Social capital is an essential complement to the concepts of natural, physical and human capital and can be used for beneficial or harmful ends—or simply be allowed to dissipate. While all forms of capital are essential for development, none of them are sufficient in and of themselves. In this paper, I focus first on the concept of human-made capital and examine some of the essential similarities between physical, human, and social capital. In the second section, four differences between physical and social capital will be examined, including: (a) social capital does not wear out with use, but rather with disuse; (b) social capital is not easy to observe and measure; (c) social capital is hard to construct through external interventions; and (d) national and regional governmental institutions strongly affect the level and type of social capital available to individuals to pursue long-term development efforts. The third section will discuss the problem of creating social capital and present a game-theoretic analysis of how a group of farmers creates rules to allocate the benefits and costs of building and operating their own irrigation system. Empirical evidence derived from a study of 150 irrigation systems in Nepal supports the conclusions of this analysis. The last section is devoted to the policy significance of the theoretical and empirical findings presented in this paper.

Years of development policies encouraged by donor agencies focusing on building infrastructure as the key to economic growth have made many individuals and government officials rich. Only the crumbling remains of poorly maintained roads, irrigation systems, and public facilities, however, are left today in many countries for all the billions invested. There is a serious need to rethink the overemphasis on physical capital.
capital alone. The recent groundswell of attention in development literature to social capital is thus a refreshing and needed change (Harriss 1997; Fountain 1997; Levi 1996; Newton 1996; Narayan 1998; Putzel 1997; Sabetti 1996; World Bank 1997).

As is to be expected with any effort to introduce a new concept into policy discourse, some authors have exaggerated claims for the universal efficacy of social capital. However, some criticisms have blanket ed carefully conducted analyses along with those that were rightfully in need of critical review. In other words, there has been a lot of serious work and some hoopla focusing on social capital. Some commentators think that social capital is just another fad. This is unfortunate. But, we must address the question of whether the concept will become a core foundation for our understanding of how individuals achieve coordination and overcome collective-action problems to reach higher levels of economic performance. Or, will this currently fashionable concept soon be retired to the dust heap of previous panaceas?

It is important that social capital be taken seriously and not allowed to be carried off as a fad. Social capital is an essential complement to the concepts of natural, physical, and human capital. Just as we have come to recognize that building roads and irrigation projects or providing education and training are not sufficient by themselves to enhance the economic and political growth of developing societies, social capital alone is not sufficient for development. Social capital can be used for beneficial or harmful ends or simply allowed to dissipate. While all forms of capital are essential for development, none of them are sufficient in and of themselves. Social capital shares some fundamental attributes with other forms of capital while it presents some attributes that differ. We need a much better understanding of how social capital is constituted and transformed over time.

In this paper, I will focus first on the concept of human-made capital and examine some of the essential similarities between physical, human, and social capital. The fourth type of capital—natural capital—encompasses the rich array of biophysical resource systems that are the ultimate source and storehouse of all human productivity (Jansson and others 1994). The problem of sustainable use of natural capital is itself a vitally important and immensely difficult topic that cannot be addressed in the confines of this paper. In the second section, four differences between physical and social capital will be examined: (a) social capital does not wear out with use, but rather with disuse; (b) social capital is not easy to observe and measure; (c) social capital is hard to construct through external interventions; and (d) national and regional governmental institutions strongly affect the level and type of social capital available to individuals to pursue long-term development efforts. The third section will discuss the problem of creating social capital—particularly self-organized resource governance systems. As an illustration
of these processes, I will present a game-theoretic analysis of how a group of farmers creates rules to allocate the benefits and costs of building and operating their own irrigation system. I will also present empirical evidence derived from a study of 150 irrigation systems in Nepal and from in-depth case studies of efforts to improve the physical capital of irrigation systems without paying attention to the social capital of these systems. In the last section I will discuss the policy significance of the theoretical and empirical findings presented in this paper.

The concept of human-made capital

All forms of human-made capital are created by spending time and effort in transformation and transaction activities in order to build tools or assets today that increase income in the future.1 "People form capital when they withhold resources from present consumption and use them instead to augment future consumption [or production] possibilities" (Bates 1990, p. 153). Investments in physical capital are usually a self-conscious decision, while human and social capital may be developed as a by-product of other activities as well as purposely. The essential role of capital is everywhere acknowledged, but not always well understood. Unfortunately, capital is sometimes equated with money. Money is not capital, but rather the means by which some forms of physical, human, and social capital may be obtained. Money, like many resources, can alternatively be used for consumption or sit unused as a store of value. Many types of capital can be created without money, or with very little of it, based on the time and energy spent by individuals in building tools and facilities, learning skills, and establishing regularized patterns of relationships with others. All human-made capital involves creating new opportunities as well as exercising restraints, a risk that the investment might fail, and the possibility of using capital to produce harms rather than benefits.

Physical capital

Physical capital is the stock of human-made, material resources that can be used to produce a flow of future income (Lachmann 1978).2 Physical capital exists in a wide variety of forms including buildings, roads, waterworks, tools, cattle and other animals, automobiles, trucks, and tractors—to name just a few. The origin of physical capital is the process of spending time and other resources constructing tools, plants, facilities, and other material resources that can, in turn, be used in producing other products or future income.3

The construction of physical capital involves establishing physical restraints that (a) create the possibilities for some events to occur that would not otherwise occur (for example, channeling water from a dis-
tant source to a farmer’s field), and (b) constrain physical events to a more restricted domain (for example, water is held within a channel rather than allowed to spread out). Thus, physical capital opens up some possibilities while constraining others. The intention to construct useful physical capital is not always fulfilled. An investment in physical capital may not generate the improved flow of future services. A new but crumbling roadway or irrigation system, or an empty building, represents a failed investment decision.

Physical capital may have a dark side and generate more harms than benefits. Investing in a weapons facility increases the quantity of physical capital existing at a particular point in time, but the product of this form of physical capital is the threat of human destruction. Even investments in the production of consumer goods can produce substantial externalities. A nuclear power plant that leaks radioactive materials, for example, is constructed in order to increase the availability of power for positive purposes but may produce more negative externalities than the net benefits generated. Physical capital cannot operate over time without human capital in the form of the knowledge and skills needed to use and maintain physical assets to produce new products and generate income. If physical capital is to be used productively by more than one individual, social capital is also needed.

Human capital

*Human capital* is the acquired knowledge and skills that an individual brings to an activity. Forms of human capital also differ among themselves. A college education is a different type of human capital than the skills of a cabinetmaker acquired through apprenticeship training. Human capital is formed consciously through education and training and unconsciously through experience. An individual who swims for the pleasure of the activity, for example, is engaging in consumption activities but also improving physical health. Health is an asset that is drawn on to achieve other goals. Some investments in human capital are not made self-consciously but result from activities engaged in primarily for other reasons. Alternatively, some individuals dislike using stationary bicycles but do so because they know that aerobic exercise is essential for sustaining future capabilities. They exercise primarily to invest in human capital and then find ways to make this activity as pleasant as possible. Thus, both self-conscious and relatively unconscious investment processes go on when building human capital.

Human capital consists of the acquisition of new capabilities as well as the learning of constraints. Learning a new language opens up different conceptions of the world. Many of the skills that individuals acquire involve the imposition of discipline on self. Like physical capital, human capital can be used for destructive purposes as well as productive
ones. An individual knowledgeable in computer languages can use this skill to write programs today that help solve many problems in the future. Those who write programs to function as a virus that invades and destroys the records of others, use their human capital for destructive purposes.

**Social capital**

*Social capital* is the shared knowledge, understandings, norms, rules, and expectations about patterns of interactions that groups of individuals bring to a recurrent activity (Coleman 1988; E. Ostrom 1990, 1992; Putnam, Leonardi, and Nanetti 1993). In the establishment of any coordinated activity, participants accomplish far more per unit of time devoted to a joint activity if they draw on capital resources to reduce the level of current inputs needed to produce a joint outcome. They are more productive with whatever physical and human capital they draw on, if they agree on the way that they will coordinate activities and credibly commit themselves to a sequence of future actions. In the realm of repeated coordination problems, humans frequently face a wide diversity of potential equilibria and a nontrivial problem of finding the better equilibria in the set. When they face social dilemma or collective-action situations, participants may easily follow short-term, maximizing strategies that leave them all worse off than other options available to them. Somehow participants must find ways of creating mutually reenforcing expectations and trust to overcome the perverse short-run temptations they face (E. Ostrom 1998a).

Agreements can be based on mutual learning about how to work better together. They can be based on one person agreeing to follow someone else's commands regarding this activity. Or, they can be based on the evolution or construction of a set of norms or rules that define how this activity will be carried out repeatedly over time and how commitments will be monitored and sanctions imposed for nonperformance.

Like physical capital and human capital, social capital opens up some opportunities while restricting others. A decision to establish majority rule as the decision rule for making particular collective-choice decisions, for example, opens opportunities that did not previously exist. Voting does not exist in nature, and the opportunity to vote is created by rules. On the flip side, a rule that prohibits a farmer from growing a particular water-intensive crop—rice during the dry season, for example—restrains activities to a more limited set than previously available.

There is a dark side to social capital as well as to physical and human capital. Gangs and the Mafia use social capital as the foundation for their organizational structure. Cartels also develop social capital in their effort to keep control over an industry so as to reap more profits than
would otherwise be the case. An authoritarian system of government based on military command and use of instruments of force destroys other forms of social capital while building its own.

Social capital takes many different forms. Putnam, Leonardi, and Nanetti (1993) identifies social capital as involving networks, norms, and social beliefs that evolve out of processes that are not overtly investment activities. Family structure is considered another form of social capital. Bates (1990), for example, summarizes research on the Luo and Kikuyu of Kenya, the Bambara of Mali, and on East African pastoralists, and clearly demonstrates that different types of lineage groups create different types of property rights and access to flows of future incomes. He points to the costs to individual families of belonging to extended lineages and the benefits that they obtain by spreading risk in those environments where ecological or economic variation is very high.

Shared norms are forms of social capital, but specific norms may have different consequences. The norm of reciprocity implies some level of symmetry among those who engage in long-term reciprocal relationships. When individuals learn to trust one another so that they are able to make credible commitments and rely on generalized forms of reciprocity rather than on narrow sequences of specific quid pro quo relationships, they are able to achieve far more than when these forms of social capital are not present (E. Ostrom 1998a). "In a reciprocal relationship, each individual contributes to the welfare of others with an expectation that others will do likewise, but without a fully contingent quid pro quo" (Oakerson 1993, p. 143). Thus, investments made in one time period in building trust and reciprocity can produce higher levels of return in future time periods even though the individuals creating trust and reciprocity are not fully conscious of the social capital they construct. Not all norms, however, are based on symmetric relationships. The norm of deference to elders or to those with more status or authority is based fundamentally on a concept of asymmetric relationships. Such norms may be used to generate higher returns in the future, but they may also lead to stagnation and a reluctance to build new types of enterprises. A norm such as retribution—even though it may be based on symmetry—can trigger quite destructive and escalating patterns of conflict and violence and thus be destructive of all forms of capital.

Conventions may be established without as much collective, self-conscious thought as is involved in creating new rules or establishing new entrepreneurial opportunities. Individuals facing a particular opportunity or problem in a specific location and time decide to handle it in a particular manner. That decision becomes a precedent for arriving at a similar agreement when a related opportunity or problem is faced again. If mutual expectations based on past behavior are fulfilled again and again, the precedent becomes a convention for how activities, costs, and benefits will be handled by individuals in the future. The conven-
Institutional analysis has economic value because transaction costs are much lower when most participants already have agreed that a particular convention is appropriate and positive gains can be achieved with a low risk of breakdown (Young 1998, pp. 113–15). While the establishment of a convention occurs without formal consideration by all participants, weighing how best to act in this situation will have been made by many separate individuals, as they have faced similar situations over time. The convention evolves as a result of precedent, shared expectations, and continued behavior that is consistent with the convention.

Both evolved and self-consciously designed rule systems are important forms of social capital that help individuals overcome the wide diversity of social dilemmas and collective-action problems faced in all societies. Conventions alone are rarely sufficient when individuals face a social dilemma. The temptation to cheat, which does not exist in coping with coordination problems, is usually relatively difficult to overcome without more self-consciously developed agreements, monitoring arrangements, and methods for imposing sanctions on nonconformance. To create social capital in a self-conscious manner, individuals must spend time and energy working with one another to craft institutions—that is, sets of rules that will be used to allocate the benefits derived from an organized activity and to assign responsibility for paying costs (E. Ostrom 1990, 1992). Rules imply asymmetries between those assigned authority to make rules and to monitor and enforce rules. Rules also contain a reference to a sanction that can be enforced if conformance to the rule is observed by such an authority (see Crawford and Ostrom 1995). While the laws established by formal legislative, executive, and judicial bodies are an important source of the rules used by groups of individuals in productive enterprises, a large proportion of rules-in-use are created by self-organized governance systems.

Self-organizing governance systems create their own rules in millions of disparate local settings to cope with a variety of private and public problems. An extensive literature including many case studies describes institutions that have been constituted by those affected in all corners of the world (see Berkes 1986, 1989; E. Ostrom 1990; Bromley and others 1992; Fairhead and Leach 1996; Fox 1993; Fortmann and Bruce 1988; McCay and Acheson 1987). 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 1995; Libecap 1989; North 1990; E. Ostrom 1998b; E. Ostrom, Gardner, and Walker 1994; V. Ostrom, Feeny, and Picht 1993).

While social capital does take on many forms, there are underlying similarities among all of the diverse forms. In all forms, individuals who devote time to constructing patterns of relationships among humans
are building assets whether consciously or unconsciously. Further, all forms of social capital share the following attributes:

- Social capital is formed over time and is embedded in common understanding rather than in physically obvious structures;
- Common understanding is hard to articulate precisely in language; and
- Common understanding is easily eroded if large numbers of people are concerned or if a large proportion of participants change rapidly—unless substantial efforts are devoted to transmission of the common understandings, monitoring behavior in conformance with common understandings, and sanctioning behavior not in conformance with the common understanding.

These commonalities are not shared with physical capital and are the source of substantial differences between these two forms of human-made capital.

**Differences between social and physical capital**

The similarities among diverse forms of social capital lead to some key differences between social and physical capital. We will discuss four key differences that include the following:

- Social capital does not wear out with use but rather with disuse;
- It is not easy to see and measure;
- It is hard to construct through external interventions; and
- National and regional governmental institutions strongly affect the level and type of social capital available to individuals to pursue long-term development efforts.

Many of these differences are due to the importance of shared cognitive understandings that are essential for social capital to exist and to be transmitted from one generation to another.

**First, social capital differs from physical capital in that it does not wear out with use but rather with disuse.** Social capital may, in fact, improve with use so long as participants continue to keep prior commitments and maintain reciprocity and trust. Using social capital for an initial purpose creates mutual understandings and ways of relating that can frequently be used to accomplish entirely different joint activities at
much lower start-up costs (Putnam, Leonardi, and Nanetti 1993). It is not that learning curves for new activities disappear entirely. Rather, one of the steepest sections of a learning curve—learning to make commitments and to trust one another in a joint undertaking—has already been surmounted. A group that has learned to work effectively together in one task can take on other similar tasks at a cost in time and effort that is far less than that involved in creating an entirely new group out of people who must learn everything from scratch. The fungibility of social capital is, of course, limited. No tool is useful for all tasks. Social capital that is well adapted to one broad set of joint activities may not be easily molded to activities that require vastly different patterns of expectation, authority, and distribution of rewards and costs than used in the initial sets of activities.

If unused, social capital deteriorates rapidly. Individuals who do not exercise their own skills also lose human capital rapidly. When several individuals must all remember the same routine in the same manner, however, the probability that at least one member of a group will forget some aspect increases rapidly over time. In addition, as time goes on, some individuals enter and others leave social groups. If newcomers are not introduced to an established pattern of interaction as they enter (through job training, initiation, or any of the myriad of other ways that social capital is passed from one generation to the next), social capital dissipates through turnover of personnel. Eventually, no one is quite sure how they used to get a particular joint activity done. Either the group has to pay most of the start-up costs all over again, or forego the joint advantages that they had achieved at an earlier time.

Second, social capital is not as easy to find, see, and measure as is physical capital. The presence of physical capital is usually obvious to external onlookers. Health centers, schools, and roads are simple to see. Social capital, by contrast, may be almost invisible unless serious efforts are made to inquire about the ways in which individuals organize themselves and the rights and duties that guide their behavior—sometimes with little conscious thought. Even when asked, local residents may not fully describe the rules they use. Robert Yoder warns those interested in helping farmers that they must probe deeply and in nonthreatening ways to get adequate information on the rules used to allocate water and maintenance duties within irrigation systems. “Intimidated by the higher status of officials, they may fail to communicate the details of the rules and procedures they use to operate and maintain their system” (1994, p. 39). Common understanding is frequently hard to articulate in precise language, particularly when status differentials make communication difficult in the first place. If external agents of change do not expect that villagers have developed some ways of relating to one another that are productive in the setting in which they live, those who are trying to help may easily destroy social capital without...
realizing what they have done. If past social capital is destroyed and nothing takes its place, well-being can be harmed rather than improved by external “help.”

The researcher or project workers interested in social capital cannot assume from the outside that a group has (or has not) established common understandings that enable them to rely on each other to behave in ways that are predictable and mutually productive. The presence of words on paper or a building with a name on the outside is not the equivalent of the common understandings that are shared among participants. The self-organizing processes that social capital facilitates generate outcomes that are visible, tangible, and measurable. The processes themselves are much harder to see, understand, and measure.

Third, social capital is harder than physical capital to construct through external interventions. A donor can provide the funds to hire contractors to build a road or line an irrigation canal. Building sufficient social capital, however, to make an infrastructure operate efficiently, requires knowledge of local practices that may differ radically from place to place. Organizational structures that facilitate the operation of physical capital in one setting may be counterproductive in another. Local knowledge is essential to building effective social capital.

Creating 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. The incentive to create social capital related to private enterprise is attributed to the profit motive. A great deal of what private entrepreneurs do is to create networks of relationships that increase the profits that can be obtained. The private entrepreneur then keeps the residuals from creating and sustaining social capital.

The incentives and motivation of public entrepreneurs who provide public goods and services is not as well understood as that of private entrepreneurs. In an earlier era, the theory of bureaucracy posited public officials who ascertained the public interest and were motivated to achieve it. More recent analyses of public bureaucracies are less optimistic about the capacity of public officials to know the public interests or to undertake the least costly ways of providing and producing collective goods. Instead of being viewed as if they were automata who do what they are told to do in the most efficient way, public employees are viewed as individual actors seeking their own interests. Pursuing their own interests may or may not generate net public goods, depending on how well the rules affecting their incentives help induce high perfor-
mance. Thus, simply turning over the task of creating social capital to make physical and human capital more effective to a public bureaucracy may not generate the intended results unless officials are strongly motivated to facilitate the growth and empowerment of others. The social capital created may instead be the organization of limited networks of individuals or cliques that engage in mutual reciprocity at the expense of the larger group they are supposed to be serving.

Fourth, national and regional governmental institutions strongly affect the level and type of social capital available to individuals to pursue long-term development efforts. Larger-scale governmental institutions can facilitate the creation of social capital by citizens trying to solve coordination or collective-action problems or make it more difficult. They facilitate the creation of social capital when considerable space for self-organization is authorized outside of the realm of required governmental action. However, when national or regional governments take over full responsibilities for large realms of human activities, they crowd out other efforts to enter these fields. When national governments take over the ownership of all forests or other natural resources or close down schools and hospitals run by religious groups in an attempt to provide all health and educational services themselves, they destroy an immense stock of social capital in short order. Rarely can this be replaced rapidly. Creating dependent citizens rather than entrepreneurial citizens reduces the capacity of individuals to generate capital.

Many local infrastructure facilities and public goods are, however, not provided either by public bureaucrats or private entrepreneurs but rather by those who directly receive the benefits of collective action. An example is the organization of an irrigation system by the group of farmers who will directly benefit from its operation (Benjamin and others 1994). 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 and over how to use them. Given the multitude of nested collective-action problems involved in the creation of institutions, explaining how individuals overcome these problems is not easy. Furthermore, the diverse sources of asymmetries among participants makes it even more difficult to explain how individuals solve thorny distribution problems (see Libecap 1994; Hackett, Dudley, and Walker 1994; Hackett, Schlager, and Walker 1994; Johnson and Libecap 1982; Hackett 1993). Consequently, let us examine the process of crafting rules more carefully.

The rule-creating game: an example of constructing social capital

Thousands of farmers who need irrigation water have organized themselves in many parts of the world in order to build and maintain their
own systems (E. Ostrom 1992; Tang 1992; Lam 1998). Many of these systems have survived for multiple centuries based on local knowledge regarding their construction and maintenance, and owing to the skills of local farmers in crafting institutions to overcome the many temptations involved. Farmers always face a series of collective-action problems in determining who will share in the costs of constructing and maintaining an irrigation system, how the benefits will be distributed, and how activities will be monitored so as to ensure that those who follow the rules of their self-organized governance system are not taken advantage of by those who cheat.

To illustrate how rules affect outcomes, I will analyze how farmers themselves bargain over rules. When they do this successfully, they solve collective-action problems that many analysts presume cannot be solved by those involved. Thus, the analysis that follows illustrates how a collective-action problem can be analyzed when the question of institutional change is the primary focus. It also illustrates how delicately balanced rules are with the constraints and opportunities afforded by the physical infrastructure itself.

**Underlying assumptions**

For farmers to consider constituting themselves into even a loose form of association to construct an irrigation system, they would need to have secure enough land tenure to believe that they can reap long-term benefits from an investment. They would need to have established a sufficient sense of community that they can engage in a full array of face-to-face relationships that value keeping promises an asset of considerable importance. Coming to a high level of common understanding (Aumann 1976) about the structure of incentives they face, the types of individuals with whom they would be interacting, and alternative ways of structuring their relationships is a prerequisite for constituting associations to undertake major, long-term collective action. Knowing that individuals share a commitment to keep their promises made to a group—so long as others keep their promises as well—affects individual expectations about future behavior. Those involved also need to switch levels of action from that of a day-to-day operational situation to a rule-making situation (E. Ostrom 1990).

If the set of beliefs outlined above is not altered by experience so as to destroy the assessment made by each farmer about the beliefs that others share and the likely strategies that others will adopt, such a set of farmers would be able to construct a system and operate 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 (Elster 1979; Schelling
Given 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. In other words, an 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. 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 on 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 run. Some farmers may be left much better off than others. The less advantaged must feel, however, that they receive a positive gain from participation or they will not voluntarily participate. 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 incentives**

Let us first assume that ten farmers own equal-sized plots of land on an alluvial plain. One of the farmers (who has a reputation for designing prudent and well-conceived community works) has proposed a plan to divert a previously undrained mountain stream to their area. If allocated carefully, the source could provide water for three crops for all ten farmers. The plan involves the construction of a short main canal and two branch canals that each serve five families. 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. A diversion works at the source sends water into a relatively short and uncomplicated canal that is then divided into an X Branch and a Y Branch, each serving five plots of equal size.

In order to get started with this project, the farmers need to agree about the rules that they will use to allocate (a) expected annual benefits from the project and (b) expected annual costs. No one will voluntarily contribute funds 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. 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—in other words, what they can expect if no agreement on constructing a new system is achieved.

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 (see Knight 1992). If they do not agree, they continue with their current rain-fed agriculture and obtain the status quo yield (SQx, SQy) 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, each year they will receive 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. Let us first assume that total annual expected benefits exceed total annual expected costs as well as the status quo yield of each branch:

\[(B - C) \geq SQ_x + SQ_y. \tag{1}\]

Each branch would most prefer a situation in which it 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 side obtains. The proportion of the expected annual benefits received by Branch X will be eI if Rule I is agreed upon, and eJ if Rule J is agreed upon. Similarly, the proportion of expected annual benefits received by Branch Y is given by gI or gJ, depending on the rule selected.

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

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

The coefficients, fI, hI, and fJ and hJ are the proportion of costs assigned to the two branches under different rules.

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

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

Let us assume that all farmers are risk-neutral (orientated neither toward taking risks nor toward avoiding them) and have equal and low discount rates that are omitted from the analysis since their inclusion would not change the results.


**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 cost of construction and maintenance is equally divided. Let us suppose that the farmers consider two rules.

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

Rule 2: A dividing weir constructed 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 1. Since we are assuming for now that the share of the benefits minus the costs of the irrigation system is greater than the status quo yield for both branches (equation 1), the branches face a benign coordination situation. There are two pure-strategy equilibria in this game: both choose Rule 1 or both choose Rule 2.13 Since communication is possible, it can be used to solve this coordination problem. Which rule is finally chosen if they come to an agreement depends on situation-dependent variables.

**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:

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**FIGURE 1: AN INITIAL ILLUSTRATION**

<table>
<thead>
<tr>
<th></th>
<th>Rule 1</th>
<th>Rule 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>X branch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rule 1</td>
<td>(.5B - .5C), (.5B - .5C)</td>
<td>SQx, SQy</td>
</tr>
<tr>
<td>Rule 2</td>
<td>SQx, SQy</td>
<td>(.5B - .5C), (.5B - .5C)</td>
</tr>
</tbody>
</table>

Rule 3: Each family sends all its adult males for every labor day devoted to the irrigation system.

Because each family owns identical plots, this cost allocation is proportionate to the aggregate benefit accruing to each family. Someone in Branch X might, however, propose the following rule:

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

Assuming that either Rule 1 or Rule 2 had already been agreed upon, these proposals would result in a bargaining game such as the one found in figure 2.

Assuming that the increased yield exceeds the costs that would be imposed on Branch X under Rule 3 (.5B - .67C > SQ.), both branches would be better off agreeing to either rule compared with having no system. But Rule 3 assigns a higher proportion of net benefits to Branch Y, while Rule 4 treats both branches equally. 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 it should not have to contribute twice the amount of labor as Branch Y simply because Branch X has more adult males. 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 to the assertion that this rule was an essential precondition to obtaining its agreement to the plan for the irrigation system.

However, Branch Y could recognize that establishing a good continuing relationship was important and that if Branch X resented being forced to agree to a rule owing to a weak bargaining situation, Branch Y might face trouble later getting Branch X to abide the agreement on a continuing basis. Even though Branch Y really thinks it is inappropriate for one-

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**Figure 2: A Second Illustration**

<table>
<thead>
<tr>
<th></th>
<th>Rule 3</th>
<th>Rule 4</th>
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</thead>
<tbody>
<tr>
<td><strong>X branch</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rule 3</td>
<td>(.5B - .67C), (.5B - .33C)</td>
<td>SQ_x, SQ_y</td>
</tr>
<tr>
<td>Rule 4</td>
<td>SQ_x, SQ_y</td>
<td>(.5B - .5C), (.5B - .5C)</td>
</tr>
<tr>
<td><strong>Y branch</strong></td>
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</tbody>
</table>

third of the adult males, who are benefited by the system, to sit at home while the other two-thirds do all the work, Branch Y might recognize that one adult male per household is considered a fair rule in this setting and not push this proposal to the point of a 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 one of the rules under consideration.

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

Rule 5: All water from the main canal is allocated to a branch in proportion to the amount of labor that the branch provides for construction and annual maintenance.\(^1\)

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:

<table>
<thead>
<tr>
<th>Rules</th>
<th>Branch X</th>
<th>Branch Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rules 1 &amp; 3</td>
<td>.50B -.67C = 10</td>
<td>.50B -.33C = 30</td>
</tr>
<tr>
<td>Rules 1 &amp; 4</td>
<td>.50B -.50C = 20</td>
<td>.50B -.50C = 20</td>
</tr>
<tr>
<td>Rules 5 &amp; 3</td>
<td>.67B -.67B = 27</td>
<td>.33B -.33C = 13</td>
</tr>
<tr>
<td>Rules 5 &amp; 4</td>
<td>.50B -.50C = 20</td>
<td>.50B -.50C = 20</td>
</tr>
</tbody>
</table>

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.

The process of negotiating about rules is hardly 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 radically depending on the other rules in the set.

**Asymmetric incentives**

Many variables potentially create asymmetries among the players in a choice of rules game. In the above analysis, we addressed the possibility that the amount of labor available per household could vary among the players. Now let us introduce a substantial asymmetry related to the physical world. 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 head-end farmers, but not for the tail-end farmers. Irrigators located at the head end of a system have differential abilities 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 abilities of farmers to work together.

In a bargaining situation over the 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 the field.

To the extent that head-end farmers depend on 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 relative to the farmers at the head end than had the amount of resources needed for maintenance been 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 figures 3a, b, and c. In figure 3a, there is no distance between the water source and the head-ender. In figure 3b, there is a short distance; and in figure 3c, there is a long distance. The costs of maintaining these three systems will be lowest for a 3a-type of system ($C'$), higher for a 3b-type of system ($C''$), and highest for a 3c-type of system ($C'''$).

The bargaining advantage of head-ender in systems such as those illustrated in figure 3a is much stronger than in systems such as those illustrated in figure 3b or 3c. 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 and that the labor costs of maintaining systems of the type 3a are 25 units, of type 3b are 50 units, and of type 3c 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: 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 tail-end farmers, and all farmers contribute labor to maintain the system voluntarily (head-enders have prior-rights rules).

Rule 7: Half of the water is allocated to the head end and half of the water to the tail end, and the labor needed to maintain the system is based on the proportion of water assigned to each set of farmers (equal split rule).
If Rule 6 were agreed upon, let us assume the head-enders would take 65 units of water per year. All labor would be contributed by the head-enders. If Rule 7 were agreed upon, the head-enders 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 head-enders and tail-enders would receive zero units of value in the situation of a breakdown.

In systems in which the cost of labor input is the lowest ($C' = 25$), there are two equilibria: both choose Rule 6 or both choose Rule 7. The head-enders would prefer Rule 6 and the tail-enders would prefer Rule 7. The head-enders would try to make a credible assertion that they will agree to Rule 6 and no other rule and refuse to engage in any further bargaining with the tail-enders. While tail-enders prefer Rule 7; Rule 6 does not leave them as disadvantaged as appears to be the case if one were to examine only the impact of the rule allocating water. Tail-enders would not contribute to the maintenance effort of the headworks. The head-enders would expect an annual return of $65 - 25 = 40$. The tail-enders 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 tail-enders do not contribute at all to maintenance, they 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 second situation, in which labor costs are 50 units. But, the preferences of the players are now reversed. Now the head-enders prefer Rule 7 while the tail-enders prefer Rule 6. And the bargaining power of the tail-enders has improved markedly. The tail-enders can credibly assert that the extra water is not worth the labor contribution. Some head-enders might end up agreeing to Rule 6. Under Rule 6, the tail-enders gain considerable advantage from their free riding on the work of the head-enders (head-enders $65 - 50 = 15$ and tail-enders $35 - 0 = 35$).

In systems with the highest need for labor input ($C''/ = 75$), head-enders 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 tail-enders, the head-enders would be willing to guarantee that the tail end receives a full half of the water. Thus the payoff to both segments under the high-cost condition would be 12.5 units.

**Empirical evidence**

The recently published book by Wai Fung Lam (1998), based on data from 150 irrigation systems in Nepal, provides an intriguing set of findings consistent with the game-theoretic analysis presented above. Lam
finds several strong relationships between the physical attributes of irrigation systems, how the systems are governed, and three dependent variables: (a) the maintenance of the physical system, (b) the equity of water delivery, and (c) agricultural productivity. In a series of multivariant analyses (controlling for terrain, size of system, variance in farmer income and other variables), irrigation systems that have been improved by the construction of permanent headworks are in worse repair, deliver substantially less water to the tail end than to the head end of the systems, and have lower agricultural productivity than the temporary, stone-trees-and-mud headworks constructed by farmers (Lam 1998, table 5.6). In contrast, irrigation systems that are governed by the farmers themselves and those in which some sections of the canals are lined with stone or concrete are in better repair, deliver more water to the tail end of the system, and have higher agricultural productivity than unlined systems and those governed by the Nepal Department of Irrigation.

It is quite intriguing that two different types of physical improvements (permanent headworks and partial lining) would have the opposite effect. And many scholars have found it hard to understand why the “primitive” irrigation systems built by the farmers themselves significantly outperform those that have been improved by the construction of modern, permanent, concrete and steel headworks (funded largely by donors and constructed by professional engineering firms). Controlling for the effect of these two physical improvements and other relevant variables, farmer-governed irrigation systems are able to achieve better and more equitable outcomes than those managed by a national agency.

Many factors contribute to these results. Most of them relate to the incentives of key participants in the finance, design, construction, operation, and maintenance of differently organized irrigation systems. On farmer-governed irrigation systems, farmers craft their own rules in processes that are similar to the stylized bargaining games presented above. These rules must counteract the perverse incentives that the farmers face given the physical and cultural setting in which they are enmeshed. The rules are frequently invisible to project planners when they design new physical systems.

In project planning, most of the effort focuses on how improving physical capital, such as creating permanent headworks, affects various aspects of the technical operation of a system. How these variables affect the incentives of participants is rarely explored. Unless the changes in physical infrastructure are undertaken with a consciousness that they will affect the incentives of participants—sometimes in perverse manners—projects intended to do good may generate harm instead.

Once one understands the relative strength and weaknesses of head-end and tail-end farmers, the differential impact of permanent
headworks and partial lining on agricultural productivity in the Nepal context can be explained. Constructing permanent headworks reduces labor contributions dramatically. For example, in the systems analyzed by Lam, the average number of labor days per household in systems with permanent headworks is 2 days while the average is 8.5 days in systems without lining or headworks \( (p = .02, \text{Lam 1998, table 5.10}) \). Those near the headworks can obtain the primary benefit of such an investment and ignore the consequences for others. Partial lining of canals is something that the farmers themselves frequently do using local stone or may be undertaken by contractors as part of an aid effort. The primary beneficiaries of lining are those who are downstream of where the lining exists, since water loss in the lined portions is reduced. Partial lining also reduces the amount of labor time needed to keep a system in minimal repair (down to 5.3 days), but not as much as the replacement of the need to repair diversion works after major rains.

The “equalizer” in many farmer-organized systems is thus a substantial need for the contributions of resources each year by the tail-enders to keep the system well maintained. The need may stem from several physical factors including the yearly reconstruction of the headworks, the clearing and cleaning out of a long canal, or both. In those farmer-organized systems in which substantial resources are needed on a regular basis to cope with maintenance, Lain finds that rules assign water in about the same proportion as resources are mobilized, that more water is allocated to the tail, and that these systems achieve significantly higher productivity (see Lam 1998). Sweat equity can generate more equitable outcomes as well as higher levels of outcomes.

**Why external assistance that ignores social capital does not improve performance**

The above analysis allows us to understand why many effective, farmer-organized systems collapse soon after their systems have been modernized using funds provided by donors or central governments (see discussion below). Project evaluations usually consider any reductions in the labor needed to maintain a system as a project benefit. Thus, investments in modern engineering works 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 head-enders versus tail-enders is not usually considered.

Let us assume that an external donor plans to invest in a system with a physical structure and benefit-cost ratio such as that of figure 3c. 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 4a, in which the only outcome projected is an equal distribution of a higher agricultural yield. The donor assumes that the farmers will somehow work out a scheme to share benefits as shown.

What frequently happens in practice, however, is illustrated in figure 4b. Instead of increasing benefits to 200, the system stays at 100 and the head-end farmers grab 90 units and make no investment in maintenance. Neither the head-enders nor the tail-enders are required to pay the annualized cost of the donor’s investment. The tail-end farmers do not invest in maintenance and receive only 10 units of water. Rule 6 has become the default “might is right.” It is not agreed upon, but rather imposed on, the tail-enders by head-enders who simply take the water.

In such systems, the head-enders can ignore the contribution to maintenance of the tail-enders because for a few years the concrete structures will operate without any maintenance. Of course, at some

**Figure 4: Planned and Actual Results of Some Types of Donor Assistance**

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<th><strong>Head end</strong></th>
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<tbody>
<tr>
<td></td>
<td><strong>Rule 6</strong></td>
<td><strong>Rule 7</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Tail end</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rule 6</td>
<td>[not in plan]</td>
<td>[not in plan]</td>
<td></td>
</tr>
<tr>
<td>Rule 7</td>
<td>[not in plan]</td>
<td>75, 75</td>
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</tbody>
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<th></th>
<th><strong>Head end</strong></th>
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<tr>
<td></td>
<td><strong>Rule 6</strong></td>
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<tr>
<td><strong>Tail end</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rule 6</td>
<td>10, 90</td>
<td>[not feasible]</td>
<td></td>
</tr>
<tr>
<td>Rule 7</td>
<td>[not feasible]</td>
<td>[not feasible]</td>
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time in the future, the productivity of the system will fall. 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 head-enders. A very disruptive aspect of many external assistance projects is that they appear to the farmers as if they were “free.” Without any need for resources from tail-enders, head-enders can ignore the tail-enders’ interests and take a larger share of the benefits.

This type of external “help” substantially reduces the short-term need for mobilizing labor (or other resources) to maintain a system each year. The calculations in the design plans, however, do not always match the results achieved. Without a realistic requirement to pay back capital investments, host government officials and the more influential farmers are motivated primarily to invest in rent-seeking activities and may over-estimate previous annual costs in order to obtain external aid (Repetto 1986). Furthermore, such help can change the pattern of relationships among farmers within a system, reducing the recognition of mutual dependencies and patterns of reciprocity between head-enders and tail-enders that have long sustained the system. By denying the tail-enders 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, 1991).

Past efforts to improve the physical capital of Nepal’s irrigation systems

Most efforts by donors and by the national government to improve the operations of the thousands of farmer-governed irrigation systems that exist in Nepal have focused on the physical capital aspect of irrigation systems and ignored social capital. To illustrate how these interventions have frequently operated in Nepal, I will draw on a study by Rita Hilton, who is now on the staff of the World Bank, analyzing the process of “improving” the Chiregad Irrigation System located in the Dang District of Nepal.19

The construction of the Chiregad system began in 1983 under a joint project of the United States Agency for International Development (USAID)-funded Rapti Integrated Rural Development Project and the Nepal Department of Irrigation (DOI). Construction of a system that serves between 302 and 425 hectares was completed in 1987. The new system was constructed in an area already irrigated by five irrigation systems built, governed, and managed by the farmers who owned the land served by their systems. The existence of these systems was not recognized by the DOI engineers who designed the project without consulting the farmers in the area.
A new, permanent headworks and lined main and branch canals were constructed. The field channels in the system, however, were left basically the same as those used by the five farmer-owned systems. The new construction has shown several serious design and construction flaws. The design engineers did not pay attention to the loose and sand-like soil in the region. As a consequence, the new deep-cut canals have frequently been blocked with mud and cause serious difficulties in operation and maintenance. Slides along canal alignments and poor drainage have brought on major problems at many locations of the system.

After construction, a water-users committee was formally established by the DOI as a mechanism described as one to facilitate farmers' participation in irrigation management. Irrigation officials played a dominant role in the process of forming a water-users committee. The way that a committee was established in these systems is similar to what has happened in many other agency-constructed systems in Asia: irrigation officials came to the system to summon farmers to a meeting and to inform them that a water-users committee had been established in their system. The officials simply appointed the Pradhan Pancha (chairman) of the local panchayat to be the secretary of the water-users committee, and the secretary in turn appointed other members in the committee. As a result, while the Pradhan Pancha—who owned no land in Chiregad’s service area—was given a crucial role on the formal committee, the aguwas (water managers) of the five farmer irrigation systems serving the area incorporated were not even included on it.

The water-users committee was designed as a unitary organization for the entire new system. In other words, other than a committee at the system level, no formal organization was to exist at branch or field-channel levels. As the system is characterized by the existence of a number of branch canals at which communities with distinct interests are located, such a unitary institutional arrangement is highly questionable. On most farmer-governed irrigation systems of any size, branch canals are organized with their own rules and governance arrangements as well as an overall association. Some farmer-organized systems have as many as five levels of organization (Yoder 1994). The formal water-users committee rarely met and undertook few activities. During her fieldwork, Hilton (1990) found that none of the members of the users committee could provide her with information about the characteristics of the system and how the system actually operated.

The formal committee was created and recognized by DOI without any effort to understand how the prior farmer associations had been organized. Each of these farmer associations was related to a mauja (village) and coordinated the efforts of farmers in that village in regard to both water distribution and maintenance. The rules for each mauja differed for water distribution and for resource mobilization related to maintenance. It would appear that the farmers in each organization were
able to design rules that suited the local situation. Furthermore, these organizations were strong enough initially to continue operating in a low-key manner to help with water distribution and maintenance of the system. These traditional organizations were not recognized by DOI. Consequently, their legitimacy and authority have been challenged repeatedly and are eroding.

The five farmer systems used to be able to provide adequate water to farmers located in all five maujas. After the Chiregad system was constructed, farmers in only three of these five maujas consistently received water from the new system. One mauja faces the problem of low reliability of water delivery in the monsoon season, as the canals are often damaged by floods. Another mauja faces the problem of excess water caused by poor drainage. Thus at the end of this effort to improve agricultural productivity through an investment in physical capital, a smaller service area is being served, water deliveries are unreliable, a newly established water-users committee is nonfunctional, and five farmer organizations that used to keep their systems operating well have been severely weakened. Not only is the physical capital of dubious value, a substantial reduction in institutional capital has resulted from this process. Similar processes have occurred with other government-constructed systems (Laitos 1986; Pradhan, Valera, and Durga 1993).

Chiregad is not the most extreme case in Nepal of lack of awareness of the social and physical capital that farmers have already created prior to a project. A more extreme case is the initial East Rapti Irrigation Project (ERIP) funded through credit assistance from the Asian Development Bank. ERIP was to have been initiated in 1987 to build a major diversion weir across the Rapti River and thus provide irrigation to a vast area of the terrain in the Chitwan district of Nepal. The benefits foreseen in the project plan were based on the difference between the productivity of irrigated and unirrigated land. All of the land in the project area was considered to be unirrigated. What is so remarkable about the initial project plan is that more than 85 farmer-managed systems were already providing irrigation services to most of the land in the project area (Shukla and others 1993). That project planners could overlook the irrigation activities of 85 farmer-governed systems in designing a large loan and the construction of a major system illustrates the type of blinders worn by those financing and designing major irrigation investment projects.

Fortunately, in this case, members of the Irrigation Management Systems Study Group (IMSSG) at the Institute of Agriculture and Animal Science in Chitwan had already conducted research in the area and documented the extent and relative efficiency of existing farmer-managed systems. They brought this to the attention of the donor community, which successfully challenged the appropriateness of the original plan. ERIP has now been significantly downsized. Its current objectives are to
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rehabilitate the existing farmer-managed irrigation system in the project area, to invest in various efforts to check stream-bank erosion, to construct better farm-to-market roads, and to construct shallow tubewells where appropriate (IMSSG 1993). Thus, the destruction of prior social and physical capital was averted because local researchers had invested time and energy studying the farmer-governed irrigation systems in the area and had excellent documentation.

While thousands of farmer-governed irrigation systems in Nepal have received no more than occasional small-scale support from external sources, those that have been the object of large, external interventions have frequently had experiences similar to that of Chiregad (or that which farmers in the East Rapti project area might have faced). The reduction in the amount of land actually served by “improved” systems—and the weakening, if not destruction, of the preexisting farmer organizations—is not unusual (Curtis 1991). Something is wrong when efforts to improve agricultural productivity by investing in physical infrastructure have the opposite result.

The policy significance of social capital

In this chapter I have attempted to discuss the similarities and differences among the three types of human-made capital: physical, human, and social capital. Further, I have tried to establish why social capital is an essential complement to both physical and human capital. At the same time, I have also stressed that all forms of capital can be used to produce harm instead of welfare and, thus, the creation of social capital is no guarantee of increased human welfare.

While there are many forms of social capital, I focus in the last half of this chapter on the creation of social capital by self-organized resource governance systems. In particular, I presented a game-theoretic analysis of how a group of farmers might overcome the free-rider problems they face in order to devise a set of rules governing how to divide the benefits and costs of constructing and maintaining an irrigation system. The analysis shows that it is possible for farmers to overcome collective-action problems and devise rules that generate higher levels of benefits for those farmers who agree to participate in such ventures. The analysis also demonstrates that many local variables affect the specific bargaining strengths of diverse participants and the likely rule system that will emerge from such a process.

Empirical evidence drawn from a study of 150 irrigation systems, as well as from case studies in Nepal, supports the game-theoretic analysis. The empirical findings are consistent with reports about the effects of centralized, infrastructure investment in irrigation systems and watershed management that have ignored local institutions crafted by farmers in other parts of Asia. Wherever extremely large sums of loan and
grant funds are channeled through processes that enhance the power (and wealth) of politicians who successfully engage in rent-seeking activities, one cannot expect project plans to reflect on-the-ground conditions accurately. Wherever the engineers assigned to operations and maintenance positions hold low-status positions, are underpaid, and are not dependent on the farmers of a system for budgetary support or for career advancement, one cannot expect large, government-managed systems to perform very well. The results in Taiwan (China) and the Republic of Korea are quite different largely because the incentive systems of engineers assigned to operations and maintenance divisions reward using local knowledge and working directly with farmers (Levine 1980; Wade 1982; Lam 1995).

When farmers select and reward their own officials to govern and manage an irrigation system that they own and operate, the incentives faced by these officials are closely aligned with the incentives of other farmers in the system. System performance is linked to the evaluation made of the performance of the officials. In many centralized, national government systems, no such linkage is present. In cases in which the revenue received by an irrigation agency is not linked to taxes placed on the value of crop yield or the amount of water taken, the agency's budget is not even loosely linked to system performance. When fees are imposed in name only, are not an important source of revenue to the units operating and maintaining systems, and when the hiring, retention, and promotion of employees are in no way connected to the performance of a public facility, nothing offsets the dependency of citizens on insulated officials. The incentives of farmers, villagers, and officials are more important in determining performance than the engineering of physical systems.

Furthermore, the evidence that farmers can overcome local, collective-action problems when they have sufficient autonomy (either because of authorization in the formal legal system or because they live in such remote areas that no one cares about what they do), is also consistent with a substantial literature on the capacity of resource users to govern inshore fisheries, mountain commons, grazing areas, and forest resources in all parts of the world. While the difficulties of sustaining long-term collective action are substantial, the benefits of creating local organizations and selecting locals as leaders who are rewarded for their performance can offset these high costs.

Instead of presuming that local users face an impossible social dilemma or collective-action problem, we are better advised to assume that it is possible, even though difficult, for those facing severe collective-action problems to overcome them. The greater the level and salience of the potential joint benefit and the existence of a supportive political system, the higher the probability that collective action will be undertaken. The impact of asymmetries among partici-
pants depends on the particular types of asymmetries that exist (Keohane and Ostrom 1995).

Donor agencies need to direct their efforts toward enhancing the capabilities of a larger proportion of citizens rather than simply trying to replace primitive infrastructures with modern, technically sophisticated investments. Investing substantial funds that only bolster political careers and build little at the ground level is a poor investment from a donor's perspective. It makes more sense to invest modest levels of donor funds in those local projects in which the recipients are willing to invest some of their own resources than in those projects in which the recipients are only patrons of a client looking for handouts in return for their political support. In such settings, involving users who are willing to invest some of their own resources, an infusion of external monetary capital and the construction of physical capital to complement the institutional capital on the ground may generate much larger returns. If the level of external funding gets very large without being strongly tied to a responsibility for repayment over time, local efforts at participation may be directed more at rent-seeking activities than at productive investment activities.

Entrepreneurship is not simply limited to the private sector. Local public entrepreneurs can develop a wide diversity of efficiency-enhancing solutions to local coordination and collective-action problems, even though they may not achieve full optimality, if there is an enabling environment that enhances their capacities to organize, mobilize resources, and invest in public facilities. Providing fair and low-cost conflict-resolution mechanisms, methods of achieving public accountability, and good information about the conditions of natural and constructed resource systems may be a more important task for national governments than attempting to plan and build local infrastructures throughout a country. In some cases, donors can encourage national governments to reduce the restrictions that exist in national legislation regarding the capabilities of individuals to form local associations, assess themselves to establish a common treasury, and undertake a wide diversity of local, joint projects that would benefit the association. Encouraging such groups to form associations of associations enhances their capabilities to learn from each other, exchange reliable information about what works and what does not work, and monitor the accountability of their own members.

In other words, investing in one of the strategies recommended in the World Development Report 1994, of giving "users and other stakeholders a strong voice and real responsibility" (World Bank 1994, p. 2), may enhance the economic benefits of investments in small- to medium-sized projects that intend to build physical capital as well as human and social capital. Investing in simple-minded, short-term projects to enhance citizen participation, by contrast, has frequently failed in the past (Sengupta 1991; Uphoff 1986). If social capital is conceptualized
too casually and projects are designed to enhance "participation" without substantial changes in the structure of institutions, then the concept will become a shallow fad. One does not give stakeholders a "voice and real responsibility" by creating short-term projects that involve outsiders "organizing the farmers" in sweeping tours of the countryside. Participating in solving collective-action problems is a costly and time-consuming process. Enhancing the capabilities of local, public entrepreneurs is an investment activity that needs to be carried out over a long-term period. Changing the incentives of national, government officials so that their work enhances rather than replaces the efforts of local officials and citizens is a challenging and difficult task. And reducing the level of corruption involved in externally funded projects is an essential but daunting task (Klitgaard 1988, 1991).

Furthermore, our analytical models need to illuminate the incentives of participants whose decisions encompass multiple arenas simultaneously (Hayami and Otsuka 1993). We have misunderstood the rich network of mutual duties and benefits that common-property institutions have generated in much of the world. Recommendations to destroy these institutions are based on an assumption that the capacity to transfer ownership was the most important right in the bundle of rights potentially involved in the ownership of any resources (Schlager and Ostrom 1992). Recent studies of the evolution of indigenous land-right systems in Africa have challenged our analytical assumptions substantially (Migot-Adholla and others 1991; Berry 1993). Investments in new institutions, as well as new infrastructures, need to be based on knowledge that takes into account the multiple incentives that are generated by institutions, as they interact with social norms and the physical world in any particular setting.

We know that social capital in the form of institutions and resulting incentives is a critical factor affecting how physical and human capital affect productivity and growth. Well-developed market institutions, for example, generate incentives for private entrepreneurs to invest in physical, human, and still more social capital. The result of these investments, when matched effectively to local conditions, is substantial economic growth that is attributable to increased productivity. We also know that a polycentric public sector with specialized and general units organized at a local, regional, and national scale helps individuals to solve problems that are not effectively solved through the operation of markets (see V. Ostrom, Feeny, and Picht 1993; V. Ostrom 1991, 1997). An active and entrepreneurial public sector invests in infrastructures (roads, schools, irrigation systems, power generation, and so on) and produces public or common-pool resource goods (public health, natural resource regulation) that enhance the productivity of the private sector (E. Ostrom, Schroeder, and Wynne 1993). And the growth of a private sector can provide the income to build and maintain more infrastructures and pub-
lic goods. It is these mutually reenforcing sets of relationships between private and public sector investments and activities that one can call economic development. Social capital plays as essential a role in achieving that development as physical or human capital. It does not represent, however, a quick fix that can be created by external or top-down processes. People who are facing extant coordination and collective-action problems have to have sufficient autonomy and incentives to build their own ways of working more effectively together.

Notes

1. Transformation activities take one set of physical inputs and transform them into another set of outputs that may then be used in still further transformation activities or be finally consumed. Transaction activities are the relationships among the individuals involved that take time and energy to accomplish the transformation activities. See E. Ostrom, Schroeder, and Wynne (1993) for a detailed discussion of transformation and transaction costs involved in the provision and production of goods and services.

2. The next sections draw on E. Ostrom (1997).

3. Cattle have frequently been a major form of capital accumulation in Africa. Robin Fielder (1973, p. 351; as cited in Bates 1990) notes that the Ilia of Zambia often say that: “Cattle are our Bank.” Fielder continues to explain:

   By this ... they mean a deposit account where their property is saved and where it will increase in value the longer it stays there. Cattle are regarded very much as shares and investments in capitalist societies.... There is no mystery about it at all: the investment is a very sound and highly rational one, and every Ila, educated or otherwise, is imbued with its sense from the time he herds his father’s cattle as a small boy (1973, p. 352; as cited in Bates 1990, pp. 155–56).

4. Parents often invest in the education of their children not only to enhance their children’s future income but also to enrich themselves, especially in developing countries. In Zambia, Robert Bates indicated that: “Parents paid the expenses of educating [their children], imparting sufficient skills that they could successfully compete for jobs in the cities of the Copperbelt. The costs of education were high.... But so too were the returns. For adults devoted resources to their children not only because they loved them but also because they expected later remittances of goods (soap, bedding, building materials, clothes, and pre-
pared foods) and money from children who held jobs in the towns. Taking into account the magnitude and duration of the costs incurred in schooling, the period of waiting for a child to gain employment, and the subsequent magnitude and duration of the payments of remittances, the rate of return to expenditures upon children lay in the range of eight to ten percent” (Bates 1990, pp. 154–55).

5. The broad-based lineage structure of the Luo in Kenya, for example, enables individuals to spread risk. “They can disperse their cattle to family members located in contrasting settings; drought in any particular area is therefore likely to affect but a small portion of the individual’s herd. They can gain access to gardens in different ecological zones.... The lineage form of property rights thus provides insurance” (Bates 1990, p. 158).


7. 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.

8. This section draws heavily on E. Ostrom (1996).

9. The following sections draw extensively on E. Ostrom (1994).

10. The assumptions about common knowledge are strong assumptions. If participants had asymmetric and incomplete information, the results described in this section would frequently be different.

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 enormous in some circumstances. Even in systems that have survived for centuries, consistent evidence shows that some shirking and some stealing is a fact of life (see 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 are selected depends 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.

14. Alternatively, they could be expressed in labor units, as in the more general game-theoretic analysis presented 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. Only pure-strategy equilibria are considered. A mixed strategy does not make sense when the alternative is a rule. However, one can model rule-breaking behavior using mixed strategies (see Weissing and Ostrom 1991, 1993).

16. 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).

17. This is an example of the “weak” exploiting the “strong” (see Olson 1965).

18. In an earlier study, the equity of water delivery was also found to be greater on the traditional, farmer-managed systems as contrasted with more “modern,” agency-managed systems (E. Ostrom and Gardner 1993).

19. The information about the Chiregad system used in this analysis is based on the work of Hilton (1990, 1992) and Shrestha (1988), plus a visit to the site during the spring of 1989 by the author.

20. Bottrall (1981); Bromley (1982); Carruthers (1981); Chambers (1988); Corey (1986); Coward (1979); Easter (1985); Korten and Siy (1988); Plusquellec and Wickham (1985); Reidinger (1974); Sampath and Young (1990); Shivakoti and others (1997); Singh (1983); Wade (1985, 1988); White and Runge (1994); and Wunsch and Olowu (1995. Meinzen-Dick (1994) summarizes extensive literature from Asia, Africa, and the Americas that is highly consistent with the findings in this paper.

21. Berkes (1989); Blomquist (1992); Bromley (1991); Bromley and others (1992); Dasgupta and Mäler (1992, 1995); Eggertsson (1990); Feeny and others (1990); Fortmann and Bruce (1988); Libecap (1989); Martin

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