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CONSTITUTING SOCIAL CAPITAL AND COLLECTIVE ACTION

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Abstract

Ignoring the impact on a form of social capital--the rules used in farmer-organized irrigation systems--of changes in physical capital can lead tot he unintended consequences that the physical capital is not as productive as intended. Analysis focuses on the choice of rules made by farmers in symmetric and asymmetric situations. Using this analysis, it is possible to illustrate why many donor-funded improvements in physical capital have had counterproductive impacts.

Keywords: institutional choice, asymmetrical interests, collective action, irrigation CPRs, development

Biography

Elinor Ostrom is codirector of the Workshop in Political Theory and Policy Analysis and the Arthur F. Bentley Professor of Political Science at Indiana University, Bloomington. She is the author of Governing the Commons and Crafting Institutions for Self-Governing Irrigation Systems, coauthor with Robert Bish and Vincent Ostrom of Local Government in the United States, and coeditor with Richard Kimber and Jan-Erik Lane of the Journal of Theoretical Politics.

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Physical and Social Capital

Collective action occurs when a group of potential beneficiaries jointly provide and maintain physical capital, such as roads, schools, community centers, bridges, dams, or irrigation systems. Physical capital is the stock of material resources or tools that can potentially be used to produce flows of future benefits (Lachmann, 1978). The purpose of physical capital is to increase the flow of future benefits achieved by a group of beneficiaries beyond those achievable without using the facility. If some individuals agree to build and maintain these facilities, others may benefit without contributing or by contributing less than agreed. This is the problem of free riding or shirking. Once an allocation rule is agreed upon, some individuals may take more benefits than they are allocated. This is the problem of stealing.[2]

Collective action is difficult if not impossible to achieve if the costs of shirking and stealing are not reduced through investments in institutions and other forms of social capital. Social capital is 'constituted' by individuals spending time and energy working with other individuals to find better ways of making possible the 'achievement of certain ends that in its absence would not be possible' (Coleman, 1966: S98). Physical capital is the arrangement of material resources to produce improved flows of future income. Social capital is the arrangement of human resources to improve flows of future income.[3]

Crafting institutions--sets of rules that will be used to allocate the benefits derived from a physical facility and to assign responsibility for paying the costs of the facility--are one form of social capital (E. Ostrom, 1990, 1992).[4] Unless preliminary agreement is reached on such rules, no one will agree to construct jointly-used physical capital. It is these rules that provide assurance that individual expected benefits exceed individual expected costs. Physical capital is the visible form of capital. Everyone can see physical capital in the facilities constructed. Social capital is invisible to the casual eye. Special effort must be made to assess how individuals allocate mutual responsibilities and benefits from the physical capital they have built.

Building strong patterns of relations based on reciprocity and mutual trust are another form of social capital. Devising effective operational policies, establishing means of monitoring and sanctioning nonconformance to established rules, and developing conflict resolution mechanisms are other forms. If beneficiaries are to overcome short-term incentives to shirk and steal that might prevent them from building and maintaining physical capital, investments in the creation and maintenance of social capital are essential.

The construction of physical capital involves establishing physical restraints that (1) create the possibilities for some events to occur that would not otherwise occur (e.g., channeling water from a distant source to a farmer's fields) and (2) constrain physical events to a more restricted domain (e.g., water is held within a channel rather than allowed to spread out). Thus physical capital opens up some opportunities while restricting others. Social capital also opens up some opportunities while restricting others. A decision to establish majority rule as the decision rule for making particular collective choices about a joint facility, for example, opens up opportunities that did not previously exist. Majority-rule decision making does not exist in nature. The opportunity to use majority-rule voting is created by rules. A rule that forbids a farmer from growing a water-intensive crop during the dry season or a participant in discussion to speak until recognized by a chair, limits alternative actions to a smaller set than available prior to the creation of the rule.

The importance of physical capital to economic growth and development is generally accepted. The importance of social capital, particularly institutions, has not as generally been recognized. Focusing primarily on the technology of constructing physical capital and ignoring social capital formation has been, however, a disastrous strategy in both domestic and international affairs. Substantial sums have been spent on the construction of unsustainable infrastructure due to the lack of appropriate institutions (E. Ostrom, Schroeder, and Wynne, 1993; Harral and Faiz, 1988; Heller, 1979; Repetto, 1986; World Bank, 1988; Israel, 1987).

Creating Social Capital

Creating the social capital that makes physical capital operational over the long run is something that individuals who successfully use physical capital repeatedly do, but it is not as well understood as the technology of constructing physical capital. For private sector activities, an important aspect of entrepreneurship is bringing relevant factors of production together and relating them effectively from one to another. Aspects of these skills are taught in schools of management and learned in the workplace through experience. Creating social capital related to private enterprise can be explained by the profit motive of those who gain the residuals from its creation and use.[5]

When a group of potential beneficiaries contemplates providing physical capital to be jointly used in a local, public economy, they also face a lengthy process of trial and error social learning and of bargaining among the participants over the rules that they will use. Given the multitude of nested collective-action problems involved in the creation of institutions, how individuals overcome these problems is not easy to explain. Further, the diverse sources of asymmetries among participants makes it even more difficult to explain how individuals solve thorny distribution problems (Johnson and Libecap, 1982).

Processes that create social capital do occur, however, in thousands of disparate local settings. Similar processes occur at the international level (Young, 1982; Keohane, 1989; Dasgupta and Mäler, 1992; McGinnis and Ostrom, 1992; Haas, Keohane, and Levy, 1993). An extensive literature including many case studies describes many of the institutions that have been constituted by those affected in all corners of the world.[6] The lack of theories of institutional change and development based on firm micro-foundations has limited the capacity of scholars to develop cumulative understanding of how individuals develop their own social capital in the form of rules used by self-governing communities. Recent work on institutional analysis and institutional change begins to provide a solid theoretical foundation for understanding the conditions needed for individuals to craft or evolve their own institutions and enforce these institutions themselves (see Bates, 1988; Calvert, 1993; Knight, 1992; Libecap, 1989; North, 1990; E. Ostrom, 1990; E. Ostrom, Walker, and Gardner, 1992; V. Ostrom et al., 1993).

Substantial progress has been made in the explanation of how institutions evolve to solve repeated coordination problems where most of the participants are symmetric in regard to relevant attributes (Lewis, 1969; Sugden, 1986).[7] These theoretical accounts are useful and important in explaining the evolution of institutions in the types of settings specified where the primary problem is selecting one out of multiple equilibria that have relatively similar distributional effects. Once an equilibrium is selected, it is self-enforcing in the sense that all participants are motivated to select strategies consistent with that equilibrium (Telser, 1980).

While substantial progress has been made, puzzles remain. How individuals who differ substantially from one another agree to sets of rules with major distributional consequences is not yet fully understood. In an important recent study, Jack Knight (1992) presents a more general theory of institutional change based on the relative bargaining power of participants to account for the evolution or design of institutions. Knight is able to account for a wide diversity of locally evolved social institutions where outcomes are distributed asymmetrically. The 'most important resources' in Knight's account of the bargaining over rules, 'are those available to the actors in the eventuality that bargaining is either lengthy and costly or ultimately unsuccessful' (Knight, 1992: 132). Knight places most of his emphasis in explaining the outcomes of rule negotiation processes on the differential status quo position of participants. The 'breakdown point' in a bargaining process is obviously one of the important dimensions affecting the choice of rules to emerge from such a process. It is not, however, the only source of bargaining power that participants can bring to the negotiating table when constituting an organization to overcome collective-action problems (see Elster, 1989).

In this paper, I will use a similar theoretical approach to that of Knight for analyzing the process of constituting a self-governing farmers' association to construct and maintain an irrigation system. This example provides a setting in which to examine (1) the process of negotiating rules among both homogeneous and heterogeneous participants, (2) how physical variables affect the relative bargaining power of participants, and (3) how external interventions may create disruptive asymmetries as an unintended effect of external assistance.

While the application is focused on one kind of collective action, many aspects of more general processes involved in creating social capital in the form of rules--particularly those related to other kinds of jointly used physical capital--are captured in the analysis. None of the simple models capture the full richness of the considerations facing participants in field settings. Only two rules are considered at one time, for example, when the number of rules that could be introduced into discussions is much larger. The models starkly illustrate, however, the major underlying problems that participants face. In this way, one can better understand the deeper dimensions of the problems being faced without all of the complications that exist in any particular setting.

Underlying Assumptions

For farmers to seriously consider constituting themselves into even a loose form of association to construct an irrigation system, they would need to share the following:

- Secure enough land tenure to presume they will reap the longer term benefits of their collective action.
- The capacity to repeatedly relate and communicate with one another on a face-to-face basis.

- Share a common understanding that they would each be able to increase their agricultural yields enough through the provision of an irrigation system potentially to compensate each of them--depending on the sharing formula agreed upon--for the costs of their immediate and long-term investments.
- Share a common understanding that they would have to enforce their own rules on a day-to-day basis but could count on external authorities not to interfere in their rule-making, rule-following, and rule-enforcement activities.[8]
- Share a common understanding of a repertoire of rules that, if enforced, can effectively counteract perverse, short-term incentives.
- Share a common understanding that if they agree to a set of rules and follow accepted procedures to signify their agreement that each participant would be pre-committed to follow these rules or be sanctioned by the others for nonconformance.
- Trust that most of the farmers, who agreed to a set of rules and denoted their agreement in an accepted way, would actually follow these rules most of the time so that the effort to monitor and enforce these rules would not be itself extremely costly.

Thus extensive common knowledge (Aumann, 1976) about the structure of incentives they face, the types of individuals with whom they would be interacting over the long run, and alternative ways of structuring their relationships are prerequisites for constituting associations to undertake major, long-term collective action.[9] Those involved also need to switch levels of action from that of a day-to-day operational situation to a rule-making situation. In an operational situation, farmers are making decisions about alternative actions to be taken within a set of rules. In a rule-making situation, farmers are making decisions about rules that affect the alternative actions they can take in future operational situations.[10] The farmers may be meeting informally at a tea house, someone's home, or at the stream that they plan to divert. The procedures used may be quite informal. The essential aspect, however, is that they have switched from taking actions to making decisions about rules that constrain and open up opportunities for future actions. With the above foundation, if they can agree to a set of rules that distribute net benefits to each participant greater than the alternatives available to them, they are likely to craft a constitutional agreement and start on the long-term process of providing such a system.

If the set of beliefs outlined above are not altered by experience so as to destroy the assessment made by each about the beliefs that others share and the likely strategies they will adopt, such a set of farmers would not only be able to construct a system but to continue operating it for a long period of time. If the precommitment that they make by signaling their agreement is followed by behavior consistent with that precommitment, each farmer's beliefs become more certain that others will follow the agreement including sanctioning nonconformers (see Elster, 1979; Schelling, 1960). Given the dual precommitments and behavior consistent with these precommitments, it is then in each farmer's interest to conform to the agreed upon rules most of the time.[11] In other words, a constitutional agreement is successful not simply because it creates joint benefits. It is successful when those who contribute to its continuance expect net benefits for themselves and their families that are greater than the alternatives available to them.

Nothing is automatic or deterministic about such a process.[12] What is crucial is that the farmers believe that their individual long-term benefits will exceed their long-term costs, that they find a set of rules upon which they can agree, and that they adopt strategies that do not constantly challenge the delicate balance of mutual expectations that they have to maintain to keep the system going over the long term. Some farmers may be left much better off than others. The less advantaged, however, must feel that they receive a positive gain from participation or they will not participate.

If experience generates information that they were incorrect in their beliefs about benefits, about their monitoring effectiveness, or about the likelihood of others following rules most of the time, then the mutual understanding that is necessary for success begins to come unglued. Similarly, if those who are less favored come to feel that they are being taken advantage of by those better favored by the rules, their low but positive economic assessment may be offset by negative feelings engendered by unfair rules. If they are unable to gain better economic returns, change rules again, and/or change the frequency with which rules are broken, then a successful operating system at one time may slip into becoming a poorly operating system at another time. Thus, individual incentives depend on farmers' expectations, the viability of the rules they have established, their consequent beliefs concerning overall net benefits, and the distribution of benefits and costs.

Symmetric Situations

In our initial model, let us assume that ten farmers own equal-sized plots of land on an alluvial plain adjacent to a series of moderate hills. One of the farmers (who has a reputation for designing prudent and well-conceptualized community works) has proposed a plan whereby they could divert a mountain stream to their area. The source would easily provide water throughout the year for all ten farmers. The plan involves the construction of a short main canal and two branch canals that each serve five families. There is sufficient water in the stream that the farms located farthest from the main canal have complete assurance that they will receive as much water as they need to grow three crops a year instead of the single rain-fed crop that they have been able to harvest during the monsoon season.

The farmers can obtain a low-interest loan in order to purchase some of the needed materials and they have the skills needed to do the actual construction themselves. Figure 1 is a stylized version of the type of irrigation system under consideration. A division works at the source sends water into a relatively short and uncomplicated canal which is then divided into a X Branch and a Y Branch each serving five plots of equal size.

[Figure 1 about here]

In order to get started with this project, the farmers need to agree to gain an initial agreement about the rules that they will use to (1) allocate expected annual benefits from the project and (2) allocate expected annual costs. No one will contribute funds and/or hard work to construct an irrigation system unless they believe that their own, discounted flow of future expected net benefits is larger than their share of the costs of construction. For purposes of analysis, we will treat all farmers on each branch as if they formed a single team player facing all farmers on the other branch (also conceptualized as a single team player) in a two-player bargaining game.[13] If they do not reach an agreement about the set of rules they will use, the farmers continue their practice of growing rain-fed crops. The yield that they receive from rain-fed agriculture thus constitutes the 'breakdown' value for each player--what they can expect if no agreement on constructing a new system is achieved.

The general structure of the bargaining situation they face is presented in Figure 2. In this situation, there are two rules being considered: Rule I and Rule J. Both players--Branch X and Branch Y--have to agree to either Rule I or Rule J, or they will not construct the system. If they do not agree, they continue with their current rain-fed agriculture and obtain the status quo yield (SQ_x, SQ_y) from growing one crop a year. In the symmetric situation, the status quo yield is equal for both branches. If both players agree on one of the rules, they will receive each year some combination of the total annual expected benefits (B) and costs (C) associated with providing this system. Both benefits and costs are expressed in crop units.[14] Let us first assume that total annual expected benefits exceed total annual expected costs. Consequently, one half of the benefits exceed one-half the costs as well as the status quo yield of each branch:

$$.5B > .5C \tag{1a}$$

$$.5B - .5C > SQ_x = SQ_y \tag{1b}$$

[Figure 2 about here]

Each branch would most prefer a situation where they obtained all of the benefits and none of the costs. But the other branch would never agree to such a distribution. Without agreement, no one will contribute to the construction of the systems. Rules used to allocate benefits and costs affect the proportion of benefits and costs that each obtain. The proportion of the expected annual benefits received by Branch X will be e^I if Rule I is agreed upon and e^J if Rule J is agreed upon. Similarly, the proportion of expected annual benefits received by Branch Y players is given by g^I or g^J depending on the rule selected. If they agree on Rule I and it assigns 60% of the benefits to Branch X and 40% of the benefits to Branch Y, then $e^I = .60$ and $g^I = .40$.

$$1 \geq e^I, e^J, g^I, g^J \geq 0 \tag{2}$$

$$e^I + g^I = 1 \text{ and } e^J + g^J = 1. \tag{3}$$

Similarly, the coefficients, f^I, h^I, and f^J and h^J are the proportion of costs assigned to the two branches under different rules.

$$1 \geq f^I, f^J, h^I, h^J \geq 0 \tag{4}$$

$$f^I + h^I = 1 \text{ and } f^J + h^J = 1. \tag{5}$$

Let us assume that all farmers are risk neutral (neither orientated toward taking risks nor avoiding them) and have equal and/or low discount rates that are omitted from the analysis since their inclusion would not change the results so long as they are the same for both players.

Rules to Allocate Benefits

Let us first focus on the authority rules that the farmers could use for allocating water. For our initial consideration of the authority rule related to benefit distribution, we will temporarily assume that that cost of construction and maintenance is equally divided. Let us suppose they consider two rules.

Rule 1: All water from the main canal is allocated to Branch Y for one week and Branch X for the next week.

Rule 2: Construct a dividing weir that permanently divides the water in half so that half of the flow of the main canal automatically flows into each branch at all times that water is present in the main branch.

The structure of this game related to these two rules (or any similar rule of equal division) is presented in Figure 3. Since we are assuming for now that their share of the benefits minus the costs of the irrigation system are greater than the status quo yield for both branches (Eq. 1), they face a benign coordination situation. There are two pure strategy equilibria in this game: both choose Rule 1 or both choose Rule 2.[15] Since communication is possible, it can be used to solve this coordination problem. Some of the discussion may relate to variables not taken into account in the above simplified payoffs, if there are any. If one of the farmers is well known for his or her capability and honesty in constructing dividing weirs so that everyone can trust them to divide the water exactly in half,[16] the two branches might be more likely to agree upon Rule 2 because it involves the least continued effort in shifting the water every week from one canal to the other. If none of the farmers knows how to construct an exact dividing weir, they would prefer Rule 1 as it is unambiguous and easy to monitor. Which rule is finally chosen, if they come to an agreement, depends on a variety of situation-dependent variables including the costs of implementing different rules or whether similar rules have been tried on neighboring systems and worked well in practice. [Figure 3 about here]

Rules to Allocate Costs

Now, let us focus on a second type of rule--one related to how the farmers allocate responsibilities for providing labor during construction and for the annual maintenance efforts. The rules proposed may or may not be quite so symmetric in their effect. If there were one adult son in each of the families on Branch X and no adult sons on Branch Y, someone on Y might well propose the following rule:

Rule 3: Each family is required to send all adult males in the household for each labor day devoted to the irrigation system.

Someone in Branch X might well propose the following rule:

Rule 4: Each family is required to send one adult male for every labor day devoted to the irrigation system.

Assuming that either Rule 1 or Rule 2 had earlier been agreed upon, these proposals would result in a bargaining game like that of Figure 4.

[Figure 4 about here]

Assuming that the increased yield exceeds the costs that would be imposed on Branch X under Rule 3 ($.5B - .67C > SQx$) both branches would be better-off agreeing to either rule as contrasted to having no system. But Rule 3 assigns a higher proportion of net benefits to Branch Y, while Rule 4 treats both branches equally. Consequently, the debate between the two branches over these two rules might be considerable. Branch Y could argue that the irrigation system was providing benefits for all households and that all adult males should pitch in. Branch X could argue that they should not have to contribute double the amount of labor than Branch Y simply because they had sons. After all, they could argue that they have to work twice as hard in their fields just to feed everyone at the table. They need their sons working in the fields and not on the irrigation system. There are again two pure strategy equilibria to this game: both choose Rule 3 or both choose Rule 4. Since the results are asymmetric, however, which rule is chosen depends on the relative bargaining strength of the participants. For Branch Y to get its way, it would have to precommit itself in a credible manner that this rule was an essential precondition to obtaining its agreement to the plan for the irrigation system.

On the other hand, Branch Y could recognize the fact that this would have to be a continuing relationship and that if the farmers on Branch X resented a rule to which they had to agree due to their weak bargaining situation, they might well have trouble later getting Branch X to hold to the agreement on a continuing basis. Even though Branch Y really thinks it is inappropriate for one-third of the adult males, who are benefitted by the system, to sit at home while the other two-thirds do all the work, they might recognize that one male per household is considered a fair rule in this setting and not push this proposal to the point of breakdown of negotiations. Further, it is unlikely that the set of rules brought forward for consideration will include only Rule 3 and Rule 4 when one branch is disadvantaged by the rules under consideration.

Branch X could, for example, propose Rule 5 that would make Branch Y change its absolute preference for Rule 3 over Rule 4.

Rule 5: All water from the main canal must be allocated to a Branch in proportion to the amount of labor that the Branch provides for construction and annual maintenance.[17]

Now whether Branch Y prefers Rule 3 or Rule 4 depends on whether it is combined with Rule 5 or Rule 1 (ignoring Rule 2, which has as an identical outcome function). If the expected benefits of building the system were 100 and the expected costs were 60, the results of different configurations of rules would be:

	Branch X	Branch Y
Rules 1 & 3	.50B - .67C = 10	.50B - .33C = 30
Rules 1 & 4	.50B - .50C = 20	.50B - .50C = 20

Rules 5 & 3	.67B - .67B = 27	.33B - .33C = 13
Rules 5 & 4	.50B - .50C = 20	.50B - .50C = 20

Once Rule 5 is introduced into the rule-making situation, Branch Y no longer finds Rule 3 essential to its interests. If combined with Rule 5, Rule 3 leaves it with the worst, rather than the best, payoff.

Thus, the process of negotiating about rules that participants themselves must eventually use in operational situations is not a determinant process. While it is useful to model the process as a succession of choices among two rules, the impact of each rule depends on the other rules that have already been agreed upon or are to be discussed in the future. In most constitutional processes, initial agreements to specific rules are tentative. Eventually, the participants must agree to the entire configuration of rules embodied in some form of agreement. The overall effect of one rule may change dramatically depending on which other rules are in the configuration.

Asymmetric Situations

Many variables may be the source of asymmetries among the players in a choice of rules game. In the above analysis, we have already addressed the possibility that the amount of labor available per household might vary among the players. Now let us briefly examine differences in outcomes that result if the assumption of equality in the status quo situation of both branches is changed. This is the major focus of Knight's theory of institutional change. If the farmers on Branch Y are able to obtain a higher yield on their farms depending only on rainfall than the farmers on Branch X (SQy > SQx), they could use this asymmetry to their advantage in bargaining over rules. In Figure 5, we illustrate how an asymmetry in the status quo yields of the two players affects their bargaining position. If the status quo yields of both players were equal to A, and I and J represent the net benefits that would be distributed under Rule I and Rule J, any rule that distributed net benefits to the two players along the line connecting I and J could be agreed upon by both players. If, however, Branch Y had a higher status quo yield, then the initial status quo position of the two players could be represented by B on the diagram. Branch Y would no longer agree to Rule I nor to any rule that did not distribute net benefits at least equal to I′. Branch Y's bargaining position is so substantially stronger that it might even be successful in demanding J as the final rule. Exactly which agreement will be reached depends on the norms of fairness shared by participants and their bargaining skills--factors that are not fully taken into account in this simple analysis. The key point is, however, that rules that could be agreed upon if the status quo yields of both players were equal, are infeasible if the status quo yields were different.[18]

[Figure 5 about here]

But, now let us introduce a substantial asymmetry related to physical location on a canal.[19] Instead of a canal that divides into two small branches, let us assume that the canal enters from one side. Now, the first five plots receive water before the last five plots. Water is sufficient to provide an ample supply for the headenders, but not for the tailenders. Irrigators located at the head end of a system have differential capabilities to capture water and may not fully recognize the costs others bear as a result of their actions. In addition, farmers located at the head end of a system receive proportionately less of the benefits produced by keeping canals (located next to or below them) in good working order than those located at the tail. These asymmetries are the source of considerable conflict on many irrigation systems--substantial enough at times to reduce the capabilities of farmers to work together.

Yoder (1991) reports on a conversation held in one system where the farmers had difficulties keeping their system in good repair. When the farmers at the head end of a long canal were asked about how they undertook system maintenance, they replied: 'Last year the farmers down there (pointing toward fields lower in the system) used water from the canal but when the canal was blocked by a landslide they refused to help clean the canal even when we called them' (Yoder, 1991: 53). Yoder indicates that the head-end farmers complained bitterly that the tail-end farmers were neglectful and refused to help repair the canal. When one farmer lower in the system was asked similar questions about maintenance, he answered: 'Why should I repair the canal? The farmers with fields up there use all the water anyway' (Yoder, 1991: 53). Why, indeed! This conversation illustrates, from the farmer's perspective, the close interrelationship among the willingness to invest in maintenance, farmers' expectations about obtaining water, their expectations about the contributions others will make, and the tensions that can exist among head-end and tail-end farmers. These asymmetries create differences in the relative bargaining power among farmers when debating about the relative merits of different rules.

Farmers at the head end of a system would prefer a set of rules that allowed them to take water first and to take as much water as they needed. Farmers at the tail end of a system would oppose such an authority rule for allocating water because this would leave them with much less water. Farmers at the tail end of a system would prefer a set of rules that would enable them to take water first and as much water as they needed. Both rules are used in practice. Frequently, modified versions of these two rules are used in combination. One version of the combined rule is that in one year a rotation system starts at the head, and in the next year the rotation system starts at the tail.

Farmers at the head end of a system would also prefer rules that required each farmer to maintain only that part of the canal that passed by their own land. Farmers at the tail end of a system would oppose such an authority rule for allocating maintenance responsibilities because head-end farmers are not likely to take into account the cumulative nature of the process of water loss along a stretch of a watercourse. Farmers at the tail end of a system would most prefer rules that assign responsibilities for maintenance in the same proportion as the amount of water that farmers obtain. That way, if the farmers at the head end receive more water, they would have to contribute more resources to maintenance.

To the extent that head-end farmers depend upon the resources that tail-end farmers mobilize to keep a main canal in good working order, the initial bargaining advantage of the head-end farmers is reduced. In other words, if the amount of resources needed to maintain the system is large, farmers at the tail end have more bargaining power in relationship to the farmers at the head end than if the amount of resources needed for maintenance is small.

Several physical factors affect the amount of resources needed to keep a system operating. Let us first assume that the water source serving the system is a perennial spring and that very little work is needed at the headworks to keep such a system operating. We can then posit three kinds of systems depending on the length of the main canal as illustrated in Figure 6a, b, and c. In Figure 6a, there is no distance between the water source and the headenders. In Figure 6b, there is a short distance between the water source and the headenders. In Figure 6c, there is a long distance between the water source and the headenders. The costs of maintaining these three systems will be lowest for a 6a type of system (C′), higher for a 6b type of system (C″) and highest for a 6c type of system (C‴).

The bargaining advantage of headenders in systems like those illustrated in Figure 6a is much stronger than in systems like those illustrated in Figure 6b or 6c. Let us illustrate this with a numerical example of the choice of rules game. Let us continue to assume that the expected benefit of the water made available regardless of the length of the canal is 100 units (denoted in labor productivity units) and that the labor costs of maintaining systems like 6a are 25 units, systems like 6b are 50 units, and like 6c are 75 units. Thus in all three systems, the expected annual benefits of water obtained are greater than the expected annual labor costs. Let us further assume that two rules were being considered in such a situation:

Rule 6: The head-end farmers are authorized to take as much water as they can put to beneficial use prior to the water being made available to the tail end, and farmers contribute labor to maintain the system voluntarily (headenders have prior-rights rules).

Rule 7: Half of the water is allocated to the head and half of the water to the tail, and the labor needed to maintain the system is based on the proportion of water assigned each set of farmers (equal split rule).

If Rule 6 were agreed upon, let us assume the headenders would take 65 units of water per year. All labor would be contributed by the headenders. If Rule 7 were agreed upon, the headenders would only obtain 50 units of water per year but would only have to put in one-half of the labor costs per year. Both headenders and tailenders would receive zero units of value in the situation of a breakdown. The payoffs for the three games are shown in Figure 7.

[Figures 6 and 7 about here]

In systems where the cost of labor input is the lowest ($C' = 25$), there are two equilibria: both choose Rule 6 or both choose Rule 7. The headenders would prefer Rule 6 and the tailenders would prefer Rule 7. In this game, the headenders could credibly assert that they will agree to Rule 6 and no other rule and refuse to engage in any further bargaining with the tailenders. Unless the tailenders were able to propose an alternative rule based on a shared concept of fairness, the tailenders would have to agree or they would get no water at all. Tailenders would not contribute to the maintenance effort of the headworks, and the headenders would expect an annual return of 65 - 25 = 40. The tailenders receive only 35 units, rather than the 37.5 (100/2 - 25/2 = 37.5) they could receive under an equal split. But since the tailenders do not contribute at all to maintenance, they are not as disadvantaged as appears to be the case if one were to examine only the impact of the rule allocating water. The tailenders might even be accused of free riding in such a situation. They could, however, point to their willingness to work if and only if they obtained an equal split of the water.

The same two pure strategy equilibria are present in a situation where labor costs were 50 units. But, now the headenders prefer Rule 7 while the tailenders prefer Rule 6. And, the tailenders have the strongest bargaining position. They can credibly assert that the extra water is not worth the labor contribution. The headenders are somewhat forced into the situation of agreeing to Rule 6. Under Rule 6, the tailenders gain considerable advantage from their 'free riding' on the work of the headenders (headenders 65 - 50 = 15 and tailenders 35 - 0 = 35).[20]

In systems where the need for labor input is the highest ($C''' = 75$), headenders cannot afford to agree to a rule that allocates them prior rights. They would receive a net loss (65 - 75 = -10) if Rule 6 were used. Consequently, Rule 7 is the only equilibrium for a choice of rules game involving only Rule 6 and Rule 7 in a high-cost environment. To get the labor input from the tailenders, the headenders would be willing to guarantee that the tail end received a full half of the water. Thus the payoff to both segments under the high-cost condition would be 12.5 units.

In order to illustrate how the agreements about rules--and their impacts--are affected by differences in physical environments, the above analysis focusing on only two rules is blatantly sparse. In a more general analysis examining the effect of several parameters, including that of the status quo, one would find a variety of rules likely to be agreed upon in different physical environments. One would expect that the rules that are negotiated in systems like that of 6a will authorize headenders to take a larger proportion of the water than those negotiated in systems like that of 6c.[21] Holding the size of the systems constant, one should observe a greater disparity in performance between the head and tail in systems like 6a than in systems like 6c. In systems where the costs of maintenance are moderate, like those of 6b, the outcome is less clear. If tailenders are fully symmetric with headenders in regard to all other variables that would affect bargaining strength (such as size of farm plots and caste), then one would expect that proportionately more water is allocated to headenders and that labor contributions are voluntary (see E. Ostrom and Gardner, 1993).

The analysis above was based on an assumption that the overall cost of maintaining the system was relatively low. If instead of this situation the farmers had to construct a new diversion works each year that required substantial resources, head-end farmers in all three types of systems would have less bargaining power. Consequently, the 'equalizer' in many farmer-organized systems is a substantial need for the contributions of resources each year by the tailenders to keep the system well maintained. The need may stem from several physical factors including the yearly reconstruction of the headworks, or the clearing and cleaning out of a long canal, or both. In those farmer-organized systems where substantial resources are needed on a regular basis to cope with maintenance, we should observe rules that assign water in about the same proportion as resources are mobilized, more water allocated to the tail, and higher productivity.

Why External Assistance Does Not Always Improve Performance

The above analysis can be used to help us understand why many effective, farmer-organized systems collapse soon after their systems have been modernized using funds provided by international donors. Project evaluations usually consider any reductions in the labor needed to maintain a system as a project benefit. Thus, investments in permanent headworks and lining canals are economically justified because of the presumed increase in agricultural productivity and the reduction in annual maintenance costs. The possibility that greatly reducing the need for resources to maintain a system would substantially alter the bargaining power of headenders versus tailenders is not usually considered in project evaluations. As indicated in the introduction, social capital is rarely taken into account in policy analyses.

Let us assume that an external donor plans to invest in a system with a physical structure and benefit-cost ratio like that of 6c. Prior to investment, total benefits minus maintenance costs are equal to 25 units. The donor assumes that it is possible to raise the benefit level to 200 by teaching the farmers new agricultural techniques and by lowering the maintenance cost to 25 units through a one-time investment whose annualized value to the donor is also 25 units. Thus, the benefit-cost analysis leads the donor to make the investment since an annual benefit of 150 (200 - 25 - 25) is substantially above the 25 net annual benefits achieved prior to the planned improvement. The payoff matrix implicit in the benefit-cost analysis is illustrated in Figure 8a where the only outcome projected is an equal distribution of a higher agricultural yield. The donor assumes the farmers will somehow work out a scheme to share benefits as shown.

But what frequently happens in practice is illustrated in Figure 8b. Instead of increasing benefits to 200, the system stays at 100 and the head-end farmers now grab 90 units and make no investment in maintenance. Neither the headenders nor the tailenders are required to pay the annualized cost of the donor's investment. The tail-end farmers also do not invest in maintenance and receive only 10 units of water. Rule 6 has become the default 'might is right' rule that is not agreed upon but rather imposed on the tailenders by headenders who simply grab the water. They can ignore the contribution of the tailenders to maintenance because for a few years the concrete structures will operate well without any maintenance. Of course, at some time in the future, the productivity of the system will fall below what it was prior to outside help. The tailenders may initiate violence against the headenders due to their perception that the water rights they had achieved with their hard labor had been taken from them (see Ambler, 1990). The end result can easily be that what had been a community knitted together by their mutual dependence dissipates into a setting of considerable conflict and low overall productivity.

[Figure 8 about here]

If the farmers were expected to pay back the costs of the investment made in physical capital (or to pay taxes to keep the system well maintained), tail-end farmers would again find themselves in a better bargaining relationship with headenders. A very disruptive aspect of external assistance is that it is 'free' to the farmers involved in most developing countries. Without any need for resources from tailenders, headenders can ignore the interests of the less advantaged and take a larger share of the benefits.

What the above analysis has shown is that there are many sources of asymmetry among participants facing collective-action problems.[22] These asymmetries affect the bargaining strength of participants and resulting outcomes. Further, rules frequently have distributional consequences. Ignoring these, the distributional effects lead to an incomplete analysis. However, how asymmetries affect the distribution of outcomes depends on the configuration of (1) attributes of participants, (2) attributes of physical systems, and (3) rules designed by participants. In other words, knowing about one asymmetry without knowing the full configuration of attributes about participant, physical systems, and rules can lead to false conclusions about overall outcomes.

Those who are rich in terms of human capital (having two sons rather than one) may find themselves disadvantaged if a rule requiring all males to contribute labor is agreed upon. The effective 'counter' to this outcome is the rule that water will be allocated using the same formula as labor input. Those located at the head end of a physical system may be strongly advantaged unless they need the labor input of those lower in the system. In collective-action settings where individuals can generate substantial improvements in the flow of future benefits by agreeing upon a full configuration of rules, it is frequently possible to design the overall configuration so that participants can agree on a final set that is perceived to be fair.

Empirical Evidence[23]

Given the above analysis, one should expect to observe a wide diversity of outcomes in field settings regarding the distribution of net benefits between the head and tail portions of irrigation systems. Some systems will not be maintained over time and will collapse. Others will operate at lower efficiency than feasible and some farmers will gain a disproportionate share of water. Still others will operate at a higher efficiency and net benefits will be more equitably shared. Given the number of variables that affect system performance and its distribution, it is difficult to conduct empirical tests of these kinds of theoretical findings.[24] Until the development of the Nepal Institutions and Irrigation Systems (NIIS) database, no large-scale data set with the appropriate variables existed that could be used for this purpose. The NIIS database contains information on 127 irrigation systems (see E. Ostrom, Benjamin, and Shivakoti, 1992).

Nepal has an area of about 141,000 square kilometers, slightly larger than England. Its 18 million inhabitants are engaged largely in agriculture. Of the approximately 650,000 hectares of irrigated land, irrigation systems operated by farmers—called Farmer Managed Irrigation Systems (FMIS)—irrigate about 400,000 hectares, 62% (Small, Adriano, and Martin, 1986). The remaining irrigated land is served by a variety of Agency Managed Irrigation Systems (AMIS), many of which have been constructed since 1950 with extensive donor assistance.

Irrigation occurs extensively in the hills (frequently quite steep), in the river-valleys (the terrain is more undulating), and in the flat and more fertile Terai, located in the southern part of the country. In the hills, irrigation systems have constructed several plateaus where it is easy for farmers on the first plateau to get most of the water to their fields before any water goes on to the second or third plateau. One expects that the problem of physical asymmetries is easier to deal with in the Terai than in the hills.

In Nepal, FMIS achieve a high average level of agricultural productivity. Of the 127 systems in the NIIS, we have productivity data for 108. The 86 FMIS average 6 metric tons a year per hectare (6 MT/ha); the 22 AMIS, 5 MT/ha, a statistically significant difference ($p = .05$). FMIS tend also to achieve higher crop intensities.[25] A crop intensity of 100% means that all land in an irrigation system is put to full use for one season, or partial use over multiple seasons amounting to the same output. Similarly, a crop intensity of 200% is full use for two seasons; 300% is full usage of all land for three seasons. Averaged over the three major terrains, FMIS achieve a higher level of crop intensity (247%) than do AMIS (208%). Again, the difference is statistically significant (see E. Ostrom, Benjamin, and Shivakoti, 1992).

The agricultural yields and crop intensities that farmers obtain depend on whether they can be assured of water during the winter and spring seasons when water becomes progressively scarcer. A higher percentage of FMIS in Nepal are able to get adequate water to both the head and the tail of their systems across all three seasons. During the spring, when water is normally very scarce, about 1 out of 4 FMIS are able to get adequate water to the tail of their systems, while only 1 out of 12 AMIS get adequate water to the tail of their systems. Even in the summer monsoon season, only about half of the AMIS system get adequate water to the tails while almost 90% of the FMIS get water to the tail of their system.

To begin to address why FMIS systems are more likely than AMIS systems to distribute water more equitably between head and tail, we analyze how physical variables and type of governance structure combine to affect the difference in water availability achieved at the head and the tail of irrigation systems. The difference in water availability is a crude indicator of how well an appropriation process gets water to the tail end of a system. We have estimated the following equation:

Water Availability Difference = f (Headworks, Lining, Terrain, Length, Labor Input, Type of Governance), where

Water Availability Difference is the difference in the score (adequate = 2, limited = 1, scarce or nonexistent = 0) achieved at the head of a system minus the score achieved at the tail of a system averaged across three seasons,[26]

Headworks is coded 1 if the headworks are permanent and 0 if otherwise,

Lining is coded 1 if the canals are partly or fully lined and 0 otherwise,

Terrain is coded 1 if the system is located in the Terai and 0 otherwise, Length is the length in meters of the canals of a system,

Labor Input is the number of labor days devoted to regular maintenance per year divided by the number of households served,

Type of Governance is coded 1 if a FMIS and 0 otherwise.

The result of a multiple regression analysis for the 76 irrigation systems for which we have complete data is:

Water Availability Difference = $.64^{**} + .34^{**}$ Headworks $-.14$ Lining

$-.10^{*}$ Terrain + 0 Length + 0 Labor Input $-.32^{**}$ Type of Governance

$F = 5.92$, Adjusted $R^2 = .28$, $^{**}\, p < .05$, $^{*}\, p < .10$.

The difference in water availability achieved at the head and the tail of these Nepali irrigation systems is significantly and negatively related to being in the Terai. The presence of a permanent headworks--frequently considered as one of the hallmarks of a modern, well-operating, irrigation system with channel lining--is positively related to an inequality between the water availability achieved at the head and the tail. The difference in water availability is significantly reduced at the tail of an FMIS as compared to that of an AMIS.

Constructing a permanent headworks is related to increased inequality between water availability at the head and at the tail of irrigation systems. As discussed above, such headworks have frequently been funded by external sources, with farmers not required to repay the cost of this investment. This type of external 'help' substantially reduces the short-term need for mobilizing labor (or other resources) to maintain the system each year. As discussed above, the calculations in the design plans do not always match the results achieved. Without a realistic requirement to pay back capital investments, farmers and host government officials are motivated to invest in rent-seeking activities and may overestimate previous annual costs in order to obtain external aid (Repetto, 1986). Further, such help can change the pattern of relationships among farmers within a system, reducing the recognition of mutual dependencies and patterns of reciprocity between headenders and tailenders that have long sustained the system. By denying the tailenders an opportunity to invest in the improvement of infrastructure, external assistance may also deny those who are most disadvantaged from being able to assert and defend rights to the flow of benefits (see Ambler, 1990).

Thinking about Rule-Making Situations

In the models presented above, the choice of rules was presented as if it were a one layered bargaining game. Expected outcomes were presented as if they were automatically received depending on which rule was agreed upon or the continuance of the status quo. If farmers have accurate information about potential benefits and costs and about the equilibrium strategies that they will all use in the day-to-day operation of the system, this is a good first approximation of the problem they face.[27] It simply aggregates the total expected annual benefits and costs from the ensuing series of games and is one way to look at the problem. For participants to actually obtain net benefits in any year, however, they face a repeated series of games played within whatever rules are chosen. And if there are multiple equilibria in the ensuing games, the initial representation needs considerable additional elaboration.

Now that we have introduced the problem of agreeing upon rules, it is better for us to think of the choice of rules as a choice among games. Games are constituted by rules that will be played repeatedly until rules (or the physical factors that also affect game structure) are changed to create a revised game or those involved stop interacting with one another. Further, in most systems, rules create games in which the outcomes are rules for still further games. In other words, many layers of rules and games are nested in one another. For purposes of analysis, it is useful to divide rule-making games into two broad types: constitutional rule-making games and collective choice rule-making games.

The outcome of decisions made in a constitutional choice rule-making game are the rules that are then used for making initial agreements about constituting an enterprise and deciding on the key initial rules to be used in that enterprise. In the models presented above, the rule of unanimity was used in the constitutional rule-making game. Unless everyone agreed, the status quo continued. For the initial consideration of whether to constitute a system or not, unanimity is frequently used in practice by many participants engaged in microconstitutional choice processes to create or not create a long-term association. Since there are usually more than two players engaged in these processes, a subset of the initial group involved in discussions may all agree on a set of rules even though other players do not. But the success of such agreements depends on the benefits of the project being great enough that even if the subset of players who reach an agreement pays all the costs, the net benefits are still positive. In most such situations, the subset also agrees to exclude anyone that did not initially agree (or does not agree at a later point and potentially pay some share of the initial costs). A farmer who did not sign or affix a thumbprint on an agreement is under no obligation to provide inputs and may be totally excluded from receiving water.[28] One of the important decisions made in these microconstitutional processes is, thus, how membership is defined and the process through which someone who had not agreed to the initial document might become a member.

A major part of the constitutional process is determining the set of rules to be used for future rule making. Thus an outcome of a constitutional game is a future series of collective choice rule-making games used to add to, refine, and change the day-to-day rules used in practice. Some decisions may be reserved for consideration by all players using various rules from simple majority. Some type of council and other official position will usually be created (through electoral or other means) that continues to revise rules related to the operation of the system as well as coping with the day-to-day contingencies of operating the system. Operational-choice rules directly affect the decisions that individuals make in the physical world and are primarily made in collective-choice games but are initially sketched out in the constitutional game.

In addition to the nested series of rule-making games, there is also a nested series of operational games. In an irrigation setting, one could simplify this series as represented in Figure 9. In this figure, I have returned to the assumption of two players who are now faced with a secret election in which they must both cast a ballot to agree or not agree to the final configuration of rules discussed in their negotiation process. Only if both of them agree to this microconstitution will they avoid the continuance of the status quo. But the annual expected net outcomes that were used in the previous series of models as the outcomes of the rule-making game are achieved only after three more games are played--the construction game, the maintenance game, and the allocation of water game.

[Figure 9 about here]

In two previous papers, Weissing and Ostrom (1991, 1993) have explored the structure and equilibria of 2-person and N-person allocation of water games. In these games, multiple equilibria exist and many are inefficient. The shapes of the equilibrium regimes depend delicately on the configuration of rules used to reward monitoring and punish stealing as well as the costs of monitoring and stealing and the detection probabilities involved. Knowing how complex the allocation of water game is, I can only presume that the annual maintenance game is also relatively complex and contains multiple equilibria. Thus, the representation of rule-making games presented in the prior sections of this paper must be looked upon as a crude first approximation to a series of nested games. What such a representation helps us understand is the kind of distributional effects that will eventually occur as a consequence of decisions made about rules that affect a series of future game situations.

A fuller representation of the linkage among the nested games--including now the collective choice rule-making game--is presented in Figure 10. Once a constitution is agreed upon and construction is completed, one can think of an annual cycle. The annual cycle contains: (1) a maintenance game in which farmers decide whether to comply with the rules specifying how resources are to be mobilized for maintenance and whether to monitor and punish rule-infractions, (2) an allocation of water game in which farmers decide whether to comply with the rules specifying how much water they are allocated and whether to monitor and punish rule-infractions, (3) annual net returns are achieved (resulting from individual agricultural production decisions as well as the two annual games), and (4) a collective choice rule-making game in which decisions are made to change or keep rules structuring the maintenance and allocation of water games after information is obtained about annual net returns to farmers. Most farmer-organized systems have annual meetings open to all members in which they do discuss whether their current operating rules are satisfactory or whether they want to change these.

[Figure 10 about here]

Since not all individuals involved in the process of choosing rules are as far-sighted as others, and since there are many asymmetries involved among the participants in field settings, crafting a full set of rules that work together to generate efficient and fair outcomes over a long time in a changing environment is a challenging task. The initial rules established in some systems are likely to be ill-matched to the problems they face. If the farmers are unable after some time to come to a better agreement about their rules, their system will not be as productive as others who have developed more effective social capital. They will face problems such as unpredictability of water and inadequate maintenance. Deep resentments can develop among individuals who have invested in hard work only to watch their mutual understandings come unglued. Other farmer associations who start off poorly may continually adjust their agreements until they arrive at a set of rules that fit their local circumstances well and are considered efficient and fair by most participants. Some systems will react to changing circumstances faster than others.

Thus, it is the continual adjustment of operation rules (and perhaps even the constitutional agreement itself) at their annual meetings--combined with relatively clear-cut annual performance indicators--that allow a group of farmers to adjust their rules (and their norms of behavior) so that eventually they may approach some of the better potential outcomes that are feasibly achieved given their physical endowments. Thus, the first approximation presented above will need to be expanded in future work by modeling the annual processes that are sketched in Figure 10.

Endnotes

1. The support of the Ford Foundation (grant number 920-0701) is gratefully acknowledged. Helpful comments made by Robert Keohane, Myungsuk Lee, James Walker, Robert Putnam, and Kenneth Shepsle on a preliminary draft are much appreciated.

2. Shirking relates to the more general problem of provision; stealing to the more general problem of assignment (see E. Ostrom, Gardner, and Walker, 1993).

3. All forms of capital can be used to improve the flow of future income for at least some individuals. For a pattern of social relationships or a set of institutions to be considered as capital, it does not need to achieve optimality for all participants--simply an improvement in the benefits of those who create the social capital. All forms of capital can be used by some groups to gain advantage over other groups, or even to harm others while benefitting from the harm. The physical capital involved in any one country's missile sites has the potential of generating vast destruction in achieving the 'benefit' of national defence.

4. Other forms of social capital may also exist--networks, norms, and social beliefs that evolve out of processes that are not investment activities (Putnam, 1993).

5. John R. Commons (1957) stressed the difference between the plant, on the one hand, and the going concern, on the other. The going concern included the working rules that enabled those in the going concern to relate to one another in a productive fashion in using a plant.

6. See F. Martin (1989/92) for an extensive bibliography of case studies describing institutions related to the use of common-pool resources.

7. See Knight (1992) for a critique of this work. See also Field (1979) and Lisa Martin's paper for this conference where she distinguishes among the types of problems faced in international settings using a similar typology.

8. Earlier noncooperative game-theoretic models have demonstrated that it is possible for farmers to undertake self-monitoring and self-sanctioning responsibilities even though it is not possible to do so, so as to reduce stealing rates to zero (Weissing and Ostrom, 1991, 1993).

9. The assumptions about common knowledge are strong assumptions. If participants had asymmetric and incomplete information, the results would frequently be different.

10. There are two broad types of rule-making situations: constitutional-choice and collective-choice situations. In a constitutional situation, the decision is made whether or not to constitute some form of association including who is a member, what are the initial operational rules to be followed, and the procedures to be used in the future to make collective choices for the association. In a collective-choice situation, decisions are made in an on-going association about policies to be adopted and operational rules to changed. These are discussed in the last section of the paper.

11. It is almost impossible for farmers to follow allocation rules in all instances. Given the stakes involved, the temptation to shirk or steal can be very large in some circumstances. Even on systems

that have survived for centuries, consistent evidence shows that some shirking and some stealing is a fact of life (see E. Ostrom, 1990; Weissing and Ostrom, 1991, 1993).

12. Even though it is possible to discover the structure of these situations and array them as diverse games, which is done in the next section, most of these games have multiple equilibria. Which of the many equilibria results in a particular situation is therefore dependent on many factors--including the shared beliefs and conceptions held by the participants--that are localized in time and space.

13. In other words, we will not consider any within team differences. One could think of the mechanism for achieving this as being of several kinds: (1) a random device picks one farmer from Branch A to bargain with one farmer from Branch B and whatever these two farmers agree (or don't agree) upon binds everyone else on the branch; (2) each set of five families are part of larger extended families and they each send the head of the family to represent them; or (3) each set of five families creates a branch organization to represent them in all decision making and select a branch representative in an annual election. The advantages of using a 2-player bargaining game for this series of models are substantial in terms of the array of questions that can be analyzed using this very simple mechanism. And I wish to ignore, for the time being, divisions among the players on the two branches so I can concentrate on the effect of various changes in physical, economics, or social variables on the structure and outcome of the 2-player game.

14. Alternatively, they could be expressed in labor units as in E. Ostrom and Gardner (1993). In either case it is the basic production function between labor input and crop yields that enables one to use a single metric when denoting both benefits and costs. In a fully monetized economy, one would simply denote benefits and costs as a monetary unit.

15. In this paper, I am considering only pure strategy equilibria. A mixed strategy does not make sense when the alternative is a rule. One can model rule-breaking behavior using mixed strategies (see Weissing and Ostrom, 1991, 1993). Rules that use one allocation formula during one season and another allocation formula during a second season will be considered as separate rules.

16. Some irrigation systems in Nepal use dividing weirs like this to allocate the flow of a canal according to the agreed-upon proportions (see Martin and Yoder, 1983).

17. This is a proportional distribution rule and would be considered an example of a 'fair rule' according to many criteria such as the one proposed by Selten (1978). A fair rule would be characterized as one where $e = f$ and $g = h$ even though $e \neq g$ and $f \neq h$. Examples of such rules abound in regard to irrigation. The Constitution for the Andhikhola Multipurpose Water User's Association (a relatively large FMIS located in the Syangja and Papal Districts of Nepal) provides an example of such a rule. In its constitution, a 'share' of the first stage of the project is defined as: '1/25,000 proportion of the water that flows out of the head gate. The initial value of a stage-one share is fixed at five days of labour' (AKWUA Constitution, Section 3c). In this system, some farmers own more shares than others and thus receive more benefits than others. But since every share involves an obligation to contribute five days of labor annually, they also pay costs in the same proportion as they receive water.

18. In general, if $g^I B - h^I C > g^J B - h^J C = SQy$, Branch Y will only agree to Rule I. If instead, $g^I B - h^I C > g^J B - h^J C > SQy$, Branch Y will strongly prefer Rule I, but could agree to Rule J if placed in a weak bargaining situation. A similar set of conditions exists for Branch X.

19. Another source of asymmetry among farmers is inequality in the amount of land owned. Farmers who own large parcels of land need more water than those who own small parcels of land (assuming similar soil and other conditions). This obvious asymmetry, so long as it is not closely correlated with other asymmetries (such as location on the canal and status), is usually handled rather simply on farmer-organized systems. If the rules allocating water benefit some participants more than others, others may agree to them so long as the rules allocating costs assign them in rough proportion to the benefits received. It is not at all unusual to find rules on farmer-organized systems that allocate water to individual plots on the basis of the amount of land to be irrigated. With such a rule, large landowners get more water. If this benefit allocation rule is used in practice, the rule for mobilizing resources such as labor is usually also related to the size of land (unless the quantity of labor needed is very low) (see Tang, 1992).

20. This is an example of the 'weak' exploiting the 'strong' (see Olson, 1965).

21. An example of such a system is Thambesi, a farmer-organized system in Nepal where the headworks is a simple brush and stone diversion works that can be adjusted each year with only a few farmers doing the work. 'The members with holdings in the tail cannot force those with land above theirs to deliver water to them equally by not participating in maintenance and other system activities' (Yoder, 1986: 179). Headenders have clearly established prior rights to water and 'fill their fields with water first before those further down the secondary are able to take water' (1986: 292). During the water scarce months, farmers at the head of the system grow water intensive crops while those at the tail do not irrigate at all.

22. An important source of asymmetries not discussed in this paper relates to that of information (see Rasmusen, 1989).

23. This section draws on a portion of E. Ostrom and Gardner, 1993.

24. Some previous empirical studies do provide evidence concerning other types of asymmetries. S. Yan Tang (1992), using our earlier CPR database, found a negative relationship between the variance in the average annual family income among irrigators and the degree of rule conformance and level of maintenance. Easter and Palanisami (1986), in their study of 10 irrigation reservoirs in India, found that the smaller the variance in farm size among farmers, the more likely farmers were to form water user associations that coped with collective-action problems. Jayaraman (1981) found a similar relationship between egalitarian community structures and effective organization of farmers (see also Wade, 1987; Bandyopadhyay and von Eschen, 1988; and Kanbur, 1991).

25. It should be pointed out that FMIS are on average smaller than AMIS, but the size of the system is not significantly related to agricultural productivity when we control for the type of governance and for other physical attributes such as the presence of permanent headworks and at least partial lining (see Lam, Lee, and Ostrom, 1993).

26. Thus, a score of zero indicates that for all three seasons, the level of water adequacy was the same in the head and tail sections of the system. A score of .33 indicates that in one season, the head received adequate water and the tail received limited water or that the head received limited water and the tail received scarce water. For the 118 systems for which we have data, the difference score ranges from -.66 to 1.66. The regression presented in the text is based on data for 76 systems for which we had data on all variables in the regression equation. A parallel analysis using multinomial

probit estimates yields parallel findings concerning the direction and significance of permanent headworks and type of system, but the negative relationship between terrain and the difference score does not reach statistical significance. Myungsuk Lee's assistance in undertaking the regression and probit analysis is deeply appreciated.

27. Because the game involves a long series of future benefits, the loss of not reaching an agreement is usually far larger than the loss involved in keeping the status quo in a one-shot bargaining situation. Further, farmers need the continued contributions of each other to operate the system over time. In agreeing on rules, farmers are establishing a system of mutual dependence. They are dependent on each other not to steal and not to shirk (the two strong short-term incentives they are trying to surmount). In choosing rules, more attention is paid by all participants to rules that are both efficient and fair than would be paid in one-shot decisions about actions.

28. Whether anyone can be excluded depends very much on the physical layout of the system and on whether exclusion will be sustained by external authorities if challenged by those who are excluded. If the soil is porous and those who refuse to contribute are located lower in the system than those who agree, they may receive substantial subsurface, usable flows of water without any need to contribute at all. Thus, while many farmer-organized systems do end up being able to exclude nonparticipatory farmers, this is a very difficult process to achieve and most self-organizing systems try hard to involve all of those who are in a physically interrelated system in the social system they create.

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FIGURE 1 A Simple Symmetric Irrigation System

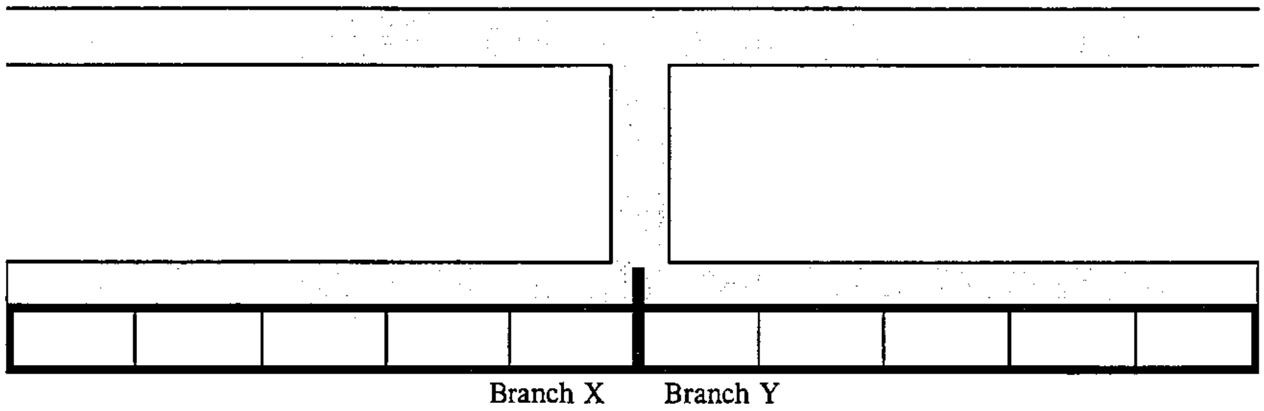


FIGURE 2 General Structure of Bargaining Game over Rules

		Y Branch	
		Rule I	Rule J
X Branch	Rule I	$(e^I B - f^I C), (g^I B - h^I C)$	SQx, SQy
	Rule J	SQx, SQy	$(e^J B - f^J C), (g^J B - h^J C)$

FIGURE 3 An Initial Illustration

		Y Branch	
		Rule 1	Rule 2
X Branch	Rule 1	(.5B - .5C), (.5B - .5C)	SQx, SQy
	Rule 2	SQx, SQy	(.5B - .5C), (.5B - .5C)

FIGURE 4 A Second Illustration

		Y Branch	
		Rule 3	Rule 4
X Branch	Rule 3	(.5B - .67C), (.5B - .33C)	SQx, SQy
	Rule 4	SQx, SQy	(.5B - .5C), (.5B - .5C)

FIGURE 5 The Effect of Status Quo Postions on the Range of Acceptable Rules

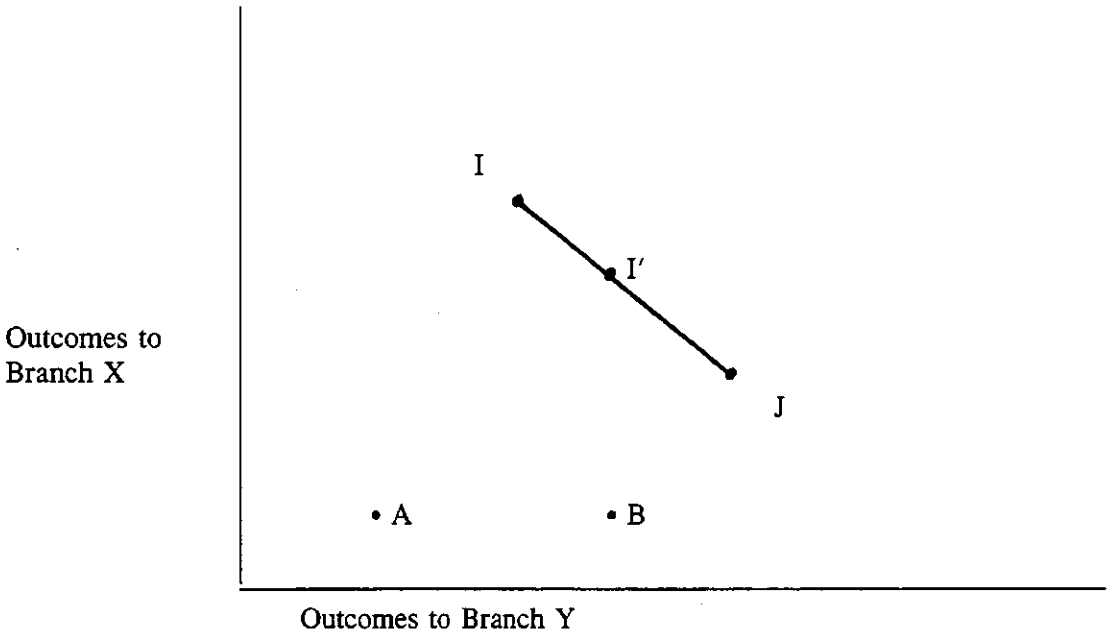
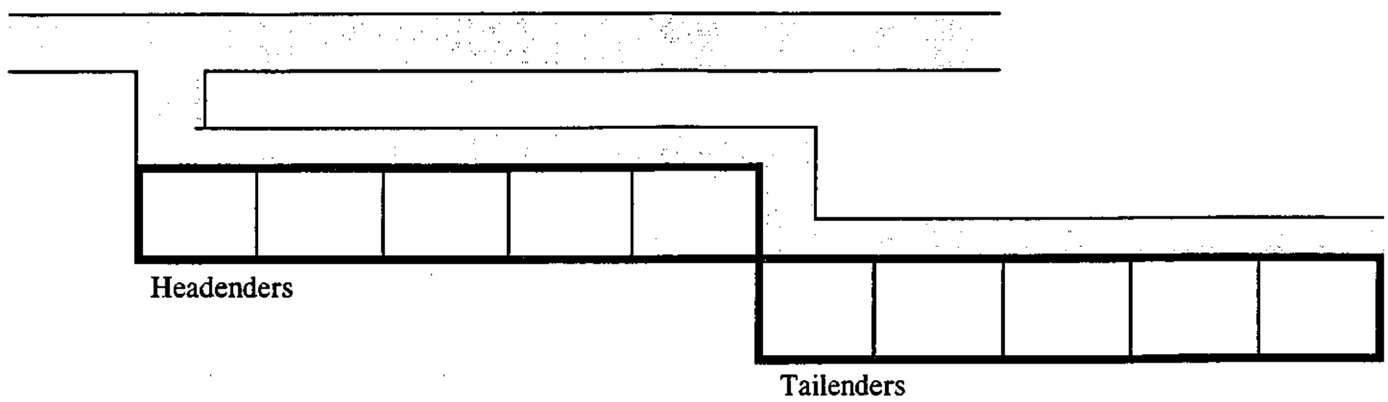
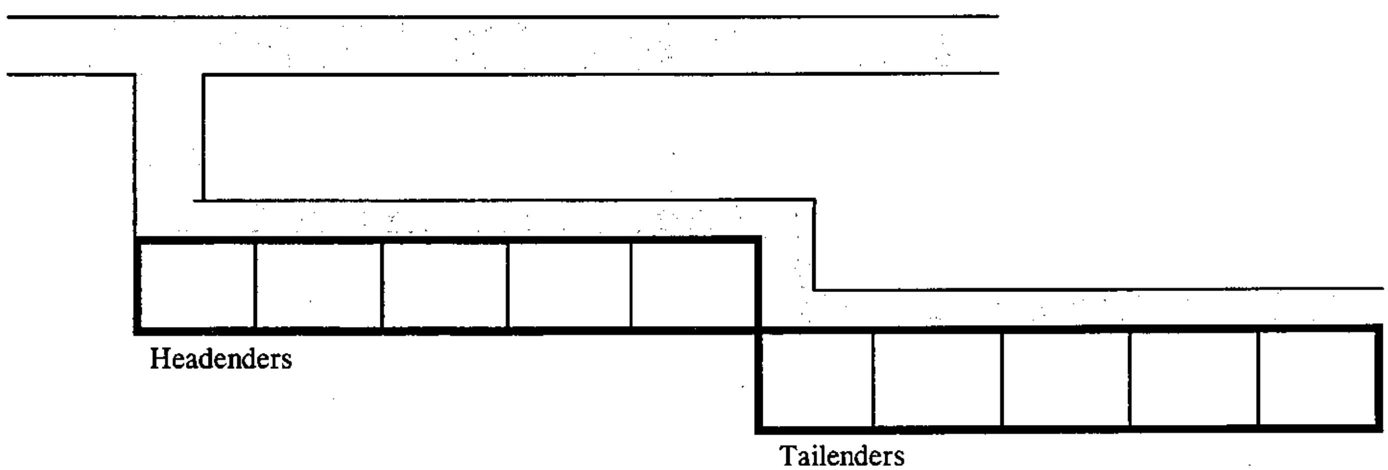


FIGURE 6 Three Irrigation Systems with Increasing Cost of Maintenance

6a) B = 100, C′ = 25



6b) B = 100, C′′ = 50



6c) B = 100, C′′′ = 100

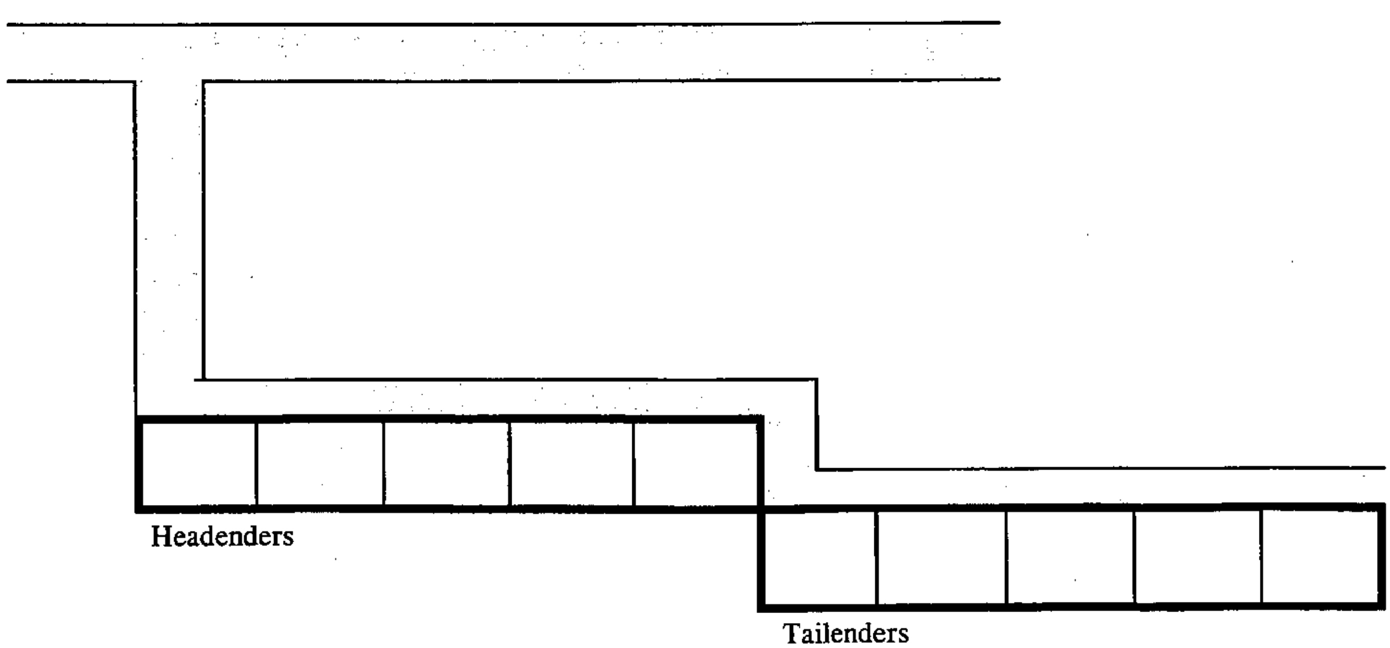


FIGURE 7 The Choice of Rules Games for the Irrigation Systems with Increasing Costs of Maintenance

7a)

		Head end	
		Rule 6	Rule 7
Tail end	Rule 6	35, 40	0, 0
	Rule 7	0, 0	37.5, 37.5

7b)

		Head end	
		Rule 6	Rule 7
Tail end	Rule 6	35, 15	0, 0
	Rule 7	0, 0	25, 25

7c)

		Headend	
		Rule 6	Rule 7
Tail end	Rule 6	35, -10	0, 0
	Rule 7	0, 0	12.5, 12.5

FIGURE 8 Planned and Actual Results of Some Types of Donor Assistance

8a)

		Head end: Rule 6	Head end: Rule 7
Tail end	Rule 6	[not in plan]	[not in plan]
Tail end	Rule 7	[not in plan]	75, 75

8b)

		Head end: Rule 6	Head end: Rule 7
Tail end	Rule 6	90, 10	[not feasible]
Tail end	Rule 7	[not feasible]	[not feasible]

FIGURE 9 The Extended Series of Games

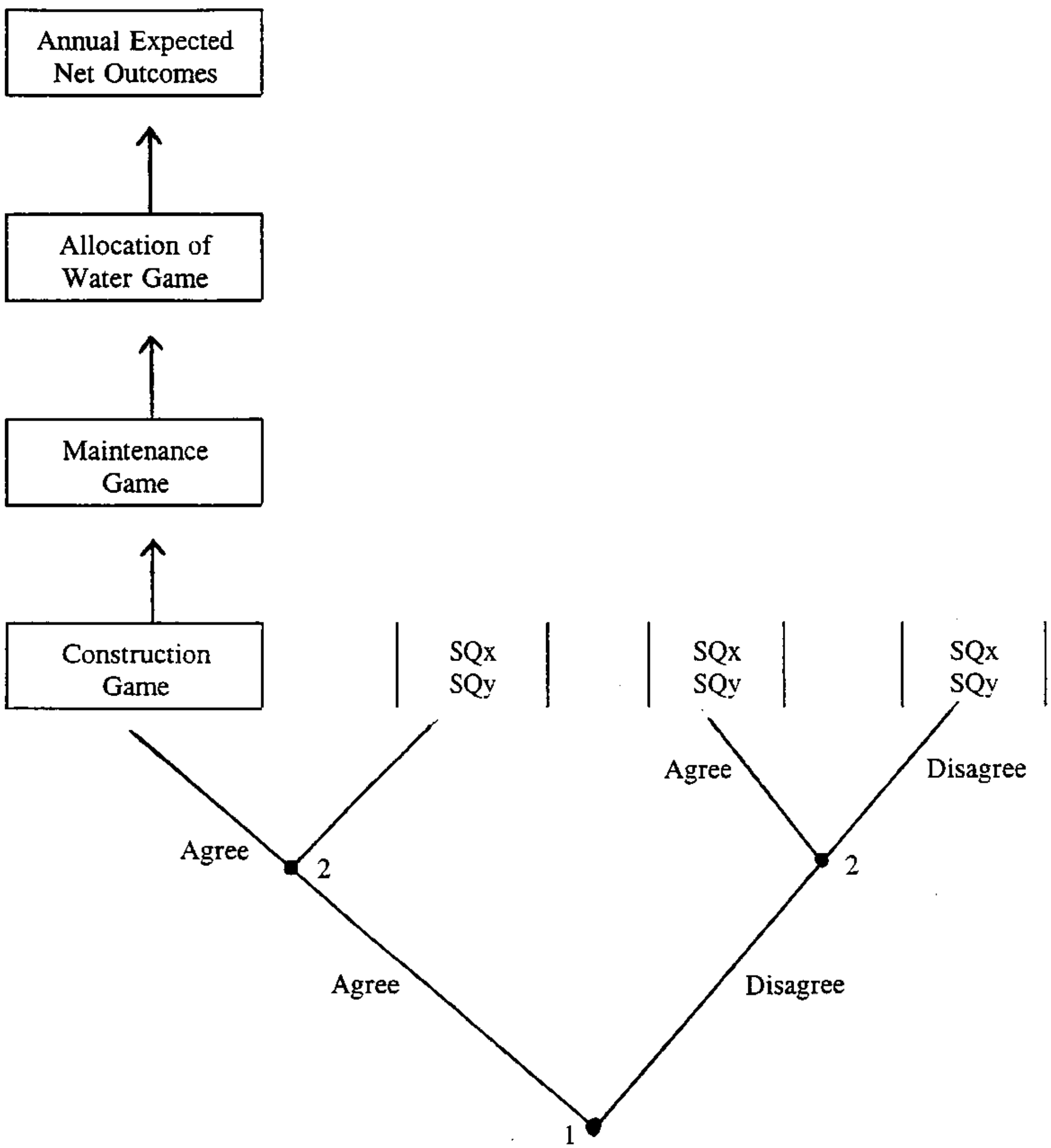


Figure 10 Nested Games: Operational, Collective Choice, and Constitutional Choice