

Inequality and the governance of water resources in Mexico and South India

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Introduction. In recent years, policy-makers and researchers have come to acknowledge that a critical dimension of environmental sustainability is the local one: the success with which communities husband collectively-managed natural-resource systems (Baland and Platteau 1996). It is furthermore by now a commonplace observation that the "Tragedy of the Commons" framework is not always the appropriate one for analyzing the use of local commons (Ostrom 1990). Nevertheless, some communities successfully manage local resource systems, while others fail to do so and suffer the consequent effects of resource degradation and poverty. The task for researchers and policy-makers today is to identify the factors and mechanisms that lead some communities to be successful and others to fail. This study focuses on a particular kind of local natural-resource system, and on a particular kind of research. We describe and analyze a pair of field studies of relatively large numbers of community irrigation systems, one in South India, the other in Central Mexico.

A controlled supply of water is a matter of life and death for poor farmers in the arid and semi-arid regions of the developing world, including South India and Central Mexico. For many such farmers, irrigation control at the local level is largely provided by community organizations, formal or informal (mostly the latter). In South Asia, for example, while main canals are often publicly-managed, water distribution and allocation are managed by local organizations at the level of secondary canals, tanks or reservoirs, and field channels. In Mexico, at least half of the country's irrigated area is served by local irrigation organizations entirely autonomous of public irrigation authorities. Community irrigation institutions attempt to solve a broad range of collective-action problems. They pool efforts and resources for the construction and maintenance of canals and field channels. They regulate water distribution and allocation and monitor violations of local rules. In cases of tank or reservoir irrigation, they mobilize resources to desilt, weed, and stop encroachments on reservoir beds. They repair, maintain, and control water allocation from public and community tubewells. Indeed, water reform, in the sense of building or promoting such community institutions of cooperation is at least as important as land reform in rural development.

What factors distinguish successful from unsuccessful community irrigation systems? It is in this context that the study of inequality among users of the commons is important. Two questions in particular will be explored in this chapter. How does inequality among the members of an irrigating community affect the success with which that community undertakes the collective tasks enumerated above? Second, how does inequality affect the crafting and evolution of local institutions for running irrigation systems?

Contextual analysis of field data collected from such community-based irrigation systems will be an important contributor to our knowledge about these issues. Game-theoretic models of cooperation among self-interested agents in repeated situations of strategic interdependence provide some useful insights. (Seabright (1993) provides a useful overview.) But, in view of their admissibility of multiplicity of equilibria, many of the comparative-static questions cannot be satisfactorily resolved without recourse to empirical research. Until recently, most empirical studies of community-based irrigation (like most studies of common-pool resource systems generally) focused on one or two systems. (Surveys of the case-study literature for irrigation communities include Chambers (1980), Coward and Levine (1987), Kähkönen (1999), Tang (1992, 1994), and Yoder (1994). Vaidyanathan (1986) provides a historical survey of irrigation organization in Asia. Dayton-Johnson (1999b) updates these surveys in an explicitly economic framework.) We have learned a great deal from these case studies, but they 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. What is needed are field studies of relatively large numbers of irrigating communities, to test hypotheses regarding institutions and group characteristics.

The relative paucity of such large-scale studies is not difficult to understand. In the last two decades, development economists have enjoyed the availability of high-quality micro-datasets, but comparable datasets regarding communities are less plentiful. Large numbers of observations for household surveys can be collected in a single village; for the kind of irrigation study we describe herein, the unit of analysis is the village itself, and collecting a single observation can take days or weeks. Moreover, variables indicating cooperation or its absence are difficult to quantify. Despite

these obstacles, several studies of relatively large numbers of resource-using communities in developing countries have been carried out recently. (These include Agrawal and Goyal (1999), Edmonds (2000), Fujita, Hayami and Kikuchi (2000), Khwaja (2000), Lam (1998), and Tang (1992); we survey this literature more generally in Bardhan and Dayton-Johnson (2001).)

Inequality and water governance. 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 landholding 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). 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. Of course, in many parts of the world, land markets notoriously do not work 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. Differences in rates of time preference (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, caste, or tribes among irrigators will also affect cooperative behavior. 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 even 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. 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.

How does heterogeneity affect commons outcomes? 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. (Much of the theoretical work is assessed in greater detail in other chapters of this volume.) That inequality may favor provision of collective goods can justifiably be called an "Olson effect". 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 groundwater extraction, for example, and cooperation with canal-cleaning efforts are approximately public goods, or at the very least generate substantive externalities: 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 irrigation management, as large landowners – through whose landholdings significant portions of the canal network pass – will clean most or all of the canals even if all others free ride on their efforts. (Aspects of Olson's hypothesis are formalized by Bergstrom, Blume and Varian (1986), and by Itaya, de Meza and Myles (1997).)

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. Powerful élites in Vaidyanathan's history are successful in part because they centralize decision-making power as much as they command material wealth. Large start-up costs of this type are an example of non-convexities in the production technology. Irrigation 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 (as in the case of aquifers) 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. 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. Aggarwal (2000) shows with data from group-owned wells in two Indian villages that, in contrast to routine maintenance activities, there is far less cooperation in matters of long-term group investment; her data furthermore demonstrate that the standard deviation in land ownership has a negative effect on cooperation in such group investments.

This ambiguous relationship between inequality and successful commons management calls for more careful theoretical work, and larger-scale empirical work that permits careful testing of hypotheses. While this chapter is largely devoted to looking at the latter kind of research, we will return to the theoretical literature (considered at various points throughout this volume) below.

The field studies. The Indian and Mexican studies summarized below were conceived and designed together in order to permit a modicum of comparative analysis. Naturally, differences between the study regions preclude perfect comparability of all concepts and measures. Nevertheless, in both cases the unit of analysis is the irrigating community (rather than, for example, the household or the individual); in both cases information was collected on the institutions of local resource management (including, notably, the rules in place), structural characteristics of the resource-using group (e.g., number of users, pattern of landholding, physical specifications of the system), and measures of cooperation; in both cases, approximately fifty communities were surveyed. Finally, in both studies, we attempt to use the structural variables to explain both the rules and the level of cooperation.

A potential problem in discerning the effect of inequality on cooperation and institutional evolution is that inequality might be endogenous. That is, cooperation or the institutions of governance might affect inequality. Certainly if we used inequality of income (which is indeed endogenous) as our indicator of inequality, this would be a serious problem. In both studies, however, wealth inequality – specifically, landholding inequality – is used rather than income as an explanatory variable. Conceptually, landholding inequality could also be endogenous, if, for example, cooperation in irrigation affected land transactions. In both South India and Central Mexico, however, the distribution of landholding can effectively be treated as exogenous. The land market in South India is so inactive that landholding inequality is probably given more by history and demography than by endogenous land transactions. In Central Mexico, meanwhile, the agrarian reform of the 1920s and 1930s essentially froze the distribution of land-holding in each irrigation system. Liberalization of the land market since the early 1990s has not resulted in an increase in land transactions as the process of individual titling has proved complex and laborious.

A second potential shortcoming of the design of the Indian and Mexican studies is that by using the irrigation community as the unit of analysis, we ignore cases where there is no cooperative community whatsoever. Strictly speaking, this is true: our results below should be interpreted as exploring the effect of inequality in communities where some minimum threshold of cooperation is already present. In practice, however, this minimum threshold is quite low: in both studies, pains were taken (at times over the objections of local agricultural officials) to include communities with low levels of cooperation. Moreover, one could argue that this potential source of selection bias would tend to mute the measured effects of inequality on cooperation. If indeed inequality thwarts

cooperation, then some unequal villages will have failed to form irrigation institutions, and thus will be excluded from our sample; those that remain in the sample, all else equal, must be at least marginally better at overcoming the obstacles to collective action, inequality among them. Thus, the generally negative effect of inequality on cooperative effort that we detect might have been larger in absolute value had the sample been extended to include villages without irrigation organizations.

South India.

The data. Data were collected from 48 villages spread over six districts in the South Indian state of Tamil Nadu. (The full results of the data analysis for the South Indian study are reported in Bardhan (2000).) The unit of analysis is the *ayacut*, a selected part of the irrigation system in each village corresponding either to a tank or a branch of canal with roughly 50 hectares of command area. Half of the selected irrigation units belong to canal systems, and the other half to more traditional tank systems. All the canal systems are under the general administration of the government (usually the Public Works Department, PWD). Among tank systems, half of the surveyed ayacuts belong to what are called isolated or chain tank systems, and the other half to system tanks where the tanks are, unlike in the former case, linked to larger irrigation units. Within each system the villages were randomly chosen; within each village a sample of ten farmers (stratified by land-size classes) was chosen. Most of the analysis reported here is based on data for the irrigation unit or ayacut as a whole; in some cases we have derived data from the individual farmers' responses. In general, on matters of cooperation differences across villages are much more prominent than intra-village differences among the ten farmers.

Irrigation organization. The majority of the water users' organizations surveyed are traditional and informal community organizations that have been in existence for some time; 27 of the 48 surveyed are either "traditional" or at least 20 years old. Nevertheless, only thirteen of these units have formal associations (and ten of these have formal associations not at the village or sluice levels, but at the supra-village zonal level). The organization in twelve of the (canal-based) irrigation units surveyed has been set up relatively recently and is run directly by the PWD. In another twelve canal-based irrigation units, although the PWD is the official management authority, the traditional village committee manages irrigation matters at the local level.

Institutions for managing irrigation – including appointment of guards as monitors and enforcers, the frequency of meetings, mobilization of collective labor, mobilization of funds, method of cost-sharing, and involvement in non-irrigation activities – vary greatly among ayacuts. One function of the water users' organization is to mobilize community labor for the purpose of maintaining and repairing the field channels. Generally, it appears that community labor is most common in those organizations that are traditional or have existed for over 40 years. While most of these units mobilize community labor both for regular maintenance and for emergency repairs, several units report mobilizing community labor only in the event of emergency repairs. Community labor does not appear to be used systematically in any of those units where the PWD directly runs the organizations.

About three-quarters (37 in number) of the units surveyed have some formal system of fundraising. Of these, 28 units have a system of dues, fines and/or taxes. Such a system is most prevalent in canal-based units. In the tank-based systems, an alternate system of fundraising is possible: the

sale of collective resources such as fish and trees. Nineteen of the tank-based units have collective funds mobilized this way; ten of these supplement the collective fund with a system of dues and/or tax collection. About half of the water users' organizations report participating in other, usually village-wide, activities, such as conducting the temple festival. This does not appear to be true of any PWD-run organizations.

Measuring cooperation. Important dependent and independent variables from the South Indian study are summarized in Table 1. Three alternative variables can be interpreted as indicators of cooperation within the community on matters of irrigation: (a) quality of maintenance of distributaries and field channels; (b) absence of conflict in water allocation in the ayacut in the last five years; and (c) extent of violations of water-allocation rules.

Explanatory variables. For the purposes of this chapter, the most important explanatory variable is heterogeneity, both social and economic. Social homogeneity or heterogeneity is captured by a dichotomous variable that takes a value of one in villages where at least 75 percent of the sampled farmers in the village are members of the same generic caste group (in most cases a "backward" caste group). By this admittedly crude measure, 69 percent of the ayacuts in our dataset are relatively socially homogeneous. Economic heterogeneity is measured by the Gini coefficient of inequality of landholding of farmers in the ayacut area: the mean value of the Gini in our dataset is 0.41. Another obvious explanatory variable to consider is group size: the number of households using the particular irrigation source varies between eleven and 279, with a mean of 53. The usual presumption in the literature on local commons, stemming from the early work of Olson (1965), is that cooperation works better in small groups. In small irrigation communities peer monitoring is

easier, the common-knowledge assumption of models of strategic decisions is likely to be more valid, shared norms and patterns of reciprocity are more common, social sanctions may be easier to implement through reputation mechanisms and multiplex relationships, and hydrologic needs of farmers may even be relatively similar. On the other hand, there may be some positive economies of scale in larger groups, particularly in matters of pooling resources, appointing guards, lobbying with officials, and so on.

Another factor that affects cooperation in water management is the physical condition of water availability. In conditions of extreme scarcity arrangements of cooperation often break down. When there is greater access to water, it pays the irrigators to cooperate in maintaining field channels, and in obeying allocation rules. In our dataset, the villages with acute water scarcity in general exhibit less cooperation, but (probably for historical reasons) the water-scarce villages are also more likely to have canal-based irrigation. Thus, the effect of water-scarcity must be disentangled from that of possible bureaucratic inefficiencies in the release of canal water. We measure water availability by the number of months in a year that the farmers in the ayacut have access to water: this varies from two to seven months, with a mean of 3.7 months overall, and 2.8 for the canal areas. Other variables related to physical conditions include whether the topographical nature of the ayacut precludes equal access to water for all the farmers, and whether the irrigation channel is lined.

Government involvement is indicated in two ways. First, half of the villages are part of government-administered canal systems. Second, we have an indicator equal to one if the PWD makes all the decisions about water allocation and distribution even at the local level. In the canal-

area villages there is not merely lower water availability, water is also more inequitably distributed: in nineteen of 24 canal-area villages in our dataset (as opposed to only two of the 24 villages served by tank systems) there is evidence of such inequity of water supply or access. In general, the water release cycles may be more unreliable from the farmers' point of view when they are administered by PWD officials. Of course, these associations may stem from a problem of endogeneity: is PWD involvement more likely where irrigators' cooperation has failed? Some background checking revealed that the villages where PWD takes all the decisions are all located in Coimbatore district and are precisely those where, for primarily physical reasons of long-term water scarcity, a large-scale system of inter-river basin water transfer scheme had been undertaken by the government. The problem of endogeneity is thus not that serious here.

A few variables relate to the locational context of the ayacut in question. In our dataset 75 percent of the villages are at the tailend of their respective system. Other things remaining the same, being at the tailend may unite the farmers of the village in their struggle to get more water away from the more favorably located villages. We have also used a variable to indicate those villages where no water conflict is reported with other villages. Only 44 percent of villages report that there is no such conflict with other villages. The locational context is also important in the matter of the exit options open to the villagers. We measure this with an indicator variable for the connection of the village to urban areas or transport and communication modes (like bus and telephone). Another variable measures the extent to which farmers sell their produce in the outside market. (Since a farmer's marketed share may be endogenous, we have used a predicted value of this variable in the regressions for determinants of cooperation). A somewhat different kind of exit-option variable may be indicated by how much access an ayacut member has to water sources outside the ayacut.

Thus we include the estimated fraction of the total irrigated land (of the sampled farmers in the ayacut) that is outside the ayacut. For all of these exit option-like variables our prior expectation is a negative effect on cooperation.

History of cooperation in a village may matter, as cooperation may be self-reinforcing, or, "habit-forming", as Seabright (1997) explains in a theoretical model. We therefore control for villages where the water users' organization has existed for twenty years or more. These villages are characterized by more use of community labor in maintenance works and emergencies, are more likely to hire guards, called "neerani" in much of this area, for monitoring and enforcement, and are more likely to use cost-sharing proportional to land holding. We also asked questions about the farmers' perception about the process of rule crafting. For example, we have an indicator for villages where at least four out of ten sampled farmers believe that the water rules were crafted by the élite. We also had a variable for villages where the rules are generally perceived as fair, but we dropped this variable as it almost exactly coincides with cases of cooperative behavior.

Analysis results: Institutional choice. Table 2 reports the results of a logit model of the likelihood that the ayacut shares costs proportionally to landholding size. The rules in place are expected to be an important determinant of cooperation; at the same time, the rules are likely to be explained by structural characteristics of the community and the irrigation system. Therefore we estimate the likelihood of observing proportional cost sharing as a function of inequality and other variables. Proportional cost sharing is observed in nineteen percent of ayacuts. The estimated coefficient on the Gini term is positive and significant: ayacuts with more unequally distributed wealth are more likely to share canal-maintenance costs proportionally to wealth. Note that equal-division of costs

would be effectively regressive in the presence of inequality. Therefore greater inequality increases the likelihood of a progressive tax to finance maintenance and repairs. (First-stage logit estimates of the presence of guards and of the market orientation of ayacut farmers were also estimated, but the results are not reported here. The interested reader is referred to Bardhan (2000, Table 5).)

Analysis results: Determinants of cooperation. Table 2 reports the results of three logit models, each with a different dependent variable measuring the degree of cooperation in surveyed villages. (Alternative specifications of all three models are reported in Bardhan (2000, Tables 2, 3, and 4); the interested reader will also find more extended discussion of the effect of variables other than inequality on cooperation.) Columns 2 and 3 show the results of an ordered-logit model of the index of quality of maintenance of distributaries and field channels. This index is uniformly lower in ayacuts with higher inequality in landholding: the coefficient for the Gini coefficient is negative and significant. Moreover, maintenance is also lower, and significantly so, in villages where rules are perceived to be crafted by the village élite. The urban linkage variable likewise has a significant and negative effect on maintenance. This demonstrates that exit options hamper cooperation, but it might also indicate a negative effect of inequality if the rich are better able to exercise those exit options. All three results point to a negative effect of inequality on canal maintenance.

The channel-maintenance results also demonstrate the positive (but not always significant) effect of the proportional cost-sharing rule on maintenance. Proportional cost-sharing could be perceived as more fair than, for example, cases where all farmers have to bear the same cost even though the larger farmers get more of the benefit, or where there is no cost-sharing rule whatsoever. The

presence of proportional cost sharing was estimated in Table 2, and the estimated probability is used as an explanatory variable in the Table 3 models. The Gini coefficient has a positive effect on the presence of proportional cost-sharing (possibly indicating social pressure for a redistributive adjustment of the cost-sharing rule to take account of wealth disparities). The estimated probability of proportional cost sharing, meanwhile, has a somewhat significant positive effect on channel maintenance. Thus the effect of inequality of land distribution on the quality of field-channel maintenance is twofold: on the one hand, the direct effect is negative, but the indirect effect, working through the cost-sharing rule, is positive.

Columns 4 and 5 of Table 3 report the results of a logit model estimating the probability that there has been no intra-village conflict over water over the previous five years. (Thus negative estimated coefficients indicate a higher probability that an ayacut has witnessed internal water-related conflict.) Once again, the Gini coefficient has a significantly negative effect, but the square of the Gini term is significantly positive, indicating a U-shaped relationship between inequality and cooperative behavior. The coefficient for within-village caste homogeneity (75 percent or more of the farmers belonging to the same caste group) is positive and significant, confirming that social homogeneity promotes cooperation.

Finally, columns 6 and 7 of Table 3 report the results of a logit model of the probability that water allocation rules are frequently violated by at least one group. (Both for the ayacut as a whole and for the sampled farmers our data definitely suggest that the rule violations are more often by the better-off farmers; one presumes they can get away with such violations more easily). Here the signs of the coefficients for the Gini coefficient, the square of the Gini, caste homogeneity, tailend

location, and ownership of irrigated land outside the ayacut are as expected from the other statistical models in the table, but they are not significant. The effect of group size is positive – that is, group size promotes rule violation – and highly significant, indicating the difficulty of preserving cooperative behavior in large groups. As in the maintenance models, the urban-linkage index has a positive and significant effect; this is an indication of the negative effect of exit options on cooperation, and potentially also of inequality, if it is the rich who are better positioned to exploit exit options.

From the list of independent variables explaining rule violation, we had to drop the dummies indicating PWD decision-making and the perception that the rules were crafted by the élite, because in both cases their values perfectly predicted the value of the dependent variable. This means in all the villages where PWD decides on water allocation and distribution, frequent rule violations are reported: this may be because the rules are typically rigid and insensitive to local needs, farmers are less normatively committed, officials are bribed to look the other way, and so on. (Lam (1998) reports from his study of irrigation systems in Nepal that in nearly half of the government agency managed systems the extent of rule-breaking is medium or high, whereas the corresponding percentage in farmer-managed systems is only about 12 percent). In contrast, in the villages where the village élite, rather than government officials, crafts the rules, there is no violation of rules reported. Since, as we have noted before, the better off are usually the more frequent violators of rules, they tend not to violate the rules they crafted.

In all twelve PWD-run units there are rotational water allocation rules by which the farmers are allotted a certain number of hours of water access per acre or are allowed access to water only in

alternate weeks. In all of these units these rotational rules are frequently violated and particularly the rich farmers appropriate more water than is their due. And yet in half of these units (particularly where the inequality in land distribution among the farmers is low), as we have seen before, field channels are well maintained and there was no incidence of water conflicts within the village in the last five years. This means inflexible rules of the government (enforced by corruptible agents) are frequently violated without necessarily damaging intra-village cooperation, suggesting again that when rules do not enjoy the backing of community norms, rule obedience is not necessarily an indicator of cooperation among farmers.

Central Mexico.

The data. The Mexican study was limited to reservoir-based, or surface-water, irrigation systems. (These would be called "tank" systems in South Asia.) In Mexico, several thousand *unidades de riego*, or "irrigation units", autonomous from public control, irrigate approximately half of the country's irrigated area; the remainder is served by public irrigation districts. Data were collected in the central state of Guanajuato by means of a survey of the governing councils (*mesas directivas*) and inspection of the canals of 54 randomly-chosen *unidades* in Guanajuato. (The Mexican data-collection exercise is described in greater detail in Dayton-Johnson (1999a).)

Irrigation organization. Table 4a presents summary characteristics of the sample systems. Among the characteristics of the water users' association noted in the table are the number of *ejidos* – quasi-communal farming groups created during Mexico's agrarian reform – represented among the members of the association; the presence of more than one *ejido* among the association members indicates social heterogeneity. The share of *ejidatarios* (*ejido* members) indicates the fraction of

irrigation system members that are members of some ejido, as opposed to private landowners. A lower share of ejidatarios likewise indicates greater social heterogeneity.

Table 4b summarizes the complex of rules chosen by the water users in 49 of the irrigation communities (in most of the five communities left out of the table, years of inactivity have led to the disappearance of rules altogether): the water-allocation and cost-sharing arrangements, the labor-mobilization regime, and the presence or absence of a water master. Water is allocated, in each unidad, either (a) proportionally to each household's landholding, or (b) in equal shares to all households. Similarly, maintenance and repair costs are shared either (a) proportionally to landholding, or (b) equally among all. (Other water-allocation and cost-sharing rules from the field-study literature are assessed in Dayton-Johnson (1999b).) Ostrom (1990, p. 92 and passim) argues that successful institutions to manage local commons frequently exhibit *congruence* between cost-sharing and allocation rules: "appropriation rules restricting time, place, technology and/or quantity of resource units are related to local conditions and to provision rules requiring labor, material, and/or money." This "congruence hypothesis" – namely, that governance regimes for the commons with equivalent rules for cost sharing and benefit allocation perform better and endure longer – is echoed in field studies of irrigation. Chambers (1980, p. 41), drawing on his experience in South Asia, asserts that "...communal labor is most likely to be effective... where labor obligations are proportional to expected benefits". Siy (1987) shows that under the *atar* distributive rule in the successful Philippine *zanjeras* (irrigation societies), the ratio of individual benefits to labor contributions is roughly equal for all members of a given organization. Dayton-Johnson (2000a) develops a simple game-theoretic model formalizing the congruence hypothesis: in that model, full compliance with the rules of the system is a noncooperative equilibrium outcome

when there is congruence between the cost-sharing and allocation rules. In Table 4b, the eight unidades with proportional water allocation and proportional cost sharing and the seventeen with equal division of both water and costs exhibit congruence in their distributive rules. From the perspective of the congruence hypothesis, the puzzle to be explained is the presence of 24 irrigation systems – a nonnegligible fraction of the sample – with incongruent rules. Other institutional characteristics summarized in Table 4b include the mode of canal-cleaning: collective canal cleaning is carried out by all households working side by side on predetermined days; household canal cleaning assigns a stretch of the canal network to each household for cleaning.

Measuring cooperation. Unlike the South Indian study, which considered a range of measures of cooperation, the Mexican study looks at one particular dimension – infrastructure maintenance – in greater detail. Thus Table 4c summarizes the distribution of several indicators of the quality of infrastructure maintenance from the Mexican survey. These measures were collected during a canal inspection at each of the sampled systems. We assume that the observed quality of maintenance in each case increases with the level of cooperation in cost sharing. For each indicator, each irrigation system was given a score of "good", "fair", or "poor". For the indicators of filtration and animals trampling the canals, the meaning of the scores is slightly different, indicating that the problem is "general", "present but not generalized", or "absent". Three of these indicators are used below in ordered-logit models of the quality of maintenance: the state of repair of field intakes, the small and simple structures that regulate the flow of irrigation water into individual parcels; the degree of definition of canal side-slopes (important since almost all are earthen canals, unlined with cement or concrete); the degree of filtration (leakage) of water around the canals.

Explanatory variables. Table 4a reports that the average Gini coefficient, calculated on the basis of irrigated landholding, is 0.27, lower than in the South Indian sample; the maximum Gini is 0.76, the minimum 0.00 (fifteen cases). The proportion of group members who are ejidatarios – members of ejidos – is another indicator of heterogeneity: such an indicator measures the degree of heterogeneity in the quality, rather than quantity, of landholding wealth. The mean share of ejidatarios is 83 percent: among the water users, ejidatarios dominate numerically. The average group size is 123 households. The average age of the water users' association is 43 years, although the oldest such organization in the sample was founded in 1883, and the newest was only four years old at the time of the survey.

Analysis: Institutional choice. What structural community characteristics are associated with particular irrigation institutions? As in the South Indian study, we estimate a model of institutional choice: Table 5 reports the results of a logit model predicting the presence of a proportional water-allocation rule. (A more extensive discussion of the statistical model and the explanatory variables is provided in Dayton-Johnson (2000a).) Note that Table 2 reports a similar model for the South Indian data, but one that estimates the probability of proportional *cost sharing* rather than water allocation. To ease interpretation of the results, the explanatory variables have been normalized so that each has a mean value equal to zero and a standard deviation equal to one. The table shows that the impact of inequality is large, positive and significant: a one-standard-deviation increase in the Gini coefficient increases the probability of observing proportional water allocation. Social heterogeneity, as measured by the number of ejidos represented among the irrigation-group members, has no significant effect on the choice of rules.

The prevalence of unidades that combine proportional water allocation with equal division of costs appears to counter the congruence hypothesis of Ostrom and others, but it is consistent with an interpretation of unequal bargaining power and institutional evolution. Compare the gains from proportional water allocation mixed with equal division of costs, relative to equal division of both water and costs (the congruent rule). For households with landholding wealth above the mean level, those gains rise with inequality in the landholding distribution: the higher a household's landholding lies above the mean, the larger the difference between its water share and its maintenance-labor share. For those group members with wealth below the mean, however, the attractiveness of this incongruent rule is decreasing in inequality: as a household's landholding size drops, its share of water benefits drops, while its labor contribution remains constant. How the actual rule choice reflects these different preferences toward adoption of the proportional or proportional-allocation rule depends on the mechanism that aggregates households' preferences. Assume for the moment that, as is plausible in a hierarchical agrarian social order, the will of the larger landholders is more highly weighted by this mechanism. Then increased inequality will be associated with a higher probability of observing the incongruent rule that we witnessed in half of the Mexican irrigation groups. This outcome could emerge even if this incongruent proportional-allocation rule performs miserably in terms both of mobilizing maintenance effort and minimizing transaction costs, if the wealthier households can impose their preference for that relatively non-egalitarian rule on the group. This process is consistent with Ostrom's (1996) interpretation of evidence regarding bargaining over rules in a group of irrigation systems in Nepal. (This raises the question of why the poorer households cannot pay off the wealthy to switch to a better-performing rule.)

Analysis: Determinants of cooperation. Table 6 summarizes results of three logit models of collective effort in the Mexican irrigation systems, as measured by the state of repair of the infrastructure. (Further details regarding these statistical models, and a more extensive discussion of the explanatory variables, is provided in Dayton-Johnson (2000b).) While there are important differences across the three models, the following generalizations can be made. First, social heterogeneity lowers cooperative effort. In all three cooperation models, social heterogeneity – the number of ejidos represented in the unidad – is associated with lower maintenance levels. Controlling for other factors, costs associated with organizing irrigation across ejido boundaries lower aggregate cooperative effort. Moreover, the quantitative importance of this form of social inequality is larger than that of economic inequality. Second, and nevertheless, economic inequality lowers cooperative effort. In all three models, a Gini-squared term is included and inequality is interacted with (the predicted probability of) the presence of proportional water allocation. Therefore, the full effect of inequality is not limited to the estimated coefficient on the Gini term; the marginal effect of an increase in inequality on maintenance effort is a function also of the level of the Gini coefficient, and the presence of a proportional water-allocation rule. Once calculated, the full effect of the Gini coefficient is negative in each of the three maintenance models. (The effect is evaluated at the mean value of the independent variables.) The full effect of inequality, thus computed, on side-slope definition is –0.1238 percent; that is, a one-unit increase in the Gini coefficient starting at its mean level reduces side-slope definition –0.12 percent. The full effect of inequality on field-intake condition is –1.03 percent, and the full effect on filtration control is –0.02 percent. The components of this full effect, however, do not all have negative signs. The estimated coefficient on the square of the Gini term is positive in all cases, suggesting a positive effect of inequality on canal maintenance that is higher at higher levels of inequality. The

estimated coefficient on the interaction between (predicted) proportional water allocation and the Gini term is negative: conditional on having chosen proportional water allocation, increasing inequality reduces the level of cooperative effort.

This full effect of inequality on cooperation, however, does not fully exhaust the effect of inequality on cooperative effort. This is because the quantitatively most important determinant of cooperative effort in all three models is the presence of proportional water allocation, which is in turn partly a function of the level of inequality. Thus Table 7 adds the indirect effect of inequality on canal maintenance (via the effect of inequality on the choice of rules) to the direct effect for each of the three models. Column A shows that one-unit increase in the Gini coefficient increases the probability of observing proportional water allocation (controlling for the other explanatory variables in Table 5) by 35.85 percent. (This number is the marginal effect of inequality evaluated at the vector of mean values of the variables in Table 5; see Dayton-Johnson (2000a, Table 8) for further details.) Column B shows the effect of proportional water allocation on each of the three indicators of collective maintenance effort; the largest negative effect of this rule, by far, is on field-intake condition. Column C multiplies these two effects to give the indirect effect of inequality on maintenance. Column D gives the direct effect; this is the marginal effect computed on the basis of the estimated coefficients reported in Table 6. The total effect of inequality (Column E) simply adds the direct and indirect effect.

Interpretation. What can we deduce about the relationship between inequality and community irrigation from our review of the Indian and Mexican evidence? First, there is a generally negative association between inequality and cooperative outcomes. An increase in the Gini coefficient of

landholding inequality is associated with lower maintenance and greater incidence of water-related conflict in South India. The full effect of the Gini coefficient on various indicators of maintenance (properly accounting for interaction terms and quadratic terms) is negative in the Mexican data as well. This suggests that Olson effects are not as prevalent in these irrigation systems as the negative effect of inequality on conservation found in Dayton-Johnson and Bardhan (2001). In that model (which is couched in terms of a fishery), conditional conservation is a best response for each fisher to conditional conservation by the other, under conditions of perfect equality of fishing capacity. ("Conditional conservation" means simply conserving when one's counterpart conserves.) As inequality increases, however, some fishers' capacity is reduced to the point where their claim on the future benefits of conservation are too small to induce them to conserve today. (A more general discussion of inequality and collective-good provision with concave production functions and capital-market imperfections is discussed in the chapter in this volume by Bardhan and Ghatak.)

In general, the statement that inequality hampers cooperation is true when the vector of explanatory variables is evaluated at its mean level; this is the standard interpretation of the estimated coefficients in the statistical models reported here. Nevertheless, the relationship between inequality and provision of collective goods is non-monotonic. Thus, there is evidence of a U-shaped relationship between landholding inequality and the absence of intra-village water conflicts in South India. In the models of infrastructure maintenance in Mexico, too, there is evidence that inequality has a beneficial effect at higher levels of inequality. Recently, Khwaja (2000), in an empirical study of the maintenance of infrastructure projects in North Pakistan, found a similar U-shaped relationship between income inequality and maintenance. These empirical results are

consistent with another theoretical result of Dayton-Johnson and Bardhan (2001), mentioned above: although increasing inequality can reduce conservation, as the capacity (wealth) distribution gets even more unequal, conservation becomes a dominant strategy for the wealthier fishers. The poorer fisher's overfishing early in the game is constrained by his wealth and is consequently too small to dissuade the wealthier fisher from conserving.

The results of the field studies also clearly underscore the importance of institutions, the local rules for managing irrigation resources and infrastructure. In the first instance, both studies provide evidence that the rules in place affect the level of cooperation. The presence of proportional cost sharing is associated with higher field-channel maintenance in South India, while the presence of proportional water allocation is associated with higher field-intake maintenance in Mexico. At the same time, economic inequality has a close relationship with these rules. Inequality is strongly associated with the presence of proportional cost sharing in South India, indicating pressure for progressive redistribution. Conversely, inequality is strongly associated with proportional water allocation in Mexico; given that most of these systems have equal division of costs, this is evidence of pressure for regressive redistribution. Also relevant in this connection is that maintenance is lower in South India in systems where a substantial fraction of farmers believe that the rules were crafted by the local élite.

These interpretations of the relationship between inequality, rules, and performance are broadly consistent with a number of game-theoretic models of cooperation (as in Dayton-Johnson and Bardhan (2001)). Nevertheless, the empirical results suggest that a critical impact of inequality on cooperation on the commons is mediated by social norms. Thus, social heterogeneity often has a

negative impact on cooperative outcomes. Caste homogeneity reduces the incidence of intra-village water conflict in South India. Social heterogeneity – the number of ejidos from which irrigation-group members are drawn – has a uniformly negative and significant effect on maintenance in all of the Mexican results. Certain types of community – caste groups or ejidos – have at their disposal means of monitoring and enforcing cooperative agreements; the efficacy of those means diminishes as they cross community boundaries. This is indirect evidence that some kinds of group-based resources – social norms or social sanctions – are critical to the successful management of irrigation resources. (Baland and Platteau (1995) refer to this as "cultural homogeneity".)

That economic outcomes might be affected by these community-level resources has been suggested by Akerlof's (1997) analysis of "social distance", for example, and indeed by the burgeoning social-science research on "social capital" (e.g., Putnam (1993), Knack and Keefer (1997), Narayan and Pritchett (1999)). Part of the disutility suffered by community members who break rules is the pecuniary loss that is imposed on them by the explicit rules: if you don't clean your stretch of the canal, you don't get any water. But certainly there is some nonpecuniary disutility from rule-breaking, and arguably, people experience more of this when the others they've cheated are more socially proximate. By extension, the internal or psychic disutility of rule-breaking is lessened the greater the social distance among players.

Results of experimental economics support, or are at least broadly consistent with, this type of finding. Indeed, one of the most active areas of experimental research in economics has to do with explaining the apparently anomalous results of the "Ultimatum Game" (Thaler (1988); Roth

(1995)), in which players inefficiently reject offers they perceive as unfair. Rabin (1997) provides a general theory of bargaining structures that suggests that fairer environments, in which asymmetries in bargaining power are relatively low, may lead to more efficient outcomes. Sally (2001) suggests that sympathy is a key factor in determining willingness to cooperate (by changing payoffs as suggested above); sympathy, in turn, is an inverse function of physical and psychological distance between a person and others. Other experimental results confirm that power asymmetries and social distance affect the outcome of games in ways not necessarily consistent with conventional economic modeling. Lawler and Yoon (1996) report results of exchange experiments in which equality of power significantly increases the probability of mutual agreements, which in turn generate feelings of cohesion between the players. (Many of these issues are considered at greater length in the context of commons games by Cárdenas and Ostrom (2001).)

An intriguing question raised by these results is whether cultural or social heterogeneity is itself fostered by economic inequality. Thus, for example, Cárdenas (1999) reports the results of laboratory commons games played by experimental subjects who are themselves farmers and commons users in rural Colombia. He finds that farmer-players with a greater wealth distance from the other players seem less willing to cooperate. (The novelty of Cárdenas's research is that he measures players actual wealth levels, not wealth measured in terms of tokens given them to play the laboratory game.)

While our review of the Indian and Mexican evidence cannot provide sufficiently refined data to discern among these varied hypotheses about norms, bargaining power, and perceptions of fairness,

our results nevertheless indicate that these issues should be at the forefront of future theoretical and empirical research on local commons.

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Inequality and the governance of water resources in Mexico and South India – Tables

Pranab Bardhan & Jeff Dayton-Johnson

Table 1: Summary of variables, South India

| Variable Name | Obs. | Mean | St. Dev. | Minimum | Maximum |
|--|------|-------|----------|---------|---------|
| <i>Measures of Cooperation</i> | | | | | |
| Index of Quality of Maintenance of Distributaries and Field Channels | 45 | 1.31 | 0.92 | 0 | 2 |
| No Conflict over Water Within Village in the last 5 Years | 48 | 0.67 | 0.48 | 0 | 1 |
| Water Allocation Rules Frequently Violated by at least One Group | 48 | 0.52 | 0.50 | 0 | 1 |
| <i>Explanatory Variables</i> | | | | | |
| No. Of Beneficiary Households Using this Irrigation Source | 48 | 52.67 | 54.29 | 11 | 279 |
| Gini Coefficient of Landholding of Beneficiary Households in Ayacut | 48 | 0.41 | 0.11 | 0 | 1 |
| At least 75% of Sampled Farmers are Members of the Same Caste Group | 48 | 0.69 | 0.47 | 0 | 1 |
| Number of Months there is Access to Irrigation | 48 | 3.65 | 1.20 | 2 | 7 |
| No equal Access to Water Because of Topographical Nature of the Ayacut | 48 | 0.46 | 0.50 | 0 | 1 |
| System is Partially or Fully Lined | 48 | 1.96 | 0.82 | 1 | 3 |
| Ayacut is in a Canal System | 48 | 0.50 | 0.51 | 0 | 1 |

| | | | | | |
|---|----|------|------|---|------|
| PWD Takes All Decisions on Water Allocation | 48 | 0.25 | 0.44 | 0 | 1 |
| Village is Situated at Tailend of the Irrigation System | 48 | 0.75 | 0.44 | 0 | 1 |
| No Conflict with Other Villages over Water | 48 | 0.44 | 0.50 | 0 | 1 |
| Index of Connection with Urban Areas | 48 | 2.46 | 0.74 | 1 | 3 |
| Measure of Extent to which Farmers are Market Oriented | 48 | 2.39 | 0.70 | 1 | 3 |
| Estimated Fraction of Total Irrigated Land Held by Sampled Farmers Outside the Ayacut | 48 | 0.26 | 0.18 | 0 | 0.66 |
| Irrigation Organization Has Been There for 20 or More Years | 48 | 0.56 | 0.50 | 0 | 1 |
| There Exists at least One Guard in the Ayacut | 48 | 0.38 | 0.49 | 0 | 1 |
| Cost-sharing Proportional to Landholding | 48 | 0.19 | 0.39 | 0 | 1 |
| Formal Water Rights Exist, as opposed to Customary Rights | 48 | 0.33 | 0.48 | 0 | 1 |

Table 2: A logit model of the choice of cost-sharing rule, South India

| Variable | Estimated Coefficient | Level of Significance |
|---|------------------------------|------------------------------|
| No. Of Beneficiary Households Using this Irrigation Source | 0.0265* | @ 5% |
| Gini Coefficient of Landholding of Beneficiary Households in Ayacut | 9.8831* | @ 10% |
| Ayacut is in a Canal System | 4.1930* | @ 5% |
| Irrigation Organization Has Been There for 20 or More Years | 2.6285* | @ 5% |
| Formal Water Rights Exist, as opposed to Customary Rights | 2.0355* | @ 10% |
| Observations | 48 | |
| Log Likelihood | -13.7212 | |
| Pseudo R-sq. | 0.4076 | |

* indicates significance at 10% level or below.

Table 3: Logit models of cooperation, South India

| Variable | Dependent Variable | | | | | |
|--|--|--------------|---|--------------|--|---------------|
| | Index of Quality of Maintenance of Distributaries and Field Channels (0-1-2) | | No Intra-village Water Conflict, last 5 Years (0-1) | | Water Allocation Rules Frequently Violated by at least One Group (0-1) | |
| | Coefficient | Significance | Coefficient | Significance | Coefficient | Significance |
| No. Of Beneficiary Households Using this Irrigation Source | -0.0339* | @ 10% | -0.0868 | @ 15% | 0.0350* | @ 5% |
| Gini Coefficient of Landholding of Beneficiary Households in Ayacut | -23.2620* | @ 5% | -106.6778* | @ 5% | 25.3600 | Insignificant |
| Gini Squared | | | 76.2725* | @ 10% | -34.9862 | Insignificant |
| At least 75% of Sampled Farmers are Members of the Same Caste Group | | | 2.9169* | @ 10% | -0.8536 | Insignificant |
| Number of Months there is Access to Irrigation | 4.5637* | @ 5% | 1.4893 | @ 20% | -0.8960 | @ 15% |
| No equal Access to Water Because of Topographical Nature of the Ayacut | | | | | 1.1632 | Insignificant |
| PWD Takes All Decisions on Water Allocation | 4.8454* | @ 5% | | | | |

| | | | | | | |
|---|----------|---------------|---------|-------|----------|-------|
| Village is Situated at Tailend of the Irrigation System | 1.5790 | Insignificant | | | | |
| No Conflict with Other Villages over Water | -2.2385 | Insignificant | | | | |
| Index of Connection with Urban Areas | -4.2900* | @ 5% | -3.2398 | @ 20% | 2.1425* | @ 5% |
| Estimated Fraction of Total Irrigated Land Held by Sampled Farmers Outside the Ayacut | | | | | 5.8283 | @ 15% |
| There Exists at least One Guard in the Ayacut (Estimated probability) | 10.3531* | @ 5% | 22.4376 | @ 15% | -7.5257* | @ 5% |
| Cost-sharing Proportional to Landholding | 9.6847* | @ 10% | | | | |
| At least 40 % of farmers feel rules were crafted by the elite | -7.9717* | @ 5% | | | | |

| | | | | | | |
|----------------|----------|--|----------|--|----------|--|
| Observations | 45 | | 48 | | 48 | |
| Log Likelihood | -16.5396 | | -10.3061 | | -15.7310 | |
| Pseudo R-sq. | 0.5619 | | 0.6627 | | 0.5266 | |

* indicates significance at 10% level or below

Table 4a. Characteristics of the sample, Central Mexico

| Variable | Units | Mean | St. Dev. | Minimum | Maximum |
|--|----------------------------|-------------|-----------------|----------------|----------------|
| <i>System Characteristics</i> | | | | | |
| Reservoir capacity | 1,000 m ³ | 3,431 | 9,665 | 30 | 50,000 |
| Command area | ha | 449 | 931 | 16 | 6,014 |
| Canal network | km | 11.2 | 12.1 | 0.5 | 54.6 |
| Lined canals | proportion | 0.23 | 0.32 | 0 | 1 |
| Government-constructed | (0,1) | 0.60 | | 0 | 1 |
| <i>Characteristics of the water users' association</i> | | | | | |
| Households | no. | 123 | 140 | 15 | 676 |
| Ejidos | no. | 1.8 | 1.6 | 0 | 8 |
| Ejidatario share | proportion | 0.87 | 0.25 | 0 | 1 |
| Mean land-holding | ha | 3.3 | 2.3 | 0.3 | 10.0 |
| Gini coefficient | | 0.267 | 0.246 | 0.000 | 0.747 |
| Year of formation | | 1953 | 22 | 1883 | 1992 |
| <i>Performance, 1994/95</i> | | | | | |
| Irrigation supply | 1,000 m ³ | 1,636 | 5,393 | 0 | 37,500 |
| Irrigated area | ha | 405 | 1,118 | 0 | 6,014 |
| Output per unit water | pesos/1,000 m ³ | 933 | 1,357 | 0 | 7,517 |
| Output per unit land | pesos/ha | 3,796 | 4,853 | 0 | 25,000 |
| <i>Economic characteristics, 1994/95</i> | | | | | |
| Wage | pesos/day | 27 | 6 | 14 | 45 |
| Output price | pesos/ton | 1,115 | 1,170 | 0 | 5,141 |

Table 4b. Joint distribution of institutional characteristics, Central Mexico

| | <i>Cost-sharing</i> | | <i>Water master</i> | | <i>Canal-cleaning</i> | |
|-------------------------|---------------------|----------------|---------------------|--------|-----------------------|-----------|
| | Proportional | Equal-division | Present | Absent | Collective | Household |
| <i>Water allocation</i> | | | | | | |
| Proportional | 8 | 23 | 25 | 6 | 11 | 18 |
| Equal-division | 1 | 17 | 10 | 8 | 9 | 8 |
| <i>Cost sharing</i> | | | | | | |
| Proportional | | | 8 | 1 | 0 | 8 |
| Equal-division | | | 27 | 13 | 20 | 18 |
| <i>Water master</i> | | | | | | |
| Present | | | | | 12 | 21 |
| Absent | | | | | 8 | 5 |

(Three systems have different canal-cleaning regimes; therefore the numbers in columns 5 and 6 sum only to 46.)

Table 4c. Infrastructure maintenance, Central Mexico

| <i>Condition of...</i> | N | Good (%) | Fair (%) | Poor (%) |
|--|----------|-----------------|-----------------|--------------------|
| Lining of primary canals | 26 | 50.0 | 38.5 | 11.5 |
| Lining of secondary canals | 13 | 53.8 | 46.2 | 0.0 |
| Water gates | 40 | 20.0 | 62.5 | 17.5 |
| Field intakes | 46 | 13.0 | 54.3 | 32.6 |
| Grubbing (control of brush and growth around canals) | 54 | 24.1 | 33.4 | 42.6 |
| Canal side-slopes | 54 | 51.9 | 35.2 | 13.0 |
| | | None (%) | Some (%) | General (%) |
| Damage by animals and vehicles crossing the canals | 46 | 65.2 | 26.1 | 8.7 |
| Filtration of water around canals and channels | 49 | 44.9 | 40.8 | 14.3 |

Table 5: A logit model of the choice of proportional water allocation, Central Mexico

| Variable | Estimated coefficient | <i>t</i>-ratio |
|--|------------------------------|-----------------------|
| Gini coefficient | 2.8839 | 2.65 |
| Number of households in the irrigation system | 2.1657 | 0.84 |
| Number of ejidos represented among irrigation-system members | -0.1890 | -0.14 |
| Age of water users' association | 1.6156 | 1.79 |
| Water depth (Reservoir capacity relative to command area of the reservoir) | -1.0819 | -1.23 |
| Ratio of smallest parcel size to local wage | 0.2344 | 0.13 |
| Proportion of canal network that is lined | 0.8775 | 1.39 |
| Constant | 1.7708 | 1.48 |
| Observations | 48 | |
| Log likelihood | -11.83 | |
| Pseudo R-sq | 0.62 | |

Each of the explanatory variables is normalized with mean zero and standard deviation equal to one.

Table 6: Logit models of infrastructure maintenance, Central Mexico

| Variable | Dependent Variable | | | | | |
|-----------------------------------|---------------------------|-----------------|----------------------------|-----------------|-------------------------------------|-----------------|
| | Definition of side-slopes | | Condition of field intakes | | Control of filtration around canals | |
| | Coefficient | <i>t</i> -ratio | Coefficient | <i>t</i> -ratio | Coefficient | <i>t</i> -ratio |
| Number of households | -0.0107 | -0.7 | 0.0112 | 0.7 | 0.0125 | 0.8 |
| Gini coefficient | 0.0087 | 0.1 | 0.1305 | 0.9 | -0.0314 | -0.2 |
| Gini squared | 0.0014 | 1.2 | 0.0051 | 2.7 | 0.0040 | 2.4 |
| Number of ejidos | -0.6916 | -2.3 | -0.7392 | -2.0 | -0.6795 | -2.3 |
| Command area | 0.0023 | 1.1 | 0.0023 | 1.1 | 0.0047 | 2.5 |
| Wage | -0.1123 | -1.3 | -0.0688 | -0.8 | -0.2392 | -2.4 |
| Irrigation supply | -0.0004 | -1.5 | -0.0004 | -1.3 | -0.0003 | -0.7 |
| Dummy for government construction | 1.4298 | 1.8 | -0.2095 | -0.2 | -0.0992 | -0.1 |

| | | | | | | |
|---|---------|------|---------|------|---------|------|
| Interaction: proportional water allocation (estimated probability) and number of households | 0.0133 | 0.8 | -0.0121 | -0.7 | -0.0187 | -1.1 |
| Interaction: proportional water allocation (estimated probability) and Gini | -0.1016 | -0.7 | -0.4814 | -2.5 | -0.1968 | -1.2 |
| Proportional water allocation (estimated probability) | 0.8587 | 0.5 | 7.0442 | 2.6 | 2.2328 | 1.0 |
| <hr/> | | | | | | |
| Observations | 48 | | 40 | | 43 | |
| Log likelihood | -42.4 | | -28.3 | | -36.2 | |
| Pseudo R-sq | 0.1228 | | 0.2577 | | 0.1784 | |
| <hr/> | | | | | | |

Table7: Calculating the total effect of inequality on cooperative effort, Central Mexico

| | A | B | C | D | E |
|------------------------------|---|--|---|--|-------------------|
| | Effect of Gini on choice of proportional water allocation | Effect of proportional water allocation on maintenance | Indirect effect of inequality via rule choice | Direct effect of inequality on maintenance | Total effect |
| <i>Maintenance indicator</i> | | | (A times B) | | (C plus D) |
| Side slope definition | 35.85 | -1.56 | -0.56 | -3.04 | -3.60 |
| Condition of field intakes | 35.85 | -186.12 | -66.71 | -25.31 | -92.02 |
| Filtration | 35.85 | -2.16 | -0.77 | -0.48 | -1.26 |