeed, the (quite heterogeneous, incidentally) field work seems to speak with one voice, and that voice says that inequality is harmful. Consider a handful of Indian irrigation examples. Jayaraman's (1981) study of surface-water irrigation projects in Gujarat notes the importance of a relatively egalitarian structure to farmers' coming together to form a water users' association. Similarly, Easter and Palanisami's (1986) study of ten tank irrigation groups in Tamil Nadu shows that the smaller the variation in farm size among farmers, the more likely that water users' associations will form.[11] Varughese and Ostrom (1998) also find a modest negative correlation between the level of wealth disparity and collective activity in forest use in eighteen Nepali villages.

This ambiguous relationship between inequality and successful commons management is borne out by more recent theoretical work in economics. Dayton-Johnson and Bardhan (1996) verify the Olson effect in a model of the commons, but show, nevertheless, that the relationship between inequality and conservation is U-shaped. They assume two things. A linear harvesting technology means that a given increase in harvesting effort always leads to the same increase in resources harvested, until the resource is completely depleted: sending one more boat into the fishery always increases catch by, say, 1000 tons as long as there are still fish in the sea. (Although a linear production technology might be considered a restrictive assumption, it permits fairly clear results. A more general assumption regarding production technology, as will be seen below, complicates the results considerably.) Second, there are no formal rules constraining commons users. With these assumptions, Dayton-Johnson and Bardhan find that communities with more equally distributed wealth exhibit higher rates of resource conservation than more unequal ones. Resource harvesters with wealth below a threshold level will not conserve, regardless of what others do. Beyond that threshold, however, a resource user will conserve *conditional* on the conservation of others on the commons. If sufficiently many resource users have wealth below the threshold – a consequence of inequality – then conservation will break down.

Bardhan et al. (2000) construct a general model of collective goods with strictly concave production functions to determine the effect of wealth inequality on provision of the collective good. Their results are generally indeterminate. On the one hand, extreme inequality favors collective-good provision, as the dominant player has an incentive to provide the collective good, even if others free-ride on his effort. This is one version of the "Olson effect," already seen above. On the other hand, with a concave technology, wealth equality promotes higher levels of collective-good provision. The net effect of inequality on collective-good provision depends on the relative magnitude of these two effects.

Bardhan et al., furthermore, show that market imperfections (for example, in land, credit, or insurance) – a pervasive feature of poor agrarian economies – complicate the Olson effect. In particular, the effect of inequality in the presence of market imperfections depends on the characteristics of the collective good in question. The authors introduce a distinction between common-pool resource products and public goods. When the positive spillovers from collective-good provision – whether the result of restraint in harvesting effort, or the addition of abatement technology, for example – outweigh the negative externalities of provision – such as the classic congestion externalities of the commons – the collective good is a *public good.* When the opposite is true – the negative spillovers exceed the positive ones – the collective good is a *common-pool resource*. (When the positive externality of a good's provision exactly cancels the negative one, incidentally, it is a private good.) Bardhan et al. consider only spillovers that affect other users of the resource.

To return to the effect of inequality on collective-good provision in the presence of market imperfections: in the commons case, if the goods traded in imperfect markets (credit, agricultural land) are complementary to the commonly-provided resources (water, grazing land) in households' production, then overall efficiency (measured by the gross rate of return on the collective good) is greater, the higher the level of inequality. (Water and land, for example, are said to be *complementary* if increased use of water raises land productivity, and vice versa. The definition generalizes to any two factors of production.) This is consistent with Olson effects, that predict better commons outcomes where inequality is greater. If those productive factors are not complementary, this result does not hold. Moreover, in the case of public goods (as opposed to common-pool resources), overall efficiency *falls* as inequality rises when complementary goods are transacted in imperfect markets.

Economic inequality might influence commons outcomes via differences in costs of resource harvesting. Although it is likely that, if there is any difference in costs, richer commons users will enjoy lower input costs, inequality in costs is conceptually distinct from inequality in wealth or income. Aggarwal and Narayan (1999) provide a two-stage model of groundwater use that incorporates differences in cost among water users. They motivate this asymmetry with the observation that in poor agrarian economies, agents face different costs of securing credit to install extraction capacity. They demonstrate a U-shaped relationship between cost inequality and the resource stock: starting from low levels of cost inequality, increasing inequality first reduces, then increases, water-use efficiency.[12]

Both economic and social heterogeneities may be especially salient in precluding the collective action needed to establish local institutions for managing the commons in the first place; that is, in the problem of *institutional supply*. Social heterogeneity increases the cost of negotiation and bargaining inherent in the process of crafting institutions; economic inequality, combined with other constraints, severely limits the possible bargaining outcomes available to commons users. Johnson and Libecap (1982), for example, formulate a model based on their observation of the South Texas shrimp fishery, where fishers are differentiated by their productivity. They find that both fisher-specific quotas and bilateral payments among fishers (which amount to the same thing) are impractical to administer: presumably such schemes are too difficult to monitor and enforce. The only option, therefore, is a system of uniform quotas. The more productive the fisher, however, the larger the restriction implied by this regime. Thus more productive fishers might stand to lose under a cooperative arrangement, and hence will oppose it. (This logic is further developed in Kanbur (1991) and Baland and Platteau (1998).)

In a related vein, Quiggin (1993) hypothesizes that common property arises as a legal mode where there are certain scale economies in production (as in Baland and Platteau's (1997) non-convexity case, summarized above). Wealthier agents will gain less from economies of scale from collectively-owned assets and consequently could seek such a high share of benefits from the collective organization that the group fails to form.[13] In both the Johnson-Libecap and Quiggin stories, the feasible set of institutional arrangements is restricted in some way; under certain configurations of parameters, this restriction makes it impossible to craft an arrangement that satisfies both rich and poor commons users. Even though especially resourceful harvesters might successfully overcome this obstacle, in general, inequality makes it more difficult to self-organize.

An important complication is the presence of *exit options*. If resource-users have relatively lucrative earnings opportunities outside the commons, this can affect their individual incentives, as well as the power of social cohesion to promote cooperative behavior. In Dayton-Johnson and Bardhan's (1996) model, the harvester can stay and conserve, stay and degrade, or degrade and then leave. They demonstrate that the effect of these exit options on conservation is predictably complicated, but depends in part on whether the relationship between wealth and exit options is concave. If a resource harvester's exit option is a concave function of wealth, then the value of the exit option increases as the harvester's wealth level rises, but, by definition, at a decreasing rate.[14] If a resource harvester's wealth were to double, her exit-option value might rise considerably; if her wealth were to double *again*, the exit-option value would increase by less than it did with the first doubling. If the exit-option function is concave, then Dayton-Johnson and Bardhan show that increases in inequality, starting from relatively equal wealth distributions, will reduce conservation. In that case, the relatively poorer harvester will optimally choose not to conserve: as her wealth declines, her gain from conserving (which is a *linear* function of her wealth) falls off more rapidly than her gain from exercising her exit option (which is a concave function of wealth). The poor harvester thus derives a higher return from staying on the commons and degrading it than she does from exiting. If on the other hand the exit option is a convex function of the wealth level (which would be true, for example, if villagers faced borrowing constraints in credit markets) then increased inequality might either enhance or damage the prospects for conservation: the effect is indeterminate.

Conservation in the Dayton-Johnson/Bardhan model occurs in a completely noncooperative setting; that is, where no management regime necessarily exists. In the presence of a management regime, exit might help resource conservation, if the out-migrants are those most likely to discount the future substantially. Nevertheless, exit might hamper collective action in this situation: for example, if the amount of labor available to maintain irrigation infrastructure falls, the infrastructure's condition could decay if the community is not wealthy enough to hire guards and workers. Furthermore, in the presence of exit options, communities may have fewer mechanisms to enforce cooperation in a footloose population. An open question is whether conservation is appreciably reduced if the poor do not conserve. The poor harvester may have such a small effect on the resource that her lack of adherence to the rules has a negligible effect, as with the pastoralists studied by Ruttan and Borgerhoff Mulder (1999). Baland and Platteau (1999), similarly, argue that with inequality, increasing participation by the wealthy can compensate for the poor's lack of participation; the net effect on conservation depends on the extraction technology involved.

There is empirical evidence that exit options weaken the prospects for cooperation. Baland and Platteau (1996) illustrate this phenomenon with reference to conflicts between artisanal and industrial fishers in fisheries around the world. The former group is tied by their technology to a very circumscribed fishing ground, while the latter are highly mobile. In Mali and Mauritania, large (usually absentee) livestock herd owners have been much less interested than small herders in local arrangements for rangeland management to prevent overgrazing and desertification (Shanmugaratnam et al., 1992). Freudenberger (1991) describes the deforestation of a forest ecosystem in Senegal by the local unit of a nationwide agricultural entity known as the Mouride. A relatively low-intensity pattern of resource use by nearby peasant producers and pastoralists gave way to intensive cash-crop (groundnut) production. After the soil's rapid exhaustion by groundnut farming, the Mouride's national decision-making body could open up new territory elsewhere, unlike traditional users who were more interested in the long-term viability of the local forest. Shanmugaratnam (1996) notes that after the privatization of some village grazing areas in Western Rajasthan, large landowners, now able to produce a large part of their fodder needs on their private land or to buy supplementary fodder in the market, tend to be uninterested in the sustainable management of the remaining commons.

In many of the cases cited above, the richer or larger commons users were prone to defect. This need not always be the case. Other authors have reported that the poorer or smaller users exercise exit options. Bergeret and Ribot (1990), in a study similar to that of Freudenberger, describe deforestation in a larger area and over a longer time frame, also in the Senegalese Sahel. Trees are harvested by Fulani refugees from Guinea, who are more likely to be landless than other peasants, in order to produce charcoal for the rapidly growing urban market. A qualitatively similar situation has been described in southern Burkina Faso, where immigrants are more prone to use destructive gathering techniques in communal forests (Laurent et al. 1994). (Because the poor in these examples are also immigrants, it may be more accurate to infer that they have already exercised their exit options from a previous place. Because of their lack of connection to their new locales, they pursue environmentally-unsound practices.)

How do non-economic sources of heterogeneity affect economic outcomes? In a completely different public-goods domain, Alesina et al. (1999) find that ethnic diversity is associated with lower public goods funding across U.S. municipalities because different ethnic groups have different preferences over the type of public good (such as language of school instruction). In the kind of rural societies considered in this chapter, ethnic heterogeneity works through social norms and sanctions. The effectiveness of social sanctions weakens as they cross ethnic reference groups. In this vein, Miguel (2000) constructs a theoretical model where the defining characteristics of ethnic groups are the ability to impose social sanctions within the community against deviant individuals and the ability to coordinate on efficient equilibria in settings of multiple equilibria. With data from the activities of primary school committees in rural western Kenya he then shows that higher levels of ethnic diversity are associated with significantly lower parent participation in parent meetings, worse attendance at school committee meetings, and sharply lower teacher attendance and motivation.[15]

If social groups (not solely ethnic groups) are defined as those whose boundaries coincide with the effective monitoring and enforcement of shared social norms, then this provides a workable concept of social heterogeneity for irrigation communities. Indeed, this is one way of understanding the earlier-cited notion of cultural homogeneity, a variant of what many authors have called social capital or social cohesion.[16] Irrigation systems whose boundaries obey hydrological rather than social boundaries will comprise irrigators from many villages.

Irrigation organizations that cross village boundaries can rely less on social sanctions and norms to enforce cooperative behavior than those that comprise a single village.

[Large-*n* studies]

The foregoing discussion demonstrates the richness of the theoretical and empirical literature on the commons. A careful reading of the empirical literature demonstrates that case studies (whether by anthropologists, political scientists, sociologists, engineers, or the odd economist) prevail. Larger-scale surveys of several resource-using systems that would permit statistical analysis of the empirical regularities present on the commons are still relatively rare. Ostrom, Gardner, and Walker (1994) attempt to remedy this shortage by systematically combining the results of the voluminous case-study literature on irrigation systems, community forests, and fisheries. While useful, such "meta-evaluations" are not substitutes for survey research of large groups of resource-using communities. Even careful compilation of case studies cannot address biases in the selection of studied systems. In this section we synthesize results from a handful of studies of farmer-managed irrigation systems that seek to fill this gap.[17] All of the studies mentioned herein share the objective of establishing empirical regularities among structural characteristics, institutions of governance, and various measures of performance; we will focus our attention on one particular characteristic, namely heterogeneity, and its links to institutions and performance. The principal studies considered in this section are Lam's (1998) Nepali study, Dayton-Johnson's (1999, 2000a, 2000b) Mexican study, Bardhan's (2000) Indian study, and Tang's (1991, 1992, 1994) meta-evaluation of the case-study literature. We will also have occasion to refer also to Fujita et al.'s (2000) study of 46 surface-water systems recently transferred to their users by the Philippine public irrigation authorities. Theirs is clearly in the vein of the other studies considered here, but its usefulness for our chapter is limited because it does not explicitly consider the effects of economic inequality on irrigation performance. Khwaja's (2000) study of infrastructure investment in Pakistan includes information on inequality, although the research is not limited to irrigation projects.[18]

Lam (1998) analyzes data from a data set covering 127 irrigation systems throughout Nepal, as well as nearly 25 further systems surveyed by the author. Unlike the Mexican and Indian studies, the sample of irrigation communities is not randomly drawn; nevertheless the data set is regionally representative within Nepal. For the basic 127-system data set, 104 systems were farmer-managed, while the remaining systems were managed by the public Department of Irrigation. The mean system area was 399 hectares, and the mean number of appropriators was 585, implying that the average irrigated area per appropriator was just over two-thirds of a hectare. Bardhan (2000) analyzes data from a survey of 48 irrigation units known as *ayacuts*, each in a different village within six districts in the south Indian state of Tamil Nadu. Half of the *ayacuts* were members of larger canal systems, and half were members of more traditional tank systems. All were ostensibly under the control of the government, but most *ayacuts* had traditional and informal community management regimes. The average number of households per irrigation source was 53; the *ayacut* area per household was just slightly over a third of a hectare. Dayton-Johnson (1999) describes a field study of 54 farmer-managed irrigation systems known as *unidades de riego* in the central Mexican state of Guanajuato. All of these *unidades* were autonomous from state control, and all were based on surface-water irrigation derived from reservoirs. The average number of irrigating households in the systems was 123; the average command area 449 hectares, and the average land-holding per household, 3.3 hectares. Tang (1991, 1992, 1994) has applied the meta-evaluation approach to the inventory of case studies of irrigation. He aggregates information from 47 irrigation systems in fifteen countries. Twenty-nine are farmer-managed, fourteen are agency-managed, and four are other types of systems. Khwaja's (2000) study of a variety of infrastructural projects in the Himalayas of northern Pakistan considers various forms of inequality with great care. His 123 externally-funded projects include investment in irrigation, but also in roads and other forms of infrastructure.

These studies define certain commons outcomes, allowing estimation of the impact of heterogeneity. Broadly, there are two types of outcomes: institutions and performance. Both may vary systematically with the degree of heterogeneity. With respect to institutions, Tang (1994) describes two types of "rules-in-use": *boundary* rules ("the requirements one must fulfill before appropriating water") and *authority* rules (the procedure and basis for withdrawal, including fixed shares or rotating turns). Bardhan (2000) and Dayton-Johnson (2000a) consider cost-sharing rules for mobilizing canal-cleaning and maintenance effort, as well as water-allocation rules that define households' claims on irrigation resources.

Performance is measured in various ways. An obvious dimension is the degree to which irrigators adhere to the rules established above: *rule-conformance*. Bardhan (2000) measures whether water allocation rules are frequently violated by one group; Tang (1994) codes more generally whether the irrigation rules are followed. Alternatively, one could measure not rule-conformance *per se*, but rather the level of infrastructure maintenance. Bardhan (2000) uses a categorical-variable index of maintenance of distributaries and field channels. Dayton-Johnson (2000b) uses disaggregated variables and estimates statistical models of three dimensions of maintenance: the degree of definition of canal side-slopes, state of repair of field intakes, and degree of control of leakage around the canals. Lam (1998) uses the overall physical condition of the system. Another class of performance variables measures the adequacy of water delivery; Lam (1998) aggregates information on adequacy of water delivery at various points in the system, equity among users, and reliability of water supply at the tail end. An imperfect indicator of the success of irrigation is crop yields, considered by Dayton-Johnson (1999), and by Lam (1998), who aggregates information on output per hectare, and cropping intensity at the head and tail ends of the system. Lam (1998) subjects the three dimensions of his performance measure (condition, water delivery, and productivity) to confirmatory factor analysis, finding, among other things, that the dimensions are not highly correlated. Fujita et al. (2000) propose a four-dimensional concept of irrigation-system performance, based on the existence of rules for maintenance, coordination in rice cropping schedules, practice of water rotation, and organized monitoring of rules. They perform a principal-components analysis on the four measures to derive appropriate weights for an index of performance. Bardhan (2000) finally, also considers the absence of water-related conflicts as a measure of performance.

All of the studies considered here are multivariate analyses, but the list of independent variables differs considerably from study to study. To some extent, then, we are comparing estimated coefficients that are not strictly comparable: this should be borne in mind when considering the results reviewed below.

Income inequality. What then, are the effects of heterogeneity? Consider first inequality in incomes. Tang (1991) finds that "...a low variance of the average annual family income among irrigators tends to be associated with a high degree of rule conformance and good maintenance." Tang (1992:72-73) identifies 27 cases where the degree of income variance can be gleaned from published research. He finds that in systems where income variance is high, 17 percent exhibit high levels of rule conformance and maintenance; where income variance is moderate, 75 percent exhibit high levels of these performance measures; and where variance is low, 89 percent exhibit high rates of performance. (Tang cautions against inferring too much from these results, as the degree of income variance could not be identified in a significant fraction of the case studies he compiled.) Lam's (1998) regression analysis shows that income inequality (measured by a zero-one variable indicating either "low/medium" or "high" variance in average annual family income) is significantly and negatively related to water delivery performance. Income inequality is also significantly and negatively related to productivity in the Nepali systems, but it is not significantly related to physical condition of the system. Khwaja (2000) finds a U-shaped relationship between inequality in one form of income – project returns – and project maintenance in his Pakistan study. Starting from a low level of inequality in project returns among beneficiaries, increased inequality tends to reduce project maintenance. Beyond a certain level of project-return inequality, however, maintenance improves as inequality widens.

Wealth inequality. Wealth inequality is likely quite highly correlated with income inequality, and its effects are similar here. Bardhan (2000) and Dayton-Johnson (2000a, 2000b) compute the Gini coefficient based on irrigated land-holding for their Indian and Mexican studies. The Gini coefficient is related to performance: the relationship, where it is significant, is negative in the Indian study. Bardhan finds that land-holding inequality is significantly and negatively associated with canal maintenance in the Tamil Nadu systems. For Bardhan's indicator of intravillage conflict over water, he finds evidence of a U-shaped relationship between the Gini coefficient and this indicator of performance.[19] That is, at low and high levels of inequality, there is little intravillage conflict, but for inequality in the middle range, conflicts are more likely. Bardhan finds no statistically significant effect of inequality on rule conformance. For the Mexican study, the full effect of land-holding inequality on maintenance (accounting for the indirect effect on the choice of rules) is negative, but complicated.[20] Khwaja (2000) once again finds a U-shaped relationship between land-holding inequality and project maintenance in his Pakistan study: starting at perfect equality, increasing inequality reduces maintenance, while at high inequality levels, increasing inequality raises maintenance.

Head-enders and tail-enders. Another source of inequality is the asymmetry between those at the head and tail ends of the canal network. As noted above, this is probably only imperfectly correlated with inequalities in land-holding wealth given that land markets do not function very well. Tang (1992:60-63,73-74) considers the impact on rule conformance and maintenance of the presence of "disadvantaged groups." In most cases, this refers to tail-enders, although in a few instances it refers to groups against which system rules systematically discriminate. In a simple bivariate comparison, most systems without disadvantaged groups exhibited high rule conformance and maintenance, while fewer than a third of those with disadvantaged groups exhibited these high performance levels.

One predictor of conflicts between irrigators at the extremities of the network is the presence of modern headworks to divert water from its source. Lam (1998) finds that the presence of modern headworks was negatively and significantly associated with *all* of his indicators of performance. A strict engineering view would predict that modern headworks would improve performance: Lam interprets his results as confirming that headworks increase the bargaining power of those at the head end of the network. For Lam, water delivery and cropping intensity at the tail end are dependent variables. The Philippine study by Fujita et al. (2000), however, considers disparities in water availability between the head and tail end as independent variables; they can do this because they measure availability before the systems were transferred from the government to their users, and they measure performance after transfer. They find that disparities wherein head-enders have relatively abundant and tail-enders relatively scarce availability are significantly associated with poorer performance.[21]

Exit options. Another dimension of economic inequality mentioned above is differential earnings opportunities not fundamentally tied to the commons. Exit options can be empirically detected in several ways. Bardhan (2000) includes an indicator of linkage (e.g., by bus or telephone) to urban centers in the south Indian study. This linkage variable is negatively and significantly related to system maintenance, suggesting that the proximity to the city makes it harder to enforce rules for cleaning canals and the like. This is verified in Bardhan's statistical model of rule conformance, where the linkage effect is negative. Linkage is similarly positively and significantly related to the presence of intravillage water conflicts. Note that this does not reveal the degree to which exit options are unequally distributed, however. The Indian results merely verify that cooperative behavior is more difficult to sustain in the presence of outside opportunities. The Philippine study by Fujita et al. (2000) attempt to measure asymmetry by the ratio of non-farm to farm households within the territory of the irrigation community. (Non-farm employment is the exit option in this case.) A higher proportion of non-farm households indicates asymmetry in the way people gain their livelihoods, an asymmetry that might weaken the enforcement power of informal sanctions within the farming subset. The non-farm household ratio is significantly and negatively associated with their measure of performance. (In a separate series of regressions where the components of their performance index are separately estimated as dependent variables, the non-farm household ratio negatively affects the probability of observing a water-rotation scheme, and the probability of observing organized monitoring.) Bardhan finds in the Indian study some (weak) evidence that when farmers have access to alternative sources of irrigation they tend to violate the water rules more frequently: this is an exit option outside the commons, but not outside of agriculture.

Ethnic and social heterogeneity. The boundary between economic and non-economic heterogeneity is a fuzzy one. Differential exit options appear to be economic because they are like unequal assets; nevertheless, the effect of different exit options, we suspect, operates through the weakening of social norms and sanctions. Less explicitly economic forms of heterogeneity have significant effects in the studies considered here. Bardhan (2000) controls for whether at least three-quarters of surveyed farmers in an *ayacut* are members of the same caste. This kind of caste *homogeneity* is strongly associated with the absence of intravillage conflict, but it is not significantly associated with rule-conformance. (Bardhan did not include caste homogeneity in his statistical models of maintenance.) Khwaja (2000) computes a "fragmentation index" that is the average of ethnic, political and religious fragmentation indices for the communities in his Pakistan study. Each fragmentation index is the probability, in a given community, that two randomly-selected individuals belong to different groups. Khwaja's fragmentation index bears a negative relationship with project maintenance.

A measure of social heterogeneity is whether or not irrigators come from more than one community. Dayton-Johnson (2000b) includes in his statistical models the number of *ejidos* (Mexican agrarian-reform communities) from which *unidad* members are drawn: it is consistently and negatively associated with infrastructure maintenance. This provides strong support that when enforcement crosses *ejido* boundaries, it is less effective. Nevertheless, the Philippine study of Fujita et al. (2000) includes a similar variable – the number of villages represented in the irrigation system – and it is not significant. Baker's (1997) study of 39 *kuhl* irrigation systems in Himachal Pradesh considers the effect of *differentiation*, which is "high when a kuhl irrigates more than one village, the irrigators of the kuhl are comprised of multiple castes, and land distribution is relatively unequal". Baker proposes that, in the presence of high differentiation, increased opportunities for non-farm employment can place intolerable stress on traditional *kuhl* management regimes.[22] Tang's (1992:68-72) evidence on the effect of "social and cultural divisions" is ambiguous and marked by small numbers of observations. The effect is mediated by the institutional nature of the irrigation system. Where it is community-managed, socio-cultural heterogeneity does not preclude good performance; where the system is agency-managed, this heterogeneity is uniformly associated with poor performance. Possibly overlooked is the selection bias in community-managed systems: if a group is not able to organize itself, or if conflicts become too severe, the system will not exist when the researcher goes into the field. The same cannot be said of agency-managed systems. Thus, we are left with a sample of community-managed systems that have survived a process that requires high levels of cooperation.

Choosing rules. Heterogeneities, finally, can affect performance indirectly by means of their effect on the choice of rules. Dayton-Johnson (2000a) finds that wealth inequality increases the probability of observing proportional water allocation (as opposed to equal shares for all farmers). This is consistent with richer landowners pressing for proportionally more of the irrigation supply. The Mexican study also finds that proportional water allocation is associated with poorer maintenance. Inequality thus may lead to a particular set of rules under which irrigation systems do not perform as well.[23] Bardhan's (2000) south Indian study also provides significant evidence that when the water-allocation rules are crafted by the village élite, the latter violate the rules less frequently; otherwise the élite more frequently violate the rules. (Overall, the élite breaks the rules more often than the non-élite, but by definition, the former is a smaller group than the latter.) It is also observed that when an average farmer believes that the water rules have been crafted jointly (i.e., with collective participation, as opposed to rule crafting only by the village élite, or by government), he is more likely to have positive comments about the water-allocation system and about rule compliance by other farmers. Joint rule-crafting of this kind is associated with the highest level of rule compliance in the Indian case. Bardhan also estimates the likelihood that villages have adopted proportional cost-sharing rules – i.e., rules that specify that the labor costs of maintaining irrigation infrastructure are shared proportionally to (irrigated and non-irrigated) land-holding wealth.[24] This rule is in general positively associated with cooperative outcomes; adoption of this rule is, in turn, significantly and positively associated with land-holding inequality. This might be an indication of social pressure for a redistributive adjustment of the cost-sharing rule to take account of wealth disparities. This points to an important and more general observation noted by Varughese and Ostrom (1998). They find that many groups "overcome stressful heterogeneities by crafting innovative institutional arrangements well-matched to their local circumstances". In their Nepal study, forest users created diverse forms of memberships with different rights and duties to cope with heterogeneity, particularly when there are substantial benefits to be obtained through collective action.

[Conclusions]

[Table 1 here]

Table 1 summarized the evidence from the large-*n* studies reviewed in the previous section. The evidence is tentative, but sufficient to permit us to hazard a few conclusions. First, there is a confirmation of the case-study literature's conclusion that heterogeneity, however it might be measured, has a negative impact on cooperation on the commons in these irrigation cases. Heterogeneity tends to have a discernable negative effect, or no effect at all. Second, the evidence is consistent with the hypothesis that heterogeneity weakens the effect of social norms and sanctions to enforce cooperative behavior and collective agreements. Support for this conclusion derives from the negative effect on performance in multi-village multi-caste irrigation systems. Third, however, controlling for this social heterogeneity, there is an independent, and largely negative, effect of economic heterogeneity *per se*: this is borne out by the significant effect of Gini coefficients, for example, in the Mexican and Indian studies. This conclusion underscores the importance of economic mechanisms in the theoretical literature, starting with Olson (1965). These economic mechanisms are based on the differential incentives to cooperate created by the distribution of wealth or income, distinct from social norms. Moreover, while economic theory cannot predict whether "Olson effects" – a positive impact of inequality – will predominate, the empirical evidence for irrigators is that they do not. This finding also underscores the value of the multivariate analysis approach adopted in the studies summarized here: such an approach allows one to isolate the effect of particular structural characteristics (like wealth inequality) while controlling for the effect of others (like social heterogeneity). Fourth, and finally, there is evidence that heterogeneity affects system performance both directly, and indirectly via its effect on the institutions adopted by an irrigating community. Inequality might affect the degree to which irrigators follow the rules, but it also affects the type of rules chosen, and not all rules are equally conducive to good performance. Quantifying the magnitude of these direct and indirect effects requires the adoption of the multivariate approach used in these studies.

A question raised by the studies summarized here is the degree to which these results based on irrigation systems can be generalized to other types of commons. Blomquist et al. (1994) consider a typology of common-pool resources that situates irrigation with respect to other types of commons. Two physical dimensions that matter are *stationarity* of the resource ("the resource units... remain spatially confined prior to harvest") and the possibility of *storage*. This two-way typology generates four classes of physical resources, and irrigation systems are found in three of the four categories: groundwater-based systems are stationary and storage is available; reservoir-based canal systems are nonstationary but storage is possible; river-diversion systems are nonstationary and storage is impossible. Many of the systems considered in this chapter are canal-based systems, with a minority of run-of-the-river systems. (In Bardhan's (2000) South Indian study, half of the systems are not served by canals.) Most other commons do not share this combination of characteristics: forests, rangelands, community threshing grounds are stationary without recourse to storage. Migratory species are nonstationary with no possibility for storage. In the presence of distinct structural characteristics, further analysis is necessary before extending these irrigation-based findings to other settings.

One distinction between a flowing resource (like water) and a standing resource (like forest) is that gravity makes locational (head-tail) heterogeneity more salient in the former (although if land markets work, one presumes that in the long run locational advantage gets capitalized into wealth inequality). Another difference is that in forests part of the collective action is in replanting and regeneration efforts, which are less important in canal irrigation. Third, issues of intertemporal conservation are somewhat less salient in canal irrigation, although they are important in groundwater irrigation: this refers not only to dynamic conservation of the resource, but intertemporal externalities of harvesters' behavior, whereby my extraction this period affects your payoff next period.[25]

One can reasonably question whether surface-water irrigation systems are common-pool resources at all. Groundwater-based irrigation, of course, draws from a resource (an aquifer) that is subject to regeneration as well as the risk of depletion, as is the case with pastures, forests, and fish. To the extent that canal systems based on reservoirs or river diversions bear a formal resemblance to such common pools, it lies in the collectively-maintained infrastructure: water source, canals, and water-control devices. Cleaning canals and repairing equipment is formally similar to replanting, recharge and regeneration. Moreover, one person's use of irrigation water reduces the availability for others, just as in other types of common-pool resource systems. Nevertheless, human intervention in natural systems is arguably much more invasive in irrigation than in, say, fishing or fuelwood collection. (These and other aspects of "irrigation exceptionalism" are considered in passing in Rose, this volume.)

To a large extent, of course, the problems of successful commons management are not necessarily based on the characteristics of the natural resource itself – as the earlier, tragedy-of-the-commons tradition would have it – but rather the more prosaic problem of getting people to cooperate. Thus the problem is particularly closely related to those of producer and worker cooperatives. Mobilizing cooperative effort is especially problematic at the level of institutional supply, but also in the running of the institution.

Another social – rather than natural – phenomenon deserving increased attention, is the effect of market failure. Market failure is said to exist when the market for a good or service fails to be efficient, or in the extreme, fails to exist at all. Such market failures in credit, insurance, and land are endemic in agrarian economies, and interact with the problem of cooperation. Optimal regulatory regimes are not difficult to describe in theory; but real-world market failures constrain the set of feasible arrangements. These constraints may be such that commons users are unable to negotiate any kind of cooperation whatsoever; or, they reach an accord that nevertheless leads to environmental degradation. Another such market failure that is frequently invoked but not quite justified is the impossibility of side payments – or equivalently the absence of secondary markets for the common-pool resource.

Our empirical reference point limits the generalizability of our results to global-scale commons, where actors are states and international agencies rather than peasant households. Our conclusions regarding the effect of heterogeneity could be implausible in the setting of international climate-change agreements, for example; there, the presence of disproportionately powerful actors might enhance the prospects for co-operation.[26]

This survey illustrates the utility of the large-scale multivariate analysis of resource-using communities. Similar syntheses could be compiled for other types of commons (fisheries, forests, rangelands), and for other structural characteristics of communities (group size).[27] Despite the impressive advances of research chronicled in this volume, the lacunae in our knowledge is still great, as is the potential contribution to commons-users' welfare of policy-makers' judicious application of that knowledge.

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Endnotes

[1] Ours is not the first attempt to survey this literature; see also Baland and Platteau (1999).
[2] The effects of many other group characteristics are considered systematically in Agrawal (this volume).
[3] Ostrom and Gardner (1993) recount the experience of an irrigation system in Nepal, where the richer farmers are located at the tail-end; this system is better maintained than those where the tail-enders are poorer.
[4] Bardhan (1997) analyzes the economic aspects of ethnic conflict.
[5] Fafchamps (1992) explores the emergence of such patron-client relationships in agrarian economies using the theory of repeated games.
[6] See Cárdenas (1999) and Henrich et al. (2000) for field-based laboratory experiments among actual commons users.
[7] See also Zwarteveen (1997) for a discussion of gender in the context of irrigation management transfer.
[8] This result is generalized in a pure public-goods model by Blume et al. (1986). (Parenthetically, Blume et al. sought to dispel the earlier conventional wisdom in economics, namely, that changes in the distribution of wealth would *not* affect the overall level of public goods provided in society.)
[9] Alternatively, the *rajakariya* case might be an example of the proportionality between costs and benefits that Ostrom (1990) claims is exhibited by successful commons-management regimes. In one variant of this story, proportionality should neutralize the effects, good or bad, of inequality. Dayton-Johnson (2000a) provides a simple game-theoretic illustration of the proportionality principle.
[10] The "lumpiness" in third-party monitoring to which Agrawal (this volume) refers is another example of non-convexity.
[11] See Bardhan (1995) for further examples from the case-study literature on farmer-managed irrigation systems in Asia.
[12] Baland and Platteau (in press) note that the effect of increased wealth inequality on inequality in costs is likely to be hard to predict. On the issue of cost inequalities on the commons, see also the paper by Hackett (1992).
[13] Parenthetically, these mechanisms might be viewed as variants of the macroeconomic redistributive-pressure mechanism modeled by Persson and Tabellini (1994). Inequality in their model leads to pressure from below to redistribute income; this in turn leads to a tax on capital that lowers investment and growth. In the arena of institutional supply on the commons, in contrast, the wealthy require more of the notional gains from cooperation than the poor are willing to accept and commons-management regimes fail to emerge.
[14] Graphically, the exit-option function (measured on the vertical axis) rises sharply from the origin, but gradually levels off as wealth increases (on the horizontal axis).
[15] Contrary to Miguel's definition, ethnicity might alternatively be conceived as an identity associated with shared norms, but not necessarily with sanctioning. As such, ethnic homogeneity or heterogeneity would affect commons management more through shared understandings than through sanctioning behavior.
[16] Dayton-Johnson (2001) constructs a game-theoretic model of social cohesion, which he differentiates from "community": the latter, is based on shared values and shared interpretation of social reality, a stronger condition than social cohesion. These concepts must be viewed in the present context as exogenous in the first instance. As Agrawal (1999:103) notes, "The aspect of community that stands for shared understanding is precisely what external interventions can do very little about. State, NGOs, bureaucratic authorities, aid agencies, and policy makers cannot directly create community-as-shared-understanding."
[17] Recent empirical research on producer cooperatives in developing countries can be interpreted as part of the same research agenda. See the recent studies by Banerjee et al. (2001) and Seabright (1997). Similarly, empirical studies of people's propensity to join voluntary organizations in Paraguay (Molinas, 1998) and rural Tanzania (La Ferrara, 1999) demonstrate a negative effect of economic inequality.
[18] A much earlier quantitative study of irrigation systems, not considered in this chapter, was carried out by de los Reyes (1980).
[19] The estimated coefficient on the Gini variable is negative and significant, while the estimated coefficient on the square of the Gini is positive and significant.

[20] The estimated coefficient on the square of the Gini term was *positive* and significant in two of the three models in Dayton-Johnson (2000b), suggesting a strongly positive effect of inequality on maintenance. Nevertheless, inequality was significantly related to proportional water-allocation; that rule, in turn, was associated with *lower* levels of maintenance. The full effect, direct plus indirect, of inequality was negative.

[21] Bardhan (2000) includes a variable indicating whether an *ayacut* is located at the tail end of a larger system; an entire village of tail-enders, however, does not behave differently from other villages, all else equal.

[22] Baker's argument is more nuanced than that stated here: he claims that the effect of exit options is mediated not only by differentiation, but by *reliance* on the water source. Where reliance is high and differentiation is low, management regimes can withstand increased exit options. Nevertheless, our reading of his argument is that where differentiation is high, regardless of the level of reliance, the stress on the institutions of governance is critical.

[23] In the Mexican study, land-holding inequality is essentially not endogenous, because the distribution of land-holding was frozen by the agrarian reform. Otherwise, it would be more difficult to determine the indirect effect of inequality on performance via the choice of rules.

[24] To recapitulate, land-holding inequality is associated with proportional *cost-sharing* in the Indian study, and with proportional *water allocation* in the Mexican study. Proportional cost-sharing is, in turn, associated with better performance in India, while proportional water allocation is associated with *poorer* maintenance in Mexico.

[25] This is the principal spillover exploited in the model of Dayton-Johnson and Bardhan (1996).

[26] These problems are considered in Young (this volume).

[27] As an example of this kind of research beyond the realm of unequal irrigators, Agrawal and Goyal (1999) analyze the question of group size based on data from 28 forest councils from the Indian Himalaya. Their appealing result is that there is a U-shaped relationship between group size and effective monitoring, rather than the classic monotonic result.