

Heterogeneity and Commons Management

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Abstract. Despite impressive advances in our understanding of the impact of institutional form on the performance of commons-using communities, unresolved questions remain. An important example is the role of heterogeneity among the users of a community-based natural resource. This survey article identifies the most important types of heterogeneity, the commons outcomes that they might affect, and the mechanisms that link the two. This exercise has policy relevance: if we can discern empirical regularities that link inequality to better or worse outcomes, then this has

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consequences for asset-redistribution programs including land reform, and poverty-alleviation programs that target communities based on the level of inequality.

There are several possible definitions of heterogeneity. We most closely analyze economic inequality -- inequality in wealth or income among the members of a resource-using group. Other types of inequality or heterogeneity include ethnic and social heterogeneity, and environmental or state variables like low levels of trust or social cohesion. (These dimensions of inequality and heterogeneity are frequently correlated.) The inter-related “commons outcomes” that might be affected by inequality include resource conservation, maintenance of infrastructure, the supply of local institutions, monitoring and enforcement of regulations, and conflict resolution. We consider two broad classes of mechanisms that lead from heterogeneity to commons outcomes. Economic mechanisms act through the effect of inequality on individual resource-users’ incentives. Social mechanisms generally interpose an intermediate step between inequality and commons outcomes.

Mancur Olson’s (1965) classic hypothesis supposes that inequality favors provision of a public good -- such as restraint in resource exploitation -- by concentrating so much wealth in one or a few resource-users’ hands that it is in their interest to conserve regardless of what their poorer neighbors do. The result has been confirmed in theoretical and empirical work: inequality can favor better commons management when there are important “non-convexities” -- high fixed costs (e.g., in money, time, or labor) to establishing a community-management regime -- or when each resource user’s cooperative effort is proportional to the benefits derived from the system. When these conditions are not met, however, inequality can harm the prospects for cooperative behavior.

Furthermore, other theoretical and empirical work has demonstrated a U-shaped relationship between inequality and commons management: very high and very low levels of inequality are associated with better commons performance, while mid-range levels of inequality

are associated with poor outcomes. We review this research, emphasizing the importance of the collective action needed to establish local institutions for managing the commons in the first place, and the existence of “exit options” or earnings opportunities outside the commons.

Case studies prevail in the empirical literature. Larger-scale surveys of several resource-using systems that permit statistical analysis of the empirical regularities present on the commons are still relatively rare. We explore two parallel studies of farmer-managed irrigation systems (in Central Mexico and South India) that seek to fill this gap.

We conclude by identifying areas for future enquiry.

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

I

There are several possible definitions of *heterogeneity*, each with different implications for analysis. We will most closely analyze economic inequality -- inequality in wealth or income among the members of a resource-using group. There are furthermore many relevant types of economic inequality: inequalities in the sacrifices community members make in cooperating with commons-management regimes; inequalities in the benefits they derive from such regimes; inequalities in outside earnings opportunities (“exit options”). There are other kinds of disparities that may have economic consequences, and those in turn affect cooperation. For example,

¹ Ours is not the first attempt to survey this literature; see also Baland and Platteau (1999).

locational differences, to the extent that they are not already reflected in landholding or wealth differences, might not be adequately taken into account if one considers only wealth inequality. Head-end and tail-end farmers in irrigation systems face different incentives to cooperate (Bardhan, 1984:215; Ostrom, 1994), as do fishers with access to more or less productive fishing spots (Berkes, 1986). Similarly, differences in ability or efficiency in resource extraction will affect cooperative behavior (Johnson and Libecap, 1982). So too will differences in what economists call *rate of time preference* -- essentially differences among resource users in the degree to which they consider the future in their current extraction activities (Ostrom, 1990:*passim*). Differences in time preference will lead to differential impatience among commons users in making short-run sacrifices for resource conservation. Types of heterogeneity that are not strictly or even primarily economic will also have important economic consequences, as is the case of ethnic heterogeneity (Bardhan, 1997).

Other types of inequality or heterogeneity are measured by environmental or state variables like trust or social cohesion -- the absence of which Baland and Platteau (1995) called *cultural heterogeneity*. Highly unequal agrarian societies might sometimes exhibit widespread adherence to a hierarchical ideology that facilitates monitoring and enforcement of cooperative agreements.² More generally, shared values or interpretations of social problems can facilitate cooperation in the use of the commons. All of these dimensions of inequality and heterogeneity are in any case frequently correlated; we will generally focus on economic inequality, but mention will be made of other types of inequality and heterogeneity.

Why is inequality important? Generally speaking, if we can discern empirical regularities that link inequality to better or worse commons outcomes, then this has consequences for asset-

² Fafchamps (1992) explores the emergence of such patron-client relationships in agrarian economies using the theory of repeated games.

redistribution policies like land reform, and for poverty-alleviation and development programs that target communities based on the level of inequality.

II

How does heterogeneity affect commons outcomes? The answer depends on which “commons outcomes” we mean. There are many of those: the success with which a community of resource users conserves a resource system (whether through a formal regulatory regime, or through social norms that prevail even in a community with no explicit resource-using rules); the success with which a community crafts rules for managing the commons (what Ostrom (1990) referred to as the problem of *institutional supply*); the success with which a community monitors and enforces its regulatory regime; and the success with which a community resolves conflicts and modifies the regulatory regime in response to changes in social and environmental conditions.

As a first cut, mechanisms that lead from heterogeneity to commons outcomes can be categorized, inelegantly, as economic and social. *Economic* mechanisms act through the effect of inequality on individual resource-users’ incentives to cooperate with others. *Social* mechanisms generally interpose an intermediate step between inequality in the distribution of wealth, and commons outcomes. Namely, inequality of one sort or another weakens what might be called *social cohesion*, and social cohesion in turn favors cooperative behavior in the economic sphere. Indeed, Knack and Keefer (1997) find, based on macroeconomic data, that the level of trust in a country (a measure of social cohesion) has a quantitatively large and positive impact on rates of economic growth. Moreover, the authors find that trust, in turn, is negatively affected by the level of inequality. Bénabou (1996) demonstrates the many ways that inequality can increase social conflict at the macroeconomic level, consistent with this evidence. Dayton-Johnson (2000b)

provides a simple game-theoretic model that demonstrates how social cohesion can lead to efficiency-enhancing cooperative behavior. These social mechanisms are especially salient in the village economy. Commons users in homogeneous villages can rely on social norms and abundant knowledge of others' actions to monitor and enforce cooperative behavior; in less homogeneous settings, the power of these mechanisms is weakened. (This is borne out by the Mexican and Indian evidence considered in the next section.)

“Olson effects”.

Olson (1965:34), in a classic hypothesis, supposes that inequality may favor provision of a public good:

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

Restraint in resource exploitation and cooperation with maintenance efforts (e.g., fire-prevention measures in community forests or canal-cleaning in irrigation systems) are approximately public goods: one villager's actions provide benefits to most or all other members of the community.

Thus Olson's hypothesis suggests that inequality is beneficial to successful commons management.³

³ This result is generalized in a pure public-goods model by Blume, Bergstrom, and Varian (1986). (Parenthetically, Blume et al. sought to dispel the earlier conventional wisdom in economics, namely, that changes in the distribution of wealth would *not* affect the overall level of public goods provided in society.)

The Olson effect makes sense if, for example, each farmer in a community-managed irrigation system is responsible for cleaning the portion of the common canal network that passes through his or her land *and* if the amount of canal passing through one's land is proportional to one's landholding size. Then an irrigator's payoff from canal cleaning is larger, the larger is his or her landholding wealth. This is the case in Leach's (1961) account of collective duties known as *rajakariya* or "king's work" in the pre-independence Ceylonese village of Pul Eliya.

Olson effects are also likely if there are large fixed costs involved in setting up a commons-management regime. These costs might be material, such as the building of fences around pasturelands, or the construction of irrigation canals. Such start-up costs also involve the organizational effort to collectively mobilize a community of resource users. Vaidyanathan (1986) illustrates the historical importance of local élites in promoting the emergence of irrigation-management regimes in India, China, and Japan. Large start-up costs of this type are an example of *non-convexities* in the production technology. Roughly speaking, benefits from collective action are a non-convex function of the effort provided to produce those benefits if there is a threshold level of aggregate effort that must be supplied before *any* benefits are realized. As effort increases beyond the threshold, however, benefits to the group begin to increase. Irrigation, for example, provides no benefit until the expense of building a dam, or drilling a tubewell, has been undertaken; but thereafter added effort systematically increases crop yields. In this setting, wealthier farmers may be able to mobilize the capital necessary to build the dam or install the tubewell. Non-convexities also exist if there is a threshold stock of the resource (e.g., fish or pasture) below which regeneration is impossible. Baland and Platteau (1997) confirm the theoretical possibility of this Olson effect when there are such non-convexities. Widening inequality in this setting can lead to discrete jumps in cooperative actions (e.g., maintenance effort or restraint in resource use) by the

wealthier players. But they show that this result depends critically on assumptions about the characteristics of the resource-using technology.

A more complicated relationship.

It is of course simple to imagine irrigation systems wherein the canal length passing through one's parcel is not proportional to one's parcel size, or commons where there are no significant non-convexities. In such cases, the Olson effect need not hold. Indeed, the (quite heterogeneous, incidentally) field work seems to speak with one voice, and that voice says that inequality is harmful. Consider a handful of Indian irrigation examples. Jayaraman's (1981) study of surface-water irrigation projects in Gujarat notes the importance of a relatively egalitarian structure to farmers' coming together to form a water users' association. Similarly, Easter and Palanisami's (1987) study of ten tank irrigation groups in Tamil Nadu shows that the smaller the variation in farm size among farmers, the more likely that water users' associations will form. Tang's (1991) synthesis of several studies of irrigation communities in many countries finds that "...a low variance of the average annual family income among irrigators tends to be associated with a high degree of rule conformance and good maintenance."⁴

The ambiguous relationship between inequality and successful commons management is borne out by more recent theoretical work in economics. Dayton-Johnson and Bardhan (1999) verify the Olson effect in a model of the commons, but show, nevertheless, that the relationship between inequality and conservation is U-shaped. They assume two things. A linear harvesting technology means that a given increase in harvesting effort always leads to the same increase in resources harvested, until the resource is completely depleted: sending one more boat into the fishery always increases catch by, say, 1000 tons as long as there are still fish in the sea. Second,

there are no formal rules constraining commons users. With these assumptions, Dayton-Johnson and Bardhan find that communities with more equal distribution of wealth might exhibit higher rates of resource conservation than more unequal ones. Resource harvesters with wealth below a threshold level will not conserve, regardless of what others do. Beyond that threshold, however, a resource user will conserve *conditional* on the conservation of others on the commons. If sufficiently many resource users have wealth below the threshold -- a consequence of inequality -- then conservation will break down.

Bardhan et al. (2000) discuss a general model of collective goods; they introduce a distinction between public goods and the commons. When the positive spillovers from the provision of these collective goods outweigh negative spillovers associated with common use, these are public goods. When these negative spillovers dominate the positive ones, then the collective good is a common-pool resource. Positive spillovers include the benefits to third parties such as unpolluted air that results from a pollution-abatement technology. The negative spillovers are the classic congestion externalities of common-pool resources: when more fishers exploit an open-access fishery, for example, it raises costs for all fishers. Bardhan et al. show that market imperfections (for example, in land, credit, or insurance) -- a pervasive feature of poor agrarian economies -- complicate the Olson effect. In particular, the effect of inequality depends on whether we are considering a public good or a common-pool resource as defined above. In the commons case, if these goods (credit, agricultural land) are complementary to the commonly-provided resources (water, grazing land) in households' production, then overall efficiency (measured by the gross rate of return on the collective good) rises with increases in inequality. (Water and land, for example, are said to be *complementary* if increased use of water raises land productivity, and vice

⁴ See Bardhan (1995) for further examples from the case-study literature on farmer-managed irrigation systems in Asia.

versa. The definition generalizes to any two factors of production.) This is consistent with Olson. But in the case of public goods, overall efficiency falls as inequality rises.

Economic inequality might influence commons outcomes via differences in costs of resource harvesting. Although it is likely that, if there is any difference in costs, richer commons users will enjoy lower input costs, inequality in costs is conceptually distinct from inequality in wealth or income. Aggarwal and Narayan (1999) provide a two-stage model of groundwater use that incorporates differences in cost among water users. They show that the relationship between inequality in costs and extraction efficiency is U-shaped: starting from low levels of cost inequality, increasing inequality first reduces, then increases, water-use efficiency.⁵

Institutional supply.

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

⁵ Baland and Platteau (in press) note that the effect of increased wealth inequality on inequality in costs is likely to be hard to predict. On the issue of cost inequalities on the commons, see also the paper by Hackett (1992).

arrangement, and hence will oppose it. (This logic is further developed in Kanbur (1991) and Baland and Platteau (1998).)

In a related vein, Quiggin (1993) hypothesizes that common property arises as a legal mode where there are certain scale economies in production (as in Baland and Platteau's (1997) non-convexity case, summarized above). Wealthier agents will gain less from economies of scale from collectively-owned assets and consequently could seek such a high share of benefits from the collective organization that the group fails to form. (Parenthetically, these mechanisms might be viewed as variants of the macroeconomic redistributive-pressure mechanism modeled by Persson and Tabellini (1994). Inequality in their model leads to pressure from below to redistribute income; this in turn leads to a tax on capital that lowers investment and growth. In the arena of institutional supply on the commons, in contrast, the wealthy require more of the notional gains from cooperation than the poor are willing to accept and commons-management regimes fail to emerge.)

In both the Johnson-Libecap and Quiggin stories, the feasible set of institutional arrangements is restricted in some way; this restriction makes it impossible to craft an arrangement that satisfies both rich and poor commons users.

Exit options.

An important complication is the presence of exit options. If resource-users have relatively lucrative earnings opportunities outside the commons, this can affect their individual incentives, as well as the power of social cohesion to promote cooperative behavior. Dayton-Johnson and Bardhan (1999) demonstrate that the effect of exit options on conservation is predictably complicated, but depends in part on the nature of relationship between wealth and the exit options.

If a resource harvester's exit option is a concave function of wealth -- meaning that the value of the outside option rises very quickly with wealth at low levels of wealth, but increases more slowly at higher wealth levels -- then increases in inequality, starting from relatively equal wealth distributions, will reduce conservation. In that case, the relatively poorer harvester will optimally choose not to conserve: as her wealth declines, her gain from conserving falls off more rapidly than her gain from exercising her exit option. If on the other hand the exit option is a convex function of the wealth level (which would be true, for example, if villagers faced borrowing constraints) then increased inequality might either enhance or damage the prospects for conservation: the effect is indeterminate.

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

land or to buy supplementary fodder in the market, tend to be uninterested in the sustainable management of the remaining commons. Fujita et al. (1999) studied a large number of public irrigation systems in the Philippines and found that, where non-agricultural economic opportunities were more readily available the groups were less successful in meeting their objectives.

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

III

The foregoing discussion demonstrates the richness of the empirical literature on the commons. A careful reading of that literature demonstrates that case studies (whether by anthropologists, political scientists, sociologists, engineers, or the odd economist) prevail. Larger-scale surveys of several resource-using systems that would permit statistical analysis of the empirical regularities present on the commons are still relatively rare. Ostrom, Gardner, and Walker (1994) attempt to remedy this shortage by systematically combining the results of the voluminous case-study literature on irrigation systems, community forests, and fisheries. While useful, such “meta-evaluations” are not substitutes for survey research of large groups of resource-using communities. Careful compilation of case studies cannot address biases in the selection of studied systems. In

this section we explore two parallel studies of farmer-managed irrigation systems that seek to fill this gap.⁶

Dayton-Johnson (1999) describes a field study that explores rules and performance in 49 irrigation systems known as *unidades de riego* in the central Mexican state of Guanajuato. All of the *unidades* are formally independent of state control and are managed by the irrigators themselves. Dayton-Johnson (in press) estimates three statistical models of the quality of maintenance of the *unidad* infrastructure. Three indicators of maintenance -- degree of definition of canal side-slopes, state of repair of field intakes, and degree of control of leakage around the canals -- are taken to be measures of the level of cooperative effort supplied by *unidad* members. The analysis finds that social heterogeneity, measured by the number of different villages from which the users of a given system are drawn, is consistently and significantly associated with lower levels of infrastructure maintenance. Inequality in landholding has a negative, though complicated, effect on maintenance.

Dayton-Johnson (2000a) studies the effect of inequality on the choice of institutional arrangements. The paper estimates a statistical model of the likelihood that a *unidad* has chosen a rule that allocates the irrigation supply proportionally to landholding --- that is, households with more land get more water. Economic inequality strongly increases that likelihood. The analysis of cooperative effort above showed that this type of distributive rule is associated with lower levels of infrastructure maintenance, likely the result of higher system-wide transaction costs of implementing such a rule. This evidence is consistent with the interpretation that wealthier

⁶ Recent empirical research on producer cooperatives in developing countries can be interpreted as part of the same research agenda. See the recent studies by Banerjee et al. (1997) and Seabright (1997). Similarly, empirical studies of people's propensity to join voluntary organizations in Paraguay (Molinas, 1998) and rural Tanzania (La Ferrara, 1999) demonstrate a negative effect of economic inequality. A very different body of empirical work has sought to replicate commons situations in laboratory experiments. The work of Cárdenas (1999) is interesting in this context in that his experimental subjects were actual commons users from rural Colombia. He finds that variance in *actual* wealth levels

landholders successfully press for larger shares of the irrigation supply. The study also finds that older water users' associations are more likely to have chosen this type of proportional distributive rule; perhaps the performance penalty of the proportional rule is lower in longer-lived irrigation groups that have learned to implement more-complex rules more efficiently over time.

Bardhan (2000) applies a similar framework to the study of 48 irrigating villages in the South Indian state of Tamil Nadu. Bardhan measures cooperation not only in terms of quality of maintenance (as in the Mexican study above), but also in terms of absence of conflict, and the extent of rule violations. Landholding inequality is negatively associated with maintenance quality, as in the Mexican study.⁷ The strength of connections to urban centers is negatively associated with maintenance, supporting the importance of exit options in determining cooperative outcomes. Landholding inequality is similarly negatively associated with the prevalence of water-allocation conflicts during recent years. In this connection, Bardhan finds some evidence of a U-shaped relationship between inequality and cooperative behavior. Moreover, caste homogeneity is significantly and positively associated with the absence of such conflicts. The effect of inequality on the frequency of rule violations is not significant, but the proximity of the urban center is positively and significantly associated with such violations. There is some (weak) evidence that when farmers have access to alternative sources of irrigation they tend to violate the water rules more frequently.

The South Indian study also provides significant evidence that when the water-allocation rules are crafted by the village élite, the latter violate the rules less frequently; otherwise the élite are the more frequent violator of rules. It is also observed that when an average farmer believes

makes subjects less likely to cooperate in the laboratory. (His paper also provides references to other, more conventional, experimental treatments.)

⁷ Varughese and Ostrom (1998) also find a modest negative correlation between the level of wealth disparity and collective activity in forest use in eighteen Nepali villages.

that the water rules have been crafted jointly (i.e., with collective participation, as opposed to rule crafting only by the village élite, or by government), he is more likely to have positive comments about the water-allocation system and about rule compliance by other farmers.

Bardhan also estimates the likelihood that villages have adopted proportional cost-sharing rules -- i.e., rules that specify that the labor costs of maintaining irrigation infrastructure are shared proportionally to wealth. This rule is in general positively associated with cooperative outcomes; adoption of this rule is, in turn, significantly and positively associated with landholding inequality. This might be an indication of social pressure for a redistributive adjustment of the cost-sharing rule to take account of wealth disparities. This points to an important and more general observation noted by Varughese and Ostrom (1998). They find that many groups “overcome stressful heterogeneities by crafting innovative institutional arrangements well-matched to their local circumstances”. In their Nepal study, forest users created diverse forms of memberships with different rights and duties to cope with heterogeneity, particularly when there are substantial benefits to be obtained through collective action.

IV

The Mexican and Indian field studies discussed in the preceding section indicate the complementary role that such larger-scale survey research can play in combination with the now considerable stock of case studies. More such studies, carefully linked to theoretical work (whether economic or based on the other social sciences) will continue to illuminate our understanding of the functional role of inequality on the commons.

One theme that emerges in reviewing the role of inequality is that the problems of successful commons management are not necessarily based on the characteristics of the natural

resource itself -- as the earlier, tragedy-of-the-commons tradition would have it -- but rather the more prosaic problem of getting people to cooperate. Thus the problem is particularly closely related to those of producer and worker cooperatives. Mobilizing cooperative effort is especially problematic at the level of institutional supply, but also in the running of the institution.

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

Having emphasized, however, the social problems of natural-resource management, there is also scope for more work that more carefully integrates these complicated social interactions with characteristics of the resources in question --- as Ostrom, Gardner, and Walker (1994) begin to do. Much of the theoretical work to date in economics relies on rather special assumptions regarding resource-harvesting technology and resource regeneration. Natural scientists could provide superior models of the way resources regenerate, and the way that regeneration responds to external influences like human activity. Interdisciplinary cooperation across the natural science/social science divide could prove fruitful in this connection.

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