## Common Property Economics

*Common Property Economics* presents the theory of natural resource exploitation under the management institution of common property, differentiates common property from open access, and tests the adequacy of resource allocation under common property empirically. Theoretical models demonstrate overexploitation under open access, and the book defines the necessary and sufficient conditions for common property. Stevenson clarifies common property with historical examples, with common property's basis in legal theory, with a contrast to public goods, and with a discussion of the transactions costs of establishing and maintaining common property. Swiss alpine grazing commons are contrasted with grazing in the English open field system, and statistical work using Swiss data compares the performance of common property with that of private property.

# Common Property Economics

## A General Theory and Land Use Applications

**Glenn G. Stevenson**

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*To Inger and Wallace*

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# Preface

A preface often justifies an author's having brought pen to paper. I have left that task to my first chapter. Here, I wish to relate how I came to Switzerland and to write this book, discuss how I pursued my research, and thank some people for their part.

Before I left for Switzerland to study the Swiss grazing commons, I had little notion that the inquiry would turn into my doctoral dissertation and no idea that it would become a book on open access, private property, and common property. I simply wished to return to a country that I had glimpsed and for which I had developed an ardency during an undergraduate stay in neighboring Germany. Professor Richard C. Bishop of the University of Wisconsin–Madison discussed with me his interest in the Swiss grazing commons as an example of common property, and given my knowledge of German and desire to revisit the country, the basic ingredients for an application to the Fulbright-Hays program existed. The opportunity to go arose with the awarding of a Swiss government fellowship through this program.

Studying the Swiss commons called on me to travel widely in Switzerland by bus and train and even on foot, speaking with farmers, academics, government officials, and fellow students. I put my bags down in St. Gallen, Switzerland, for most of my stay, living with three Swiss students studying at the Graduate School of Business and Economics in St. Gallen, but I also lived for a period in Bern to be closer to the subject of my most intensive study, the Bernese alpine grazing areas. Because of the gracious welcome I received from the people I moved among, I came to know the Swiss, their country, their language, and their culture as well as an outsider might in two years' time.

I employed a number of methods to reach the two goals that I set out for myself in Switzerland: to understand common property rights systems and to find a way to compare the economic performance of commons and private grazing. Initially I met with specialists in alpine agriculture at the Swiss Federal Department of Agriculture. These men had visited hundreds of alpine grazing areas in the course of a two-decade-long, federally sponsored land registry effort. These experts and the reports they wrote were helpful to me repeatedly. As my research continued, I extended such contacts to the cantonal level and to the universities, gathering the wisdom of authorities on alpine grazing among agriculturalists, economists, ethnologists, and government and cooperative association officials.

To understand the commons rights systems and formulate the commons categorization found in Chapter 4, I tapped the wealth of descriptive material in the university libraries in Zürich, Bern, and St. Gallen. I also visited many alpine grazing areas to observe their conditions and examine the farmers' operations firsthand. I inspected their barns and milk and cheese production facilities; I talked to the farmers about their operations; I even shared some meals and spent some nights with the alpine graziers in their alp huts. I began using a questionnaire to gather consistent data on costs, returns, and rights types from the users, recording my interviews on tape. In addition, I observed user meetings of various types, ranging from small commons user meetings of a half-dozen individuals around a Swiss tavern table to large, open-air meetings of the *Korporations* of inner Switzerland, in which several hundred farmers participate. I attended town meetings in communities that own grazing areas, *Korporation* legislative and executive body meetings, celebrations before ascensions to the mountain pastures, and other types of commons meetings.

For a year, I searched libraries, government agencies, and private institutes for data on the grazed condition of private and commons grazing areas to compare the impacts of the different property systems. I finally concluded that such data were not available for more than a handful of grazing areas. As a proxy, I decided to use milk yields, which were available from milk producer associations. I subsequently developed intimate ties with personnel at one such organization.

I note as an encouragement to future researchers in foreign environments that part of my success derived precisely from my being an American student studying alpine grazing in Switzerland. I believe that this set of circumstances intrigued the Swiss ("Why would an American want to study *that*?"). Because of this fascination, because I came to them in their own language, because the Swiss generally like Americans, and because the Swiss are an extremely considerate people, I was afforded their fullest attention and hospitality.

Whereas the Swiss research provided the substance for understanding an operating common property system and the data for an empirical comparison with private management, other parts of the book had their beginnings in the United States. My review of open access theory and the development of a theory of common property germinated during my graduate course work and dissertation research at the University of Wisconsin–Madison. Open access theory is well known among economists, but I hope to have added something by tying it together and studying the important question whether excessive inputs come from existing users or new entrants. My development of common property theory builds on the seminal concept from S. V. Ciriacy-Wantrup and subsequent elaborations by Bishop and Bromley. Of course, my development of the theory also incorporates others' ideas from the literature. The evolution of the theory progressed after I joined Oak Ridge National Laboratory in 1984; I continued to change and refine my definitions and my thought on common property from the ideas found in my doctoral work. The book's finishing touch is a description of common grazing under the medieval English open field system and a comparison of it with the Swiss commons. This expansion arose from the suggestion of a reviewer for Cambridge University Press that caused me to delve into intriguing new secondary source research. The resulting chapter, I think, is a nice extension to a contrasting common property system.

I owe thanks to many people, whose whereabouts span two continents. Although the book has undergone extensive revisions since I finished my doctorate, my greatest gratitude is to Richard C. Bishop, my academic mentor and personal friend, whose patience, intellectual curiosity, and personal integrity mark him as an exceptional man. His contribution is embedded in every sentence of my doctoral dissertation, which served as the initial draft of the work before you. Daniel W. Bromley played the role of a second major professor, and his influence throughout the book is considerable. He suggested to me a number of ideas that are developed here, especially in the property rights section of Chapter 3. The third major influence on the work comes from Anthony D. Scott, who initially served as an anonymous reviewer. Professor Scott graciously consented to disclose his name so that I could thank him publicly. His input caused me to rethink and research anew; reformat, prune, and winnow; defend, create, and rewrite throughout the book. I am deeply grateful for his comments.

Other substantive contributions came from Don W. Jones, especially in helping me rewrite Chapter 6 but also in theoretical thought and moral support elsewhere in the book. Arthur Goldberger and Jean-Paul Chavas were helpful in forming some of the econometric questions, although any errors that remain are mine. Matthew Hendryx, an economist and my editor at the press, contributed to the definition of common property. I am indebted also to Colin Day, formerly of Cambridge University Press, whose vision for the book initially got the project off the ground, and to Ina Isobe and Janis Bolster of the Press, who also provided gentle, helpful advice. Alexa Selph was instrumental in preparing a thorough index.

This book would not have been possible without the warm reception of the Swiss people. The Swiss government generously provided the two-year fellowship. In addition, the Swiss people welcomed me with open arms into their offices and homes and onto their agricultural operations to answer my questions. I am forever indebted to them for their graciousness. Particularly the users of the alpine grazing areas, several dozen of whom I could mention, deserve my heartfelt thanks. In the Swiss Department of Agriculture, Mr. Fritz Aeschlimann, Mr. Adrian Imboden, Mr. Andreas Werthemann, and Dr. Josef Von Ah gave me their time to explore my questions and data requirements. Mr. Aeberhardt of the Bernese Milk Producers' Association deserves particular recognition for his aid in gathering information on milk yields from his files. I also thank Mr. Ulrich Peter, Director of the Association, for permission to use the Association's information on milk yields. In the Bernese Cantonal Tax Administration, I am immeasurably indebted to Mr. Würgler of the Agricultural Inspectorate, who personally wrote requests for assessment sheets on alpine grazing lands and gathered hundreds of them into his office. I thank Jack Solock for assistance in data entry and Allison Baldwin for the high-quality graphics throughout. I also acknowledge the support from the University of Wisconsin Graduate School at the dissertation stage.

Finally, general support from friends and colleagues has been invaluable to me. First, I wish to give a word of appreciation to my Swiss roommates, Franz Broger, Martin Noser, Andreas Joost, Jürg Amrein, and Ruedi Reichmuth, for helping an American out of his cultural element and away from his mother tongue. Tom Wilbanks of Oak Ridge National Laboratory provided assistance, Tony Catanese a reviewer's eye, and Shelby Smith-Sanclare and Carl Petrich the moral support of friends. Finally, I especially want to thank Melody Gaye Stone and Dianne Knief, both of whom supported me when I was laboring hard on the dissertation and the book and who have enriched my personal life.

CHAPTER 1

# What Is Common Property?

## A Confusion of Definition

Since the publication of Garrett Hardin's influential article in *Science* (1968), the "tragedy of the commons" has become a household phrase among economists and others concerned with environmental and natural resource problems. The concept has been used to explain overexploitation in fisheries, overgrazing, air and water pollution, abuse of public lands, population problems, extinction of species, fuelwood depletion, misallocation in oil and natural gas extraction, groundwater depletion, wildlife decline, and other problems of resource misallocation. Yet the rush to explain with a single concept a whole range of natural resource problems—which happen to be similar only in having multiple users—has obscured some important distinctions in the physical characteristics and the manner of use of these resources. We ought not to fall prey to a "tyranny of words," as Leamer (1983) in another context aptly warns, for the "tragedy of the commons" is such a catchy phrase that we are wont to apply it indiscriminately. We look about us and everywhere find resources being used by groups of people in common and are tempted to say, "Aha! Here is another 'tragedy of the commons.' "

What is this "tragedy of the commons"? The next chapter reviews the theory behind it in detail, but I will state it briefly and intuitively here. Where resource use is unlimited, many users are present, and there is excess demand for the resource, overexploitation results. It is said that "everybody's property is nobody's property," as each user rushes to harvest the resource before the next person does. Abuse of the resource occurs because each user, while striving for private gains, can spread some of the costs of his or her use to the other users. Hardin's (1968: 1244) classic description of a grazing commons illustrates this process in simple terms:

As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility *to me* of adding one more animal to my herd?" This utility has one negative and one positive component.

1) The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1.

2) The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of −1.

Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited.[1]

Although faults exist with some particulars of the reasoning—there is for instance a theoretical limit on the herd's increase—the argument is compelling. How is it then that some commons seem to survive despite the dire predictions of tragedy? For example, the Swiss alpine grazing commons, which serve as the major case study for the current work, have been in use in some cases for a thousand years. If the tragedy of the commons always occurs, then surely it would have transpired in Switzerland by now. Dahlman (1980) points out that common property was the preferred form of land management for grazing across northern Europe for centuries during the Middle Ages. He argues that this was not due to the ignorance of the peasants who used the land, but that it was economically rational. How are these counterexamples reconcilable with Hardin's "tragedy of the commons"?

The answer is quite simple. I have pulled a sleight of hand, but it is casuistry that the literature on "common property" has performed over and over again. Hardin's commons and the grazing commons of Switzerland are two different systems. Indeed, Hardin's commons and many examples of common property ought not to be spoken of in the same breath. What distinguishes them? There are two things, the main one being limitation of entry. The inputs to Hardin's commons may increase until economic exhaustion of the resource occurs. In the common property systems that have survived, people have learned to limit use. The second distinction is that with limited entry often comes coordinated management. There is no coordinated man-

[1] Quoted by permission of the author and the American Association for the Advancement of Science. Copyright 1968 by the AAAS.

agement in Hardin's "commons" because no identifiable group has been distinguished as the managers. Where limited entry has been accomplished, the group of included users has the ability to collude and systematize use.

These distinctions seem basic, yet all too many students of resource use institutions have missed them. The class of resources that has been labeled "common property" should more accurately be divided into two subsets. The subset that experiences overuse should be labeled "open access resources," for it is unlimited access that causes the tragedy. The subset that has succeeded by limiting access and employing joint management is *true* common property. For reasons that Chapter 3 makes clear, this subset retains the label "common property" in the present book; in short, only when access has been limited can one talk about "property."

Thus, the condemnation of a potentially viable resource use system, true common property, has been due partially to a problem of semantics. "Common property" has been applied to any natural resource used in common, whether it is an open access resource or a limited access, managed resource. Because the theory in which a tragedy results really applies only to open access resources, rightfully speaking one would talk about the "tragedy of open access." Partly as a result of the semantic problem, however, the belief has grown that any multiple-user system will lead to overexploitation.

This confusion between open access and common property resources has not had benign consequences. Certain authors, launching their reasoning from the assumption that all commonly used resources are overexploited, conclude that there is only one solution: private property.[2] Private property, of course, is one solution to the open access problem. A secure, exclusive right to resource extraction imparts the incentive to the user to utilize the resource at an optimal rate: The private rights holder not only reaps the benefits but also incurs all the costs of additional resource extraction, and a balancing of these benefits and costs leads the user to an optimal extraction rate.[3]

There may be a problem, however, in thinking that private property is the *only* solution to open access. Common property, in which group control over the resource leads to the balancing of benefits and costs, might also be a solution. The ardent private property advocate

[2] Defenders of this position include Demsetz (1967), Cheung (1970), Alchian and Demsetz (1973), Anderson and Hill (1977), and Libecap (1981).

[3] Of course, for private property to provide the optimal solution, there must be no divergence between social and private discount rates, no externalities, no imperfect capital markets, and no other market imperfections.

refuses to recognize this possibility because of the belief that individual incentives to cheat will ruin a group solution. This position, however, ignores the incentive that individuals have to collude: Through collusion, the group can increase the size of the joint product that they divide.

It is important to recognize that common property might provide a solution to the open access problem, because certain resource characteristics or social situations may require a common property solution, whereas a private property solution might fail. Consider a fishery, a groundwater aquifer, or certain wide-ranging wildlife. How do we vest private property rights in such natural resources? Short of committing them to a sole owner, which may be completely incompatible with optimal firm size, it is impossible. The resources themselves cannot be physically divided up into individual units. Clearly, if these resources are to be exploited, multiple users must perform the job. To avoid the undesirable results of open access, some type of common property solution must be found.

Thus, the physical characteristics of the natural resource sometimes dictate a common property solution. At other times, the social circumstances do so. Runge (1981) has pointed out that some traditional societies have long depended on group use of a natural resource. Where technological change, population growth, or contact with a nonlocal market economy has rendered traditional use rules incapable of properly allocating the resource, a new solution has to be found. Because of the society's experience with group control over resource use, the people may accept a common property solution more readily than a private one.[4] In such cases, moreover, adverse impacts on wealth and income distribution, which are a regular occurrence when common property is transformed into private property, can also be avoided.[5]

Some agreement between the conventional wisdom that supports

[4] Bottomley (1963: 94) provides an example of this in his study of land use in Tripolitania. He advocates increasing the rents accruing from the resource by vesting private property rights in trees, but he urges that the land on which the trees grow remain in tribal control. The land should remain common property because "attempts to violate hallowed rights regarding common land will, no doubt, run into considerable resistance."

[5] The culmination of the enclosure movement in England during the eighteenth and nineteenth centuries is often cited as an example of wealth transfers from poorer to richer classes as commons were converted to private property. One epigram of unknown authorship from the period, quoted in Cheyney (1901: 219), is

> The law locks up the man or woman
> Who steals the goose from off the common
> But leaves the greater villain loose
> Who steals the common from the goose.

private property and a view that backs common property as a solution might be ferreted out. Open access is an undesirable regime under which to exploit a natural resource, at least when extraction becomes intensive. The theory of the next chapter makes this plain. The solution that is often given is to "vest property rights" in the resource in certain users. Vesting property rights means defining who may participate in resource extraction and to what degree, and designating who makes the management decisions regarding the resource. But it is important to note: Common property performs these tasks within the framework of group control, even as private property accomplishes them under individual control. Common property also possesses a set of property rights relationships designed to eliminate open access exploitation. The number of users is limited, each user understands how much of the resource he or she may extract, and decisions about resource allocation are made by some group process. Property rights have been vested in this situation, and they may be adequate to prevent the tragedy of open access. The advocate of vesting property rights who recognizes this may agree that common property provides a viable solution. Those in the mainstream who insist on vesting property rights in scarce resources and the defenders of common property are perhaps not all that far apart.

Thus, although private property can provide the incentives to attain proper resource allocation, it may not be the solution toward which all resource allocation systems must move. To investigate this idea, this book develops theory to characterize common property and examines empirically whether it competes economically with private property.

## Objectives

I can summarize the previous discussion by saying that (1) open access and common property regimes are generally confounded with one another, and (2) common property is consequently condemned as inferior to private property. In view of this, the current work's main task is to separate out the three use systems and to look at resource allocation under each. With this general goal in mind, the study has the following objectives:

1. To differentiate open access from common property conceptually and theoretically;
2. To describe real-world, working examples of common property, including mechanisms for resource protection and management;

3. To formulate hypotheses and empirically test whether common property protects the resource as well as private property;
4. To draw conclusions about the efficiency of common property and apply common property principles to other natural resources that can be exploited jointly by a number of economic units.

## The Swiss and English Commons

The current work concentrates on the alpine grazing commons of Switzerland as an example of an actual, working common property system. Examining this system provides an understanding of the structure and functioning of a common property institutional setup, as well as supplies information for empirical testing. The study also examines commons grazing in medieval England in order to investigate the commons system in another environment and compare it with the Swiss case.

The alpine grazing areas in Switzerland are seasonal pastures to which cows and other animals are driven in the summer. They lie in the mountains above the villages, which are nestled in the mountain valleys. Fortuitously, different rights systems have developed on different grazing areas. One finds private grazing areas intermixed with common property grazing areas, and thus the opportunity for comparison exists.

The study area for the present work is restricted to the German-speaking part of Switzerland. This encompasses one of the major regions in which alpine grazing occurs. Alpine grazing systems, however, extend beyond this region into French- and Italian-speaking sections of Switzerland, as well as beyond the borders into Germany, Austria, Italy, and France. My limited experience with these other areas indicates that alpine grazing practices there are similar to those described here, but I cannot claim generality for my description to areas beyond the German-speaking part of Switzerland. Moreover, I based the statistical work on an even smaller area, the canton of Bern, Switzerland.[6] The Swiss grazing commons description and statistical investigation are both based on two years of fieldwork in Switzerland.

An integral part of the medieval English open field system was common grazing in the "waste," the meadows after haying, the arable after harvest, the arable during fallow periods, and the balks within

[6] The canton is the provincial or state level of government in Switzerland. See Figure 4.1 for a map of the cantons.

the arable. It complemented grain and other food production in the cultivated fields. Although this is unlike the Swiss commons, which integrates into a grazing-dependent economy, the two systems bear many resemblances, as well as provide interesting contrasts.

## What's in Store

To begin the investigation, it is helpful to understand the open access resource model that inspires the conclusion that a tragedy results from open access. Knowing precisely the conditions that encourage the tragedy will help us see how common property is different. Chapter 2 reviews several models of open access using graphic and game theoretic approaches and thereby makes the assumptions and results clear. In Chapter 3, I clarify how common property is different and why the term "common property" can be taken to mean something different from open access. The chapter draws mainly on the institutional economics tradition in explicating a theory of common property. In Chapter 4, I describe the working common property system found in the Swiss grazing commons: how it limits entry, what its management tools are, and how decisions are made. Chapter 5 draws the medieval English open field system into the discussion, describing it and contrasting it with the Swiss grazing commons in order to help those more familiar with the English system. Chapter 6 turns to an empirical comparison of the performance of common property with that of private property. This inquiry compares the productivity of the Swiss private and commons grazing areas statistically. Chapter 7 contains conclusions and extensions to other natural resources, drawing on the theoretical chapters of the early part of the book, the descriptive work on the Swiss commons, and the empirical comparison to private property.

CHAPTER 2

# Open Access Theory

The economics literature is rife with theory on natural resource use under open access and its results.[1] I will not review this literature exhaustively but rather will present three models that encapsulate the results. Once grounded in the effects of open access, we can proceed to examine how common property is different. The open access models that I wish to review are two graphic open access fisheries models, one of which draws on work by Anderson (1977), and two game theoretic approaches. To corroborate the results of the graphic models, the appendix to this chapter presents a mathematical interpretation by Dasgupta and Heal (1979).

Before we forge into these theories, I define an open access resource and overuse of a resource more precisely. Both of these concepts have different meanings to different scholars, and a common basis will be helpful for the work that follows.

## Definition of Open Access

An open access resource is a depletable, fugitive resource characterized by rivalry in exploitation; it is subject to use by any person who has the capability and desire to enter into harvest or extraction of it; and its extraction results in symmetric or asymmetric negative externalities.

The rivalry in production of an open access resource indicates that one agent's extraction of the resource precludes another agent's possession. If one agent catches a fish, another cannot possess the same fish. For some ubiquitous open access resources, such as the air, the relevance of this rivalry in use does not set in until rates of use are

[1] A little-known article by Warming ([1911] 1981) is perhaps the earliest more or less accurate description of the open access problem. The modern development of the theory is generally recognized as beginning with Gordon in his 1954 article on fisheries economics. Anderson (1977: chaps. 2 and 3) provides perhaps the most complete description of the static fisheries model. Whereas most of the models have couched exploitation levels in terms of inputs, Haveman (1973) has modeled open access in terms of outputs. See note 3 to this chapter for further references.

high. In the range of use that is of economic concern, however, the resource is scarce and competition between users occurs. Rivalry in extraction indicates that the open access resource is not a pure public good at all potential use rates.

The depletability of an open access resource reflects not only that there is rivalry in exploitation but also that some use rate exists that reduces resource supply to zero. This is true both of strictly exhaustible resources, such as oil and minerals, and of renewable resources, such as fish and trees. Simple physical or economic exhaustion can reduce the former's supply to zero, and sufficiently high use rates can exterminate the latter's capability to reproduce (Ciriacy-Wantrup 1952: 38–40, 256–57; Dasgupta and Heal 1979: 3–4).

The fugitive nature of an open access resource means that it must be "reduced to ownership by capture" (Ciriacy-Wantrup 1952: 141–42). There are no enforceable property rights over the *in situ* resource, as I discuss further in Chapter 3. Hence, as the definition indicates, anyone with the skills, the capital to invest in extraction equipment, and the desire may enter into resource harvest.

The meaning of symmetric versus asymmetric negative externalities also deserves clarification, because this distinction divides open access resources into two groups. The symmetric externality is present in an open access resource in which each entrant to resource use imparts a negative externality to all other producers, but similarly these other producers have negative external effects on the new entrant. The externality is reciprocal or symmetric. Common examples include fisheries, wildlife, open grazing land, groundwater, unregulated wood lots and forests, and common oil and gas pools. The asymmetric externality occurs when production or consumption decisions of economic actors enter the production or utility functions of others while the recipients of the externality do not cause any reciprocal effects. Typically, this situation is labeled simply an externality, and it is illustrated in the classic example of a smoking factory dirtying a nearby laundry's clothes.

The literature on open access resources has concentrated on symmetric externality situations, although the concept of open access can be extended to cover both types of externalities. (Some authors, for example, reason that water pollution, which clearly exemplifies an asymmetric externality, is a problem of firms' having "open access" to a river.) For the purposes of this book, a main one of which is to make a clear distinction between open access and common property, it will be conceptually easier to remain largely confined to symmetric externality situations. This the theory of Chapters 2 and 3 does. Many of the distinctions and comparisons among open access, common property, and private property, however, extend to asymmetric externalities as well.

## Definition of Overuse

Because the literature on open access has grown up both within and without economics, the definition of when use of the open access resource becomes excessive has varied. The common, noneconomic definition of overuse is exploitation of the resource beyond carrying capacity, or equivalently, beyond its maximum sustainable yield. We see this use in Hardin's famous article (1968). He talks about an open access grazing area that operates satisfactorily for centuries during which it is used below "carrying capacity." By implication, social and economic problems arise only when use exceeds this level. For many years, however, economists have been trying to substitute another definition for overexploitation. They point out that social policy should be to maximize net economic yield, which in general is not synonymous with maximizing output; that is, it is not the same as utilization at carrying capacity. Economists argue that any level of inputs beyond that which would maximize net return from the resource is overuse.

This is not a major point of contention between economists and noneconomists, because open access resources are often overexploited by either definition. Nevertheless, the level of inputs to resource extraction that causes economic overuse generally differs from the level of inputs that causes physical yield declines. For this work, overuse will mean the former: use that depresses net economic yield below its maximum.

Given these definitions, we turn to two static, graphic fisheries models, the results of which can be generalized to other open access resources.

## Graphic Models of Open Access

The two graphic fisheries models that we examine are complementary. The first is an overview at the fishery level, without any view of the dynamics at the level of the firm. The second expands on the results of the first by examining firm-level interactions.

These static fisheries models offer results on equilibria and optima where the goal is to maximize sustainable net economic yield in a single period. Because they are essentially one-period models, they do

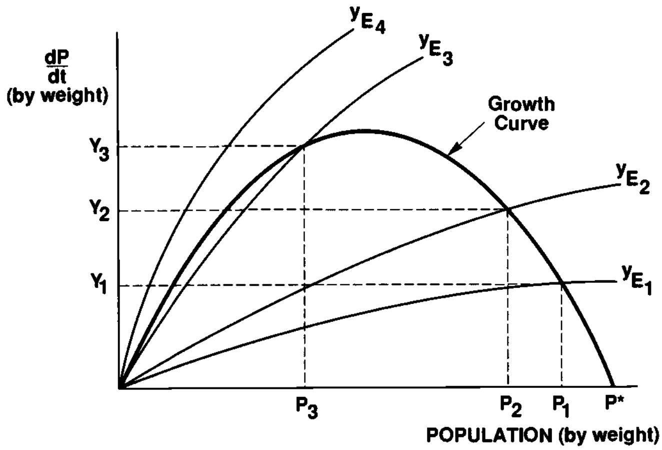


Figure 2.1. Growth Curve of a Typical Fish Population

not weight future net benefits any differently from present net benefits; that is, the discount rate is implicitly zero. Still, for any discount rate less than infinity, dynamic open access models indicate identical conclusions on the relative positions of optimal and open access exploitation levels. Because the static models indicate the correct relative positions of open access and optimal exploitation levels, and because it is sufficient for our purposes to understand the positions of these exploitation levels relative to each other, I confine myself to static open access models.[2]

### *The General Static Fisheries Model*

The static fisheries model was first proposed by Gordon (1954) and refined by Anderson (1977) and others.[3] A graphic treatment of the general model best begins with some simple biology. For many species, the rate of growth of a fish population depends on the standing stock. This relationship is represented in Figure 2.1, where $P$ equals population size by weight and $t$ is time. At low population sizes, population growth $dP/dt$ is low owing to the scarcity of spawners and the low biomass available for growth; at intermediate populations, growth is high owing to large additions to the stock and rapid growth of the

[2] The interested reader may refer to Clark (1976) or Anderson (1977) for explications of dynamic open access models.

[3] See, for example, Crutchfield and Zellner (1963: chap. 2); Cheung (1970: sec. 3); Clark (1976: chap. 2); Dasgupta and Heal (1979: 55–63); and Howe (1979: chap. 13). A concise version of the model can be found in Townsend and Wilson (1987).

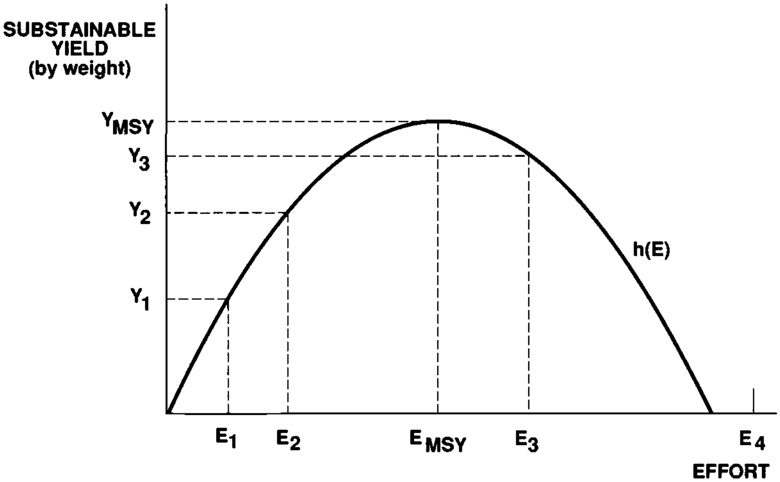


Figure 2.2. The Yield–Effort Function

existing stock; and at high populations, population increase is again slow as environmental constraints become binding. At $P^*$, the population reaches equilibrium (zero growth), as recruitment (new fish fry) and biomass growth exactly match natural mortality.

Fishing pressure is most often measured by a composite input variable called effort ($E$); it can be thought of as a fixed-proportion combination of labor, boats, nets, and so forth. At any given level of effort, larger population sizes mean greater catches. In Figure 2.1, fishing yield functions $y_E$ have been drawn to show this relationship. The effort levels in Figure 2.1 are ordered such that $E_1 < E_2 < E_3 < E_4$.

For one of these constant effort catch curves, an equilibrium catch and population pair occurs at the intersection of the growth curve and the catch curve. For effort level $E_1$, for instance, equilibrium population is $P_1$ and equilibrium catch is $Y_1$. This is true because at populations greater than $P_1$, catch exceeds growth, and population falls; for populations less than $P_1$, catch is less than growth, and population rises.

As effort increases, that is, as we rotate the $y_E$ curve upward and to the left, two things occur: (1) Equilibrium population decreases monotonically, and (2) catches or "yields" first increase and then decrease. This latter relationship is called the yield–effort function and is graphed in Figure 2.2.

The yield–effort function $h(E)$ of Figure 2.2 indicates that increased effort increases catch up to a point, as just argued. At this point, effort has increased until it is cropping off the maximum growth rate of the

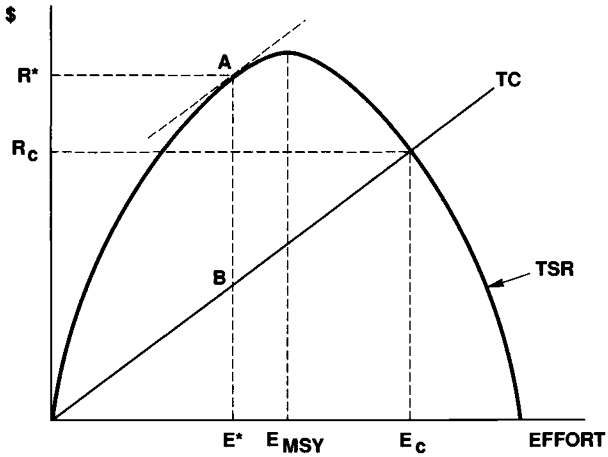


Figure 2.3. Graphic Analysis of an Open Access Fishery

fish, that is, until the maximum sustainable yield (*MSY*) has been reached. If effort is increased further, catch will actually decline because the fish population will be reduced to the point where it grows more slowly.[4] The yield–effort function is an equilibrium concept: The industry settles on $h(E)$ only after a particular level of effort has been maintained for several periods and the growth in the fish population is in equilibrium with natural mortality and human predation.

The model is given economic content in Figure 2.3. Assume that the fishery is one of many such fisheries for the particular species, and that it cannot affect market price no matter how much it supplies. Multiplying total catch by the constant price gives total sustainable revenue (*TSR*). In effect, the yield–effort function in Figure 2.2 is scaled by a factor equal to the price of fish to obtain the total revenue sustainable over time at each level of effort. Thus, as fishing effort increases, catch and revenue increase up to the point $E_{MSY}$. Further additions to effort cause absolute declines in catch level and total revenue.[5]

[4] Crowding effects among the fishermen also eventually have a dampening effect on catch. The primary influence in the downturn of total catch beyond $E_{MSY}$, however, is the reduced productivity of the resource.

[5] The inverted parabolic shape of the *TSR* function derives from the correspondingly shaped yield–effort function (Figure 2.2). This form of the production function for an open access resource is not essential. Gordon (1954) and Dasgupta and Heal (1979), for instance, use monotonically increasing production functions. The parabolic production function and the functional forms of these other authors, however, all display decreasing rates of resource extraction as effort increases, i.e., $d^2h(E)/dE^2 < 0$, a necessary property for the model (Gordon 1954; Dasgupta and Heal 1979:

Assume that additions to industry effort can be made at constant marginal costs, which implies a linear total cost curve (*TC*), as Figure 2.3 indicates. This does not mean that firms necessarily face constant marginal costs, but we assume it is true for effort added to the industry as a whole. This may mean adding additional identical firms to the industry to increase effort at constant marginal costs. *TC* includes a normal rate of return to capital and labor.

Demonstrating the nonoptimality of open access is now quite easy. The socially optimal level of effort occurs where net revenue is maximized, that is, where the difference between *TSR* and *TC* is greatest. This occurs at $E^*$ in Figure 2.3, where a line tangent to *TSR* is parallel to *TC*, ensuring that *TSR* lies the greatest distance above *TC*. At $E^*$, however, firms in the industry are earning positive profits, precisely because *TSR* exceeds *TC*. These profits in excess of a normal rate of return will attract the commitment of new inputs to the industry, either by existing firms or by new entrants. The literature is very unclear about the source of excessive inputs to an open access resource, as I discuss in the next section. For the moment, I simply note that additional effort will be expended because of the attractive profit situation in the industry.

As new effort is added, total industry revenues increase, but not in proportion to total industry costs. This can be seen in Figure 2.3, where beyond $E^*$, *TSR* rises more slowly than *TC*. Nevertheless, additional effort will be supplied as long as positive profits exist. The process stops only when effort has been driven to the point $E_c$—where total costs and total revenues are equated ($TC = TSR$), and no further excess profits can be reaped by additional effort from new or existing fishermen. At this point, the potential rent obtainable from the scarce fishery resource, which reached a maximum at $E = E^*$, has been totally dissipated by the excessive inputs to the industry.

### *The Firm-Level Graphic Model*

To devise appropriate corrective measures, it is important to understand whether expansion of effort comes from new entrants to resource use or from existing users. There is great confusion in the descriptive and graphic literature about the source of excessive inputs

56). The point of resource overexploitation may never be reached at any level of effort if this assumption is not met: If decreasing rates of return to effort do not occur, output can always be increased by adding more inputs, and under constant marginal costs of producing the output, infinite amounts of inputs and outputs would be optimal (Dorfman 1974: 10–11).

in an open access resource. For instance, in his popular model Hardin (1968: 1244) talks of "each herdsman" asking himself:

> "What is the utility *to me* of adding one more animal to my herd?" . . .
> Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons.

Thus, excessive inputs here come from within the group, even if the group is fixed in size. Similarly, Davidson (1963: 94) in describing the common oil pool problem writes:

> If there is more than one producer from a common pool, then adjacent producers are in danger of losing all "their" oil to their neighbors. Hence, it is in the self-interest of each producer to attempt to bring to the surface as much crude oil as quickly as possible, before his neighbor draws off more oil.

Howe (1979: 244–45), whose notation for the socially optimal rate of output is $X^*$, on the other hand writes:

> [Assume] $X^*$ could be induced or enforced. . . . Since price has been equated to the firm's marginal cost, each *existing* firm is maximizing its profit. $X^*$ appears to be a stable competitive equilibrium, except that a pure economic profit is being generated. . . . If the firms constituting the industry at $X^*$ shared among themselves the *exclusive right of access* to the resource, they would, indeed, protect this rent on the early units of production by refusing to expand output and by . . . refusing admission to any more firms. . . . However, the firms that would exist at $X^*$ cannot keep other firms out, simply because of open access to the resource. Other firms, observing the excess profits being made in this particular resource, are attracted to enter the industry, expanding the rate of output beyond $X^*$.

Howe obviously blames excessive inputs on new entrants and not at all on expansion by existing resource users. This is the same explanation given by Clark (1976: 26), whose notation for the open access level of effort is $E_\infty$:

> No level of effort $E < E_\infty$ can be maintained indefinitely, because of the open-access condition: at such an effort level the fishermen would earn a profit, *additional fishermen* would be attracted to the fishery, and effort would increase. (Emphasis added)

Some authors, Gordon (1954) and Turvey (1964) being examples, do not specify at all how superoptimal inputs enter the industry. Others, such as Haveman (1973: 280), vaguely refer to both avenues. Haveman, also using $X^*$ as the socially optimal rate of output, says:

> As long as there exists open access to the resource stock, the existence of quasi-rent at $X^*$ will induce entry of additional firms and resources.

In another paragraph (p. 281) he states:

With free and open access to the resource by any and all potential entrants, additional resources are artificially attracted into the activity.

A liberal interpretation of his first quotation indicates that additional inputs come both from entry and from existing firms. The second quotation is less clear. This reflects the general confusion about the source of excessive inputs in much of the literature.

It turns out that the excessive effort can come from either source, depending on certain conditions. If the number of firms is greater than one, but limited, excess inputs will come from existing firms, contrary to Howe's argument. If the number of firms is unlimited, excessive effort will come *only* from new entrants in the long run. A graphic analysis in the remainder of this section and a mathematical treatment in the appendix to this chapter show these conclusions.

The source of excess inputs can be isolated by focusing the discussion at the level of the firm. By precisely specifying firm revenue and cost conditions, and by varying the number of firms, firm effort, and industry effort, we can shed light on firm entry and exit from the industry and the implications for industry optimality. The graphic treatment here is an adaptation from Anderson (1977: chap. 3).

Consider each fishing firm as being a *producer of effort*, where effort is regarded as an intermediate good. Conceptually, the firm applies this intermediate good to the fishery to produce the final output, fish. This construct is useful because a firm can "produce" effort at costs that are independent of total industry effort: The cost of effort depends only on outlays for boats, crew, and so on, which are assumed to have constant prices. In contrast, the costs to the firm of producing a certain amount of fish depend upon the production level of the rest of the industry, because industry marginal and average product curves decline as industry output increases, reflecting the external diseconomies of open access.

Given this construct, we can draw a set of short-run[6] firm cost curves of effort. Anderson (1977) assumes that these cost curves take the U-shape of traditional production theory, and that they are identical for all firms (Figure 2.4*a*). Implicitly, he assumes that the long-run cost curves *for the firm* take the gentle U-shape of traditional production theory.[7] Figure 2.4*a* pictures the short-run average vari-

[6] The short run is that period during which firms cannot adjust the fixed input component of effort, and new firms cannot enter the fishery.

[7] Anderson does not state this as an assumption, but it is necessary to arrive at a determinant firm size and a determinant number of firms in the industry as discussed shortly. Anderson ignores the fact that beyond his single set of firm short-run cost curves there is a set of long-run cost curves for the firm reflecting that period during

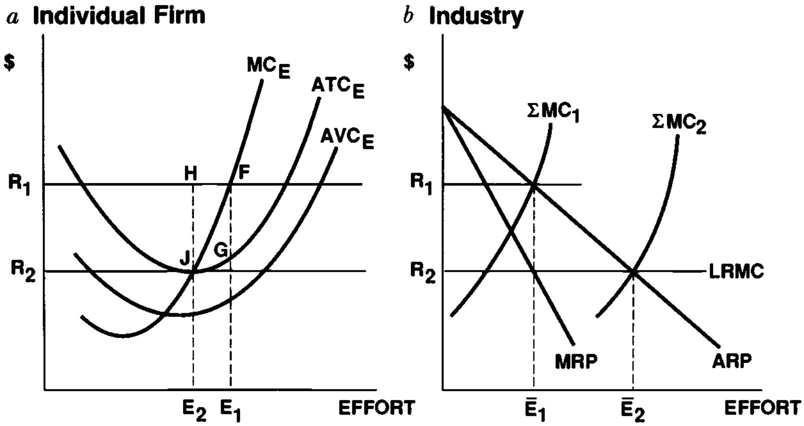


Figure 2.4. Firm-Level Analysis of Entry, Exit, Firm Size, and Firm Number

able cost of effort ($AVC_E$) and average total cost of effort ($ATC_E$). All costs include a reasonable rate of return to the factors constituting effort.

The summation of the individual firms' marginal cost of effort curves ($MC_E$) above the $AVC_E$ curves gives the industry supply schedule for effort in the short run. Figure 2.4*b* gives two possible industry supply schedules, which correspond to different numbers of firms: $\Sigma MC_1$ and $\Sigma MC_2$. Figure 2.4*b* also shows the industry average revenue product (*ARP*) curve that is associated with the total sustainable revenue curve in Figure 2.3. *ARP* is linear because the *TSR* curve is assumed to be quadratic (i.e., it forms an inverted parabola). The industry *ARP*, which each firm faces, is similar to a demand curve from price theory, because the industry *ARP* determines the individual firm's unit return on effort. Therefore, short-run equilibrium effort and unit return on effort will settle at the intersection of the industry supply and the industry *ARP* curves.

We turn now to the dynamics of open access equilibrium. First

which fixed inputs are also adjustable. The long-run $ATC_E$ curve is the well-known envelope of all short-run $ATC_E$ curves. Anderson's omission is excusable, for it would make the graphic analysis unnecessarily complicated to consider the changes in firms' sizes as they obtained optimal scale (minimized short-run $ATC_E$) in response to each change in industry effort and consequent changes in total, average, and marginal revenues. Although it is a shortcut, it simplifies matters greatly to consider the short-run cost curves of Figure 2.4*a* to be those at the minimum of the long-run $ATC_E$ curve. This means that right from the beginning and throughout the analysis the fishing firm has the optimal scale of fixed inputs; that is, it has the size of a firm found at eventual industry equilibrium.

imagine that $\Sigma MC_1$ is the industry supply curve of effort. Total industry effort will be $\bar{E}_1$ and return on effort will equal $R_1$. Figure 2.4*a* indicates that each individual fisherman, equating $MC_E$ with $R_1$, supplies $E_1$ units of effort and earns profit $FG$. In the long run, this profit will attract new entrants to the fishery and push the industry supply curve of effort to the right. As effort increases, the fish population declines and $ARP$ will decrease. Individual firms, equating $MC_E$ to $ARP$, will move back down their $MC_E$ curves, *contracting* their individual contributions to effort. Thus, while the number of firms increases, effort per firm decreases. In the industry as a whole, however, the former outweighs the latter, since total industry effort expands. Entry will continue as long as supernormal profits exist. Therefore, the process stops only when the industry supply schedule in Figure 2.4*b* has been pushed to $\Sigma MC_2$, the industry applies $\bar{E}_2$ units of effort, and $ARP$ has been depressed to $R_2$. Individual firm effort in Figure 2.4*a* will have contracted to $E_2$, and no abnormal profits will be earned ($ARP = ATC_E$). At this point, firms are smaller (expending less effort), and total industry effort is greater. A determinant number of firms exists in the industry, and each has a determinant size, as measured by effort expended. They are also operating at their most efficient levels, at the minimums of their $ATC_E$ curves.

Using Figure 2.4, we can also investigate the optimal level of effort for the firm and for the industry. Figure 2.4*b* shows long-run marginal cost ($LRMC$) as horizontal, because additions to industry effort may be achieved at constant marginal costs by adding firms to the industry. The optimal industry output occurs where marginal revenue product equals marginal input cost. This occurs at $\bar{E}_1$ in Figure 2.4*b*. Again, open access equilibrium effort $\bar{E}_2$ exceeds optimal effort $\bar{E}_1$.

The number of firms must be reduced to curtail effort from $\bar{E}_2$ to $\bar{E}_1$. This is because at the open access equilibrium $\bar{E}_2$, firms produce at their most efficient points, the minimum of their $ATC_E$ curves, as shown above. To produce the optimal $\bar{E}_1$ units of effort, with each firm producing at its most efficient rate $E_2$, the number of firms must be reduced. If this reduction can be achieved, each firm will receive rent $HJ$ per unit of effort.

Limiting entry to the correct number of firms, however, is not sufficient. The final step to ensure optimality is also to limit the effort expended by each firm to its optimal rate $E_2$. This is necessary, because the firms are no longer in equilibrium by supplying $E_2$ units of effort each. Cutting industry effort to $\bar{E}_1$ increases the standing fish population and raises $ARP$ to $R_1$. As a result, unit return on effort $R_1$ exceeds $MC_E$ by $HJ$. There is an incentive for each existing firm to expand effort, moving up the $MC_E$ curve in Figure 2.4*a*, until $MC_E$ equals *ARP*, at which point each would still be enjoying positive rent *FG*. But if the firms are allowed to do this, not only would they no longer be producing at the minimums of their $ATC_E$ curves, but they would expand the industry supply of effort beyond $\Sigma MC_1$ (but to a level less than $\Sigma MC_2$). Industry effort would exceed the optimal $\bar{E}_1$ (but be less than the open access $\bar{E}_2$). Of course, *ARP* would fall and the firms would readjust effort yet again. So the process would continue in successively smaller adjustments of individual firm effort and industry *ARP* until an equilibrium was reached. In this equilibrium, however, firm and industry amounts of effort would exceed the optimal amounts. Positive rents would still accrue to each firm, but these rents would not be at their maximums. Thus, limiting the number of firms is not sufficient for ensuring optimal amounts of inputs. The amount of inputs per firm must also be restricted.

In summary, I have shown four results that will be helpful in comparing open access with common property, results that the mathematical treatment in the chapter appendix corroborates.

The first is the complete dissipation of rent at open access equilibrium.

Second, the externality that firms impose on one another under open access leads individual firms to *contract* their effort as industry effort expands. The source of excessive effort under complete open access—when both inputs and number of firms are unlimited—becomes clear: It comes from entry of new firms.

Third, if the number of firms is limited to less than the number reached at open access equilibrium, positive rent will accrue, *even without restricting input from these firms*. However, firm and total industry inputs will not be optimal; rather they will expand to some point between the optimal and the open access amounts. Nor will resource rent be at its maximum. Thus, "limited user open access," where the number of firms is restricted but their input levels are not, also leads to nonoptimality. The nonoptimality is simply not as severe as under complete open access.

Finally, it is therefore necessary to limit not only the number of firms but also their input levels, if the socially optimal amount of effort and the rent associated with it are to be realized. The incentive always exists, however, to expand beyond these limits. Because of the rent available, excluded firms want to enter and existing firms strain against restrictions under an incentive to expand inputs.

## Game Theoretic Models of Open Access

Open access also can be presented in game theoretic terms, and expressing it in this structure leads to new insights. Commonly, open access has been represented by the "prisoner's dilemma" game, a version of which I reproduce here so that all readers have a common basis for the discussion in this book. However, I will also discuss an alternative, two-person, nonzero-sum game that gives some different results and additional understanding of the open access problem.

The prisoner's dilemma can be shown to represent open access[8] if we imagine two cattle owners who use a grazing area that is at its maximum economic yield. Each grazier has the choice of either adding a head of cattle or not adding a head, and the graziers may not collaborate. Assume that the marginal revenue product for the grazing area is −$2 per animal, and that this is composed of −$6 in reduced output from other animals in both graziers' herds and +$4 in value from the animal added.[9] Assume identical players and individual herds, so that the loss in value of outputs from existing animals from adding a head divides equally between graziers (i.e., −$3 each). For simplicity, assume these values are constant for the first two animals grazed beyond the optimum.[10]

Given these assumptions, Figure 2.5 gives payoffs for the game. If both Herdsman 1 and Herdsman 2 decide not to add an animal (the lower right-hand box in the game) there will be no loss to either one; both payoffs are zero. If Herdsman 1 adds, but Herdsman 2 does not,

[8] The assumption of a constant number of herdsmen (i.e., two) confines this model to the situation of limited user open access, i.e., a limited number of firms but open access toward inputs. This is also true of the second game in this section, in which the number of herdsmen is greater than two, but constant.

[9] Assume that the marginal revenue product to the grazing area (−$2) and the value of the additional animal (+$4) are net of costs of providing the animal, e.g., purchase price, supplementary feed costs, veterinary costs, etc.

[10] These assumptions are arbitrary, but they meet a set of conditions that make the open access herding example a prisoner's dilemma. These conditions are

$$c_i < b_i < 0 < a_i \text{ and } a_i + c_i < 0,$$

where $c_i$ = the loss to each individual's existing herd (or one-half the total loss to both individuals' existing herds) from adding an animal (this equals −$3 in the example); $b_i$ = the marginal revenue product of an additional animal to the grazing area, composed of both a negative component of reduced existing herd output and a positive component of the additional animal's output (−$2 in the example); $a_i$ = the *net* private gain from adding an animal when the other individual does not add an animal, also composed of a negative and a positive component (+$1 in the example; see text); and $i$ = 1, 2 for Herdsman 1 and Herdsman 2. The last condition, $a_i + c_i < 0$, must be met, because if it is not, the net private gain from adding an animal $a_i$ exceeds the loss to the other individual's herd $c_i$ when only one individual adds animals. This would indicate that fewer animals stock the grazing area than are economically optimal at the beginning of the game.

| | | HERDSMAN 2: ADDS | HERDSMAN 2: DOES NOT ADD |
|---|---|---|---|
| HERDSMAN 1 | ADDS | (-2,-2) | (1,-3) |
| | DOES NOT ADD | (-3,1) | (0,0) |

Figure 2.5. The Open Access Problem as a Prisoner's Dilemma

the former will gain the value of the additional animal less the costs he imposes on the rest of his own herd ($4 – $3 = $1). Herdsman 1 enjoys a net gain, which is necessary, for otherwise he would not make this move in the absence of Herdsman 2's adding an animal. Herdsman 2's loss is greater here than in any other scenario, because he has not added an animal to offset costs imposed on him ($0 – $3 = –$3). This is the upper right-hand box in the game. Reverse payoffs occur if Herdsman 2 adds a head while Herdsman 1 does not (the lower left-hand box); Herdsman 1 incurs his greatest loss while Herdsman 2 faces his sole chance for gain. Finally, if both add a head of cattle, losses to each are moderate because they are offset by the value each herdsman gains from the additional animal he grazes ($4 – $6 = –$2), but the total loss to the grazing area is greatest.

Playing the game without collusion results in both herdsmen's choosing to add a head of cattle, even though it causes losses to both of them and their mutual restraint would have resulted in losses to neither. Consider the problem from Herdsman 1's standpoint. If Herdsman 2 adds a head (first column), Herdsman 1 finds that he minimizes losses by adding a head: In absolute value terms –$2 is less than –$3. Considering his possibilities if Herdsman 2 does not add a head (second column), Herdsman 1 still decides to add a head, since +$1 > $0. That is, he stands to gain rather than standing pat with no loss. Thus, Herdsman 1's dominant strategy—the strategy he pursues no matter what Herdsman 2 chooses—is to add a head. Since the game is symmetric, Herdsman 2 will make the same choice. Both add a head and the tragedy of open access occurs. Moreover, after each has added a head, if the private gains and losses from adding a head of cattle shift only slightly from those assumed here, the herdsmen will add more cattle in future plays of the game. This will continue until private gains and losses shift enough to reach an open access equilibrium as described in the graphic model.

This game theoretic explanation of open access is simple and well known, and I give it mainly to introduce a more realistic version of the game that gives some new insight into open access and common property. In this alternative game, which I have adapted from Muhsam ([1973] 1977), the number of herdsmen is expanded to $h > 2$, but it still is played as a two-person game. Herdsman 1, now called "our individual herdsman," plays against a collective second player, "all other herdsmen."

Assume that each of the $h$ herdsmen has an average-sized herd of $n$ cattle when the grazing area is optimally stocked. Define also $N = nh$ to be the total number of animals on the grazing area at the economic optimum, and let the net economic value of each animal be 1 at this point. In accordance with the discussion of the economic and physical yield optimums in the section on resource overuse earlier in this chapter, I define these quantities and values at the input level (number of cattle)[11] where the net economic yield is at a maximum. Moreover, the value that each of the animals has at this point (i.e., unity) is defined as a *net* value so that the summation over all animals gives the maximum total *net* value of the herd (i.e., $N$), by definition the economic optimum. In this way, costs are subsumed into the model.

Let us assume that the percentage decrease in the net value of each head of cattle as a result of adding a head of cattle beyond the grazing optimum is $a$. Also suppose that this percentage remains constant no matter how many head are added beyond the optimum. Although unrealistic, this is a conservative assumption because the decrement in value[12] per head likely would increase as more cattle are added. If the failure of open access can be shown with a constant percentage, it would also occur under the more realistic assumption of progressively worsening overexploitation costs.

As a preliminary step in viewing the game, it is useful to derive a condition that indicates when overgrazing has occurred. I call this condition the overgrazing constraint. If $x$ extra head are added beyond the grazing optimum, assuming $a$ is constant, the value of each head will be $1 - ax$. The total number of cattle will be $N + x$, and the total value of the herd

[11] To make the parallels clear between a fishery and a grazing area, consider what elements in each example are the inputs, the resource base, and the outputs. In a fishery, the inputs (effort) are boats, nets, labor, etc.; the resource is the fishing grounds or, some would say, the fish themselves; and the output consists of the fish. In the grazing example, the inputs are cattle (capital applied), labor, fencing, etc.; the resource is the grass; and the output is milk, meat, wool, hides, etc., depending on the product used from the animals. Thus, I consider the cattle as *inputs*, not outputs.

[12] Here, as often below, I simply substitute "value" for "net value," but the reader should understand that I always mean "net value."

$$(N + x)(1 - ax). \tag{2.1}$$

By definition, overgrazing occurs if the addition of an extra head decreases the total net value of the herd found in expression (2.1). Also by definition, this occurs when $x$ increases from $x = 0$ to $x - 1$. Therefore, the value of expression (2.1) must be lower when $x = 1$ than when $x = 0$:

$$(N + 1)(1 - a) < N. \tag{2.2}$$

Condition (2.2) can be rewritten as

$$a > \frac{1}{N + 1}. \tag{2.3}$$

Condition (2.3), a definitional constraint on the value of $a$, can be called the overgrazing constraint. To interpret (2.3), substitute the approximately equal condition

$$a > \frac{1}{N}, \tag{2.4}$$

for if (2.4) holds, then (2.3) also holds. Condition (2.4) (and by approximation the overgrazing constraint) says that if the percentage drop in value of each head of cattle exceeds the percentage of total *herd* value that one head of cattle represents ($1/N$), then overgrazing has occurred. When this condition is met, as it is at or beyond the optimum, the addition of one animal adds less to total herd value than the sum of the losses in value incurred by all other animals in the herd.

With these definitions, we can construct the open access model as another two-person, nonzero-sum game. Again, the game is played between "our individual herdsman" and the collective of "all other herdsmen." Our individual herdsman decides between adding another head of cattle and not adding another head, while all other herdsmen decide between adding $h - 1$ head and zero head of cattle. In reality, all other herdsmen could pursue a variety of strategies, ranging from adding zero to adding $h - 1$ head of cattle, but the results are insensitive to all these possible strategies, as will be proved below (see note 14).

The payoff matrix for our individual herdsman is shown in Figure 2.6. Each element is found by comparing the value of our individual herdsman's herd before and after the other players have decided to add or not to add animals. For example, the upper left-hand element is found first by taking the size of the individual herdsman's herd after he has added an animal; this is $n + 1$ if he started with an

| | | ALL OTHER HERDSMEN: ADD | ALL OTHER HERDSMEN: DO NOT ADD |
|---|---|---|---|
| OUR INDIVIDUAL HERDSMAN | ADDS | $1 - a(N + h)$ | $1 - a(n + 1)$ |
| | DOES NOT ADD | $- a(N - n)$ | 0 |

Figure 2.6. Muhsam's Game for Our Individual Herdsman

average-sized herd. We multiply by the value of an animal after all have added a head of cattle, namely by $(1 - ah)$. Thus, our individual herdsman's herd has value $(n + 1)(1 - ah)$. The herd's initial value was $n$. Therefore, our individual herdsman's payoff is $(n + 1)(1 - ah) - n = 1 - a(N + h)$. The other elements are found analogously.

Now compare the choices available to our individual herdsman. If all other herdsmen do not add an animal, the possible payoffs to our individual herdsman are found in the right-hand column. He will add an animal if $1 - a(n + 1) > 0$, that is, if

$$a < \frac{1}{n + 1}. \tag{2.5}$$

Roughly speaking, condition (2.5) indicates that our individual herdsman will add an animal if the percentage decrease in value of each of his animals is less than the value of the additional animal divided up over his $n + 1$ animals. Under these conditions the additional animal will at least cover all of the losses in value of his other animals.[13] We may assume, at least over some range of values of $N$, that these conditions hold. Condition (2.5) becomes another restriction on the value of $a$ for the model to represent the open access problem.

If all other herdsmen add an animal, the payoffs to our individual herdsman are contained in the left-hand column of Figure 2.6. The herdsman will add an animal if $1 - a(N + h) > - a(N - n)$, which can be rewritten as

$$a < \frac{1}{n + h}. \tag{2.6}$$

This condition is even more restrictive on the value of $a$ than (2.5), since

[13] This is only a rough interpretation because the numerator of $1/(n + 1)$ only approximates the value of an animal. At herd size $N + 1$, an animal has value $1 - a$, not a value of 1.

$$a < \frac{1}{n + h} < \frac{1}{n + 1}.$$

Therefore, if we assume that (2.6) holds, by implication (2.5) also holds. Unfortunately, there is no good economic interpretation of (2.6) that I can see. However, putting (2.3) and (2.6) together yields the restrictions on the value of $a$ necessary for the model to work for our individual herdsman:

$$\frac{1}{N + 1} < a < \frac{1}{n + h}. \tag{2.7}$$

To sum up, if (2.6) holds, which means (2.5) also holds, then our individual herdsman *always* decides to add an animal, independent of the decision made by all other herdsmen.[14] He will add a head of cattle if the others do not, because he stands to profit by doing so: The upper right-hand cell in Figure 2.6 is greater than zero under our assumptions. He will also add an animal if the others do so, because he will minimize losses: The upper left-hand cell is less negative than the lower left-hand cell in Figure 2.6, under our assumptions. Our individual herdsman's strategy of adding a head of cattle dominates the strategy of not adding a head. This is the "strict dominance of individual strategies" also found in the prisoner's dilemma.

It hardly needs pointing out that, assuming all herdsmen make the same rational decision, all will add a head of cattle. This naturally means that the range will be overgrazed, because there will be $N + h$ head on a range that was at economic carrying capacity with only $N$ head. Again, as in the prisoner's dilemma, it is entirely possible that at $N + h$ head on the range, the values of the model parameters—in particular, the value of $a$ in relation to the other parameters in (2.7)—will be such that the independent decisions by all herdsmen will be again to add more animals.

So far, this two-person, nonzero-sum game has yielded results identical to those of the prisoner's dilemma. Results diverge, however, when we consider the decision of all other herdsmen. Not only is it to our individual herdsman's advantage if all other herdsmen do not add a head of cattle—because then he can make a profit by adding to

[14] In fact, we now can see the analytical equivalence of assuming that all other herdsmen have only two choices, adding no head or adding $h - 1$ head of cattle, with them having the variety of choices of adding between 0 and $h - 1$ head. Since our individual herdsman finds it to his advantage to add a head of cattle whether the others add 0 or $h - 1$ head, he will find it advantageous if they add any number between 0 and $h - 1$. Therefore, we needed only to consider the two extreme choices available to all other herdsmen.

his own herd—but it is to the advantage of all other herdsmen (as a collective) if they do *not* add. This can be seen by examining the payoff matrix for the second player, all other herdsmen, in Figure 2.7. Elements in this figure are derived in the same fashion as those in Figure 2.6. For instance, for the upper left-hand element, the initial value of the herd of all other herdsmen is subtracted from the value of their (larger) herd after all $h$ herdsmen have added an animal:

$$(n + 1)(h - 1)(1 - ah) - n(h - 1) = (h - 1)[1 - a(N + h)].$$

Now look line by line at the choices of all other herdsmen. If our individual herdsman does not add a head of cattle (bottom line), all other herdsmen incur a loss if they each add a head of cattle, whereas they suffer no loss if they refrain from increasing their herds. They incur a loss by adding a head, because for most values of the model parameters, $(h - 1)[1 - a(h - 1)(n + 1)] < 0$, which is equivalent to

$$\frac{1}{(h - 1)(n + 1)} < a. \tag{2.8}$$

Condition (2.8) holds for most values of the model parameters, because $(h - 1) \cong h$ and $(n + 1) \cong n$, making (2.8) approximately the same as condition (2.4), $1/N < a$, which in turn approximates the overgrazing constraint (2.3), as argued above. Strictly speaking, (2.8) must be added as a new restriction on the value of $a$, because $1/[(h - 1)(n + 1)]$ may be greater than, less than, or equal to $1/(nh + 1)$, the previous lower bound on $a$ required by conditions (2.3) and (2.7).

On the other hand, if our individual herdsman does add an extra animal (top line), all other herdsmen minimize their losses by each choosing *not* to add another head of cattle. This is true because, in general,

$$(h - 1)[1 - a(N + h)] < -a(N - n). \tag{2.9}$$

Condition (2.9) is generally true, because (2.8) was true for most values of the model parameters. Condition (2.9) is equivalent to

$$\frac{1}{(h - 1)(n + 1) + 1} < a,$$

which is certainly true, if (2.8) holds, because

$$\frac{1}{(h - 1)(n + 1) + 1} < \frac{1}{(h - 1)(n + 1)} < a.$$

Thus, given the assumptions in (2.7) and (2.8), all other herdsmen pick the optimal strategy by *not* adding to their herd, no matter what our individual herdsman does.

| | | ALL OTHER HERDSMEN | |
|---|---|---|---|
| | | ADD | DO NOT ADD |
| OUR INDIVIDUAL HERDSMAN | ADDS | $(h - 1)[1 - a(N + h)]$ | $-a(N - n)$ |
| | DOES NOT ADD | $(h - 1)[1 - a(h - 1)(n + 1)]$ | $0$ |

Figure 2.7. Muhsam's Game for All Other Herdsmen

The situation, then, is paradoxical. It is in the best interest of our individual herdsman to convince all other herdsmen not to add an animal, because he then avoids losses and could even make a profit. Further, it is in the best interest of all other herdsmen as a group to be convinced of precisely that—not to add any animals.[15] Ironically, it is then in the best interest of our individual herdsman to add an animal. Because any herdsman can be considered our individual herdsman, there is a constant incentive for any individual to disregard any pact made by all herdsmen not to add animals beyond the optimal use rate of the resource.

This reemphasizes the essential nature of the open access problem. Agents are better off with an agreement to limit entry than with no agreement, yet under any agreement, there exists a constant incentive for individuals to break it. This result comes from the strict dominance of individual strategies and lack of assurance in collusive agreements. Still, group solutions do exist for the problem, a matter that we will take up in Chapter 3. As we will see, both enforcement and assurance in collusive agreements can play important roles in providing better outcomes.

## Underinvestment in Common Improvements

Besides overinvestment in the private inputs necessary to extract the resource and dissipation of the economic rent attributable to the resource, several other effects have been ascribed to open access for

[15] These circumstances indicate that this two-person, nonzero-sum game is not a prisoner's dilemma, because both players do not have the same dominant strategy. The reason is that the two players do not have symmetric payoff matrices, as they do in the prisoner's dilemma. Because the second player is a collective of many individuals who impose costs on one another, they end up worse off as a group if they decide to add animals than if they refrain. Only in the limiting case where $h = 2$ does the game collapse to a true prisoner's dilemma, as can be shown by substituting $h = 2$ into Figure 2.7.

which no rigorous models, but rather intuitive arguments, have been given. One of these is particularly relevant to empirical work discussed in this book.[16]

The notion is that investment in common improvements to the resource will be lacking. Several rationales can be given for this idea, and I discuss them more completely in subsequent paragraphs. The simplest reason, however, is that no user in an open access situation can be assured of reaping the benefits of improvements to the resource before others do so. If a herdsman fertilizes an open access grazing area, there is nothing to prevent other herdsmen's animals from consuming much of the increase in grass. As a consequence, there is insufficient motivation to invest in the improvement.

The lack of incentive to invest in the resource results from a divergence between the party who incurs costs and those who reap benefits. The idea that inadequate resource use results has a long history. It goes back, in fact, to Adam Smith himself, although not as part of a discussion of open access. Smith ([1786] 1880: bk. 3, chap. 2), and other classical economists after him (Say [1821] 1964: bk. 2, chap. 9; Mill 1878: bk. 2, chap. 8), discussed the economic acceptability of share tenancy, the land tenure system in which a tenant paid land rent by delivering a set proportion of the gross product to the landowner.[17] Typically, rent was 50 percent of the produce. The classical economists decried the lack of incentive under this system, because it reduced the fruits of the tenant's labor by half. This reduced not only the incentive to labor but also the inducement to invest in the land. Half of any increase in yield that a farmer's investment might coax from the land would be shared with the landlord, and the dampening effect on tenant investment was obvious. The same effect also would discourage the landlord from any investment that he contemplated, for he too would give up half the investment's benefit—in his case to the tenant. The parallel to open access is clear: Benefits resulting from improvements that one party makes may accrue to another; consequently, the improvements probably will not be made.

Both nineteenth- and twentieth-century economists also attacked

[16] Other effects of open access not described here have also been discussed by Bottomley (1963), Cheung (1970), and Anderson (1977: 173–74). They include the ideas that inputs and outputs may be different under open access than under a system of coordinated management; rent on the land may decline because the input–output mix is suboptimal even before entry dissipates rents; the misallocation of inputs and outputs may have side effects on adjoining resources managed under private or cooperative means; and technological innovations will be introduced too quickly under open access.

[17] Some of the classical economists used the French term for share tenants, *metayers*.

other types of rental tenure (e.g., fixed rent) for providing insufficient incentive to improvement (Sidgwick 1883: bk. 2, chap. 7; Ely 1914: pt. 1, chap. 13; Pigou 1932: pt. 2, chap. 9). A lack of investment incentive exists, they argued, whenever there is no arrangement between the tenant and the landlord to compensate the tenant for improvements at termination of the contract (and the contract duration is insufficient to allow recovery of investment costs).

Although the classical and early neoclassical economists spoke regularly of tenancy problems, they referred less frequently to the problem of underinvestment in common improvements to open access resources. The idea nevertheless emerged as early as the beginning of the nineteenth century:

> Capital and industry [i.e., labor] will be expended upon [land] in vain, if all are equally privileged to make use of it; and no one will be fool enough to make the outlay, unless assured of reaping the benefit. (Say [1821] 1964: bk. 2, chap. 9)

Natural agents, like land, would not yield nearly so much if they were not subject to appropriation and if the proprietors were not assured of exclusive benefits from them (Say [1821] 1964: bk. 1, chap. 5). The certainty of enjoying the undivided benefit of one's land, labor, and capital, and of one's skill and economy, was cited as one of the surest inducements to promote productivity and "accumulation" (Say [1821] 1964: bk. 1, chap. 14; Mill 1878: bk. 1, chap. 13). Indeed, even a person excluded from the use of others' goods is better off living in a system of appropriation than if the system did not exist at all, because that person abides in a community that has benefited from the inducements to labor and accumulation of capital that result from exclusive property (Sidgwick 1883: bk. 3, chap. 6).

The idea of underinvestment in common improvements to jointly used resources emerges with greater clarity with Ely (1914: pt. 1, chap. 15). Ely cites the oyster beds in Chesapeake Bay, where the taking of oysters had long been free to all. Private property or long individual leases in oyster beds are necessary, he asserts, to avoid the "principle of the twenthieth man." If nineteen well-meaning men cultivate (i.e., invest in) the oysters, but the twentieth does not, the latter can invade the beds and destroy all oyster cultivation. Ely calls for a system that assures reward to the one who puts forth effort and invests capital.

Until now, I have spoken of underinvestment in common improvements as resulting from only a single phenomenon—lack of assurance of reaping benefits. Actually, it may result from one of several separate but related circumstances. First, as already explained, an individual who invests in resource improvements may receive some benefit from the investment but may not be able to capture all benefits. The leakage of benefits to others reduces or destroys the incentive to invest. Viewed in a slightly different light, this is a typical positive externality. One may fertilize the land for oneself, but in doing so one generates fertilization externalities for others. It is well known that, from the standpoint of social optimality, private agents underinvest in activities that generate positive externalities.

The second set of circumstances is closely akin but not completely equivalent to the first. Some larger resource improvement projects may exist that would have net benefits to all users in the group, but their benefits to a single individual do not exceed total costs. This may occur if there is lumpiness or a public goods nature in the investment. Examples might be a large barn or watering troughs on a grazing area. Because private costs exceed private benefits, no single individual would be willing to provide improvements at personal expense, even though the project is economic for the group as a whole. Both this case and the previous instance, in which benefits are fugitive, represent circumstances in which the private cost of the investment exceeds the private return. The individual will be unwilling to contribute to the investment unless some arrangement is devised by which all share improvement costs (Ostrom 1977; Ostrom and Ostrom 1977).

Viewed in a certain manner, Scott's (1955) article on the economic objectives of fishery management presents yet a third way in which underinvestment occurs in common improvements. Scott emphasized that the economic objective for jointly exploited resources should be not to maximize single-period resource rent but rather to maximize the return from the resource over present and future periods. In order to do this, users must take into account the effect of current resource extraction on future extraction possibilities. The link between present and future is clear when we are talking about a renewable resource such as fish, because the resource reproduces. The connection often also holds for nonrenewable resources, for which present exploitation may increase future extraction costs. In addition, in both cases, discounting links the present with the future. Therefore, for both physical and financial reasons, users should consider the balance between extraction and conservation of the resource. In an open access situation, however, the competition for the resource causes users to ignore the so-called user cost, the present value of forgone future extraction benefits or increased future extraction costs caused by current resource exploitation. This is equivalent to saying that they ignore the potential returns from investing in (i.e., conserving) the resource. In yet another way, underinvestment in the jointly exploited resource occurs.

Thus, we have a long history of argument and a number of reasons for suspecting underinvestment in common improvements to open access resources. This, in addition to overexploitation of the resource, is a primary problem that any system of joint resource management must address.

## Summary

To this point, I have described one-half of the open access–common property dichotomy, having defined open access and explained its consequences in theoretical detail. Open access resources have been defined as depletable, fugitive resources that are open to extraction by anyone, whose extraction is rival, and whose exploitation leads to negative externalities for other users of the resource. Although the externalities may be either symmetric or asymmetric, most of the literature on open access concentrates on resource use exhibiting symmetric externalities.

The theory that we have reviewed has indicated the undeniable conclusions of superfluous input levels and resource overuse under open access. We further have been able to pinpoint the source of excessive inputs, namely, existing firms in the short run and in limited user open access situations, and entering firms in the long run in complete open access situations. Therefore, limits on both the number of firms and their individual input levels are necessary to attain socially optimal resource rents. As a corollary, there is always an incentive to increase one's input level beyond the limits, even though this leads to declines in overall group welfare.

Open access also leads to underinvestment in common improvements to the resource base, which could increase the benefits to all who extract the resource. This underinvestment results from a divergence between those who invest in the improvements and those who reap the benefits, from a mismatch of the scale of some investments and the amount of potential individual benefit, and from a lack of incentive to invest in the resource for future benefits because of a competitive rush for the resource in the present.

This description of open access and its results has given us a strong foundation for understanding common property, to which we turn in Chapter 3.

## Appendix: A Mathematical Treatment of Open Access

This appendix presents a mathematical model that corroborates the results of the graphic model of open access resources presented in this chapter. The mathematical model confirms the results on excessive investment and rent dissipation, as well as pinpoints the source of excessive inputs, that is, whether superoptimal inputs come from existing firms competing for the costless resource or from new entrants attracted by excess profits in the industry. The model shows again that (1) superoptimal inputs will come from existing firms if the number of firms is limited below the number that would occur at complete open access equilibrium, and (2) excessive inputs will come from new entrants if access is completely open. In the former case all rent is not dissipated, whereas in the latter it is. In addition, the mathematical model reaches one conclusion that differs from the results of the graphic model, namely, (3) open access equilibrium is reached only as the number of firms goes to infinity and each firm contributes only an infinitesimal amount of effort. This result occurs because of an implicit assumption about constant marginal costs of producing effort at the firm level. This assumption of course differs from Anderson's (1977) assumption of U-shaped cost curves for the firm. The model is an adaptation from Dasgupta and Heal (1979: chap. 3).

We begin by assuming that $N$ firms extract the resource, for example, fish. Although the number of firms is initially fixed, this assumption will be relaxed later. To extract the resource, each of the $N$ firms applies an amount of variable input $x_i$, $i = 1, \ldots, N$. The $x_i$ can be considered the number of boats introduced by firm $i$, although the variable input is assumed perfectly divisible. Total inputs[18] to the fishery area

$$X = \sum_{i=1}^{N} x_i.$$

Also assume that total harvest from the fishery $Y$ is a function of $X$:

$$Y = F(X),$$

where

$F(0) = 0;$
$F'(X) > 0;$
$F''(X) < 0;$
$F(X)$ is bounded above.

[18] To preserve Dasgupta and Heal's notation, total inputs to the fishery are noted as $X$. This replaces the notation $E$ used in the graphic presentation.

These assumptions are not identical to those of the graphic analysis; in particular, $F'(X)$ never turns negative. The crucial assumption, however, is $F''(X) < 0$—diminishing returns on variable inputs (see note 5, this chapter)—and this we find in both presentations. The assumptions imply that average product lies above marginal product:

$$\frac{F(X)}{X} > F'(X) \tag{2.10}$$

and that average product goes to zero:

$$\lim_{X\to\infty} \frac{F(X)}{X} = 0. \tag{2.11}$$

Denote by $X_{N-i}$ the inputs of all other firms besides a single representative firm, such that $x_i + X_{N-i} = X$, and define $y_i$ as the $i^{\text{th}}$ firm's catch. We assume that a vessel of the $i^{\text{th}}$ firm catches fish at the rate of the average product:

$$y_i = x_i \frac{F(X)}{X} = x_i \frac{F(X_{N-i}+x_i)}{X_{N-i}+x_i}.$$

Suppose the markets for catch and inputs (boats) are perfectly competitive, so that the prices for both are constant at all levels of input and output. Take catch to be the numeraire good and $r$ to equal the rental rate of boats. If all firms are identical and firm $i$ supposes that every other firm will introduce $\hat{x}$ vessels, then firm $i$ will attain its goal of maximizing profits by choosing $x_i$ to maximize

$$y_i - rx_i = \frac{x_i\, F[(X_{N-i}+x_i)]}{X_{N-i}+x_i} - rx_i = \frac{x_i\, F[(N-1)\hat{x}+x_i]}{(N-1)\hat{x}+x_i} - rx_i.$$

By differentiating with respect to $x_i$ and setting the result equal to zero, we obtain the condition for profit maximization:

$$\frac{(N-1)\hat{x}F[(N-1)\hat{x}+x_i]}{[(N-1)\hat{x}+x_i]^2} + \frac{x_i F'[(N-1)\hat{x}+x_i]}{(N-1)\hat{x}+x_i} = r. \tag{2.12}$$

Because all firms are identical, they will make the same profit-maximizing decision, and $x_i = \hat{x}$ for all $i$ under open access (unlimited inputs, limited number of firms). If we make this substitution in (2.12), the open access equilibrium number of boats per firm $\hat{x}$ will be the solution to the equation:

$$\frac{F(Nx)}{Nx} - \frac{1}{N}\left[\frac{F(Nx)}{Nx} - F'(Nx)\right] = \mathrm{r}. \tag{2.13}$$

In equilibrium, $Nx = X$, so the open access equilibrium number of total vessels in the fishery $\hat{X}$ is the solution to

$$\frac{F(X)}{X} - \frac{1}{N}\left[\frac{F(X)}{X} - F'(X)\right] = r. \tag{2.14}$$

A positive solution value $\hat{X}$ to (2.14) exists if $F'(0) > r$; that is, in Figure 2.3, if the slope of the *TC* curve is less than the slope of *TSR* at zero inputs.

To nail down the nonoptimality of open access, we must derive the condition for the socially optimal amount of inputs and compare it to (2.14). The Pareto efficient amount of inputs per firm is the solution to the maximization with respect to $x$ of total net revenue:

$$\max_{x} F\,(Nx) - rNx.$$

Employing the calculus as before, we obtain the optimality condition

$$F'(Nx) = r, \tag{2.15}$$

which alternatively may be written

$$F'(X) = r. \tag{2.16}$$

Denote the solution values to (2.15) and (2.16) as $\tilde{x}$ and $\tilde{X}$, respectively. Because of the identicalness of firms and the potential for upsetting the optimal solution if rent is divided unequally, $\tilde{X}$ will equal $N\tilde{x}$. Equations (2.15) and (2.16) are equivalent restatements of the familiar condition for profit maximization that the value of the marginal product must equal the rental rate of the input.

It remains to compare the open access equilibrium condition (2.14) with the efficiency condition (2.16). After substituting its solution value $\hat{X}$ and subtracting $F'(\hat{X})$ from both sides, (2.14) can be transformed to

$$\mathrm{r} - F'(\hat{X}) = \frac{N-1}{N}\left[\frac{F(\hat{X})}{\hat{X}} - F'(\hat{X})\right]. \tag{2.17}$$

Using (2.10), we can see that the right-hand side of (2.17) is positive. Therefore,

$$r - F'(\hat{X}) > 0,$$

or equivalently,

$$r > F'(\hat{X}).$$

Recalling the optimality condition (2.16), $r = F'(\tilde{X})$, we now have

$$F'(\hat{X}) < F'(\tilde{X}).$$

Since we have assumed diminishing marginal rates of extraction, that is, $F''(X) < 0$, $F'(\hat{X})$ can be less than $F'(\tilde{X})$ if and only if

$$\hat{X} > \tilde{X},$$

or equivalently,

$$\hat{x} > \tilde{x}.$$

Thus, open access (unrestricted inputs, limited number of firms) leads to an excessive total number of inputs and an excessive number of inputs per firm. These conclusions correspond to those of the graphic analysis.

The mathematics also confirm another conclusion from the graphic model. If access is limited to $N$ firms, where $N$ is less than the open access number of firms, rents will accrue to each firm, even if the amount of inputs remains unrestricted. As we shall see, open access equilibrium occurs in the current model only as $N$ goes to infinity; thus $N$ needs only to be restricted to any number less than infinity for positive rents to accrue. Mathematically, we show this by rearranging (2.14) and using (2.10) to obtain

$$\frac{F(X)}{X} - r = \frac{1}{N}\left[\frac{F(X)}{X} - F'(X)\right] > 0,$$

which implies

$$\frac{F(X)}{X} - r > 0.$$

Average revenue product less unit input cost is strictly positive, indicating positive profits. The result does not depend on $N$. Thus, even though optimal rents are obtained only by restricting industry inputs to $\tilde{X}$, some rents accrue if only the number of firms is limited.

Finally, we look mathematically at complete open access, where not only input levels but also the number of firms is unrestricted. This means relaxing the assumption that the number of firms is fixed at $N$. However, because firms will earn positive profits for any $N < \infty$, new entrants theoretically will be attracted to the industry at any level of $N$. For results on complete open access, therefore, one must examine what happens as $N$ goes to infinity. The main result can be seen if we substitute the equilibrium open access solution $\hat{X}$ into (2.14) and evaluate its left-hand side as $N$ goes to infinity:

$$\lim_{N\to\infty}\left\{\frac{F(\hat{X})}{\hat{X}} - \frac{1}{N}\left[\frac{F(\hat{X})}{\hat{X}} - F'(\hat{X})\right]\right\} = r. \tag{2.18}$$

One's immediate impulse is to evaluate the left-hand side of (2.18) by treating $\hat{X}$ as a constant. However, $\hat{X}$ changes as $N$ changes. Therefore, we must examine $\hat{X}$ as $N$ goes to infinity first. To do this, define the left-hand side of (2.14) as $G(\hat{X}, N)$:

$$G(\hat{X}, N) \equiv \frac{F(\hat{X})}{\hat{X}} - \frac{1}{N}\left[\frac{F(\hat{X})}{\hat{X}} - F'(\hat{X})\right] = r, \tag{2.19}$$

and regard $N$ as continuous. In equilibrium, then, we have[19]

$$\frac{d\hat{X}}{dN} = -\frac{\dfrac{\partial G}{\partial N}}{\dfrac{\partial G}{\partial \hat{X}}}. \tag{2.20}$$

Finding the partial derivatives on the right-hand side shows that[20]

[19] To show (2.20), start with the equilibrium condition (2.19):

$$G(\hat{X}, N) = r. \tag{a}$$

Differentiate totally with respect to $N$:

$$\frac{dG}{dN} = 0, \tag{b}$$

which is true because $r$ is a constant. Since $\hat{X}$ is a function of $N$, the general formula for the total derivative is

$$\frac{dG}{dN} = \frac{\partial G}{\partial N} + \frac{\partial G}{\partial \hat{X}}\frac{d\hat{X}}{dN}. \tag{c}$$

Equate (b) and (c):

$$0 = \frac{\partial G}{\partial N} + \frac{\partial G}{\partial \hat{X}}\frac{d\hat{X}}{dN}.$$

Solve for $\frac{d\hat{X}}{dN}$:

$$\frac{d\hat{X}}{dN} = -\frac{\dfrac{\partial G}{\partial N}}{\dfrac{\partial G}{\partial \hat{X}}}.$$

[20] To show (2.21), first find the signs of the partial derivatives:

$$\frac{\partial G}{\partial N} = \frac{\dfrac{F(\hat{X})}{\hat{X}} - F'(\hat{X})}{N^2} > 0 \text{ using equation (2.10);}$$

$$\frac{\partial G}{\partial \hat{X}} = \frac{\hat{X}F'(\hat{X}) - F(\hat{X})}{\hat{X}^2} - \frac{1}{N}\left[\frac{\hat{X}F'(\hat{X}) - F(\hat{X})}{\hat{X}^2} - F''(\hat{X})\right]$$

$$= \frac{1}{\hat{X}}\left[F'(\hat{X}) - \frac{F(\hat{X})}{\hat{X}}\right] - \frac{1}{N}\frac{1}{\hat{X}}\left[F'(\hat{X}) - \frac{F(\hat{X})}{\hat{X}}\right] + \frac{1}{N}F''(\hat{X}) < 0,$$

where in the last equation, I have used (2.10) and the assumption $F''(\hat{X}) < 0$. Therefore, using these signs on the partial derivatives,

$$\frac{d\hat{X}}{dN} = -\frac{\dfrac{\partial G}{\partial N}}{\dfrac{\partial G}{\partial \hat{X}}} > 0.$$

$$\frac{d\hat{X}}{dN} > 0. \tag{2.21}$$

Thus, $\hat{X}$ is monotonically increasing in $N$. However, it must be bounded from above.[21] We know this because (2.14) holds at equilibrium for *any* $N$. If $\hat{X}$ were not bounded, then

$$\lim_{\substack{X\to\infty \\ N\to\infty}} G(\hat{X}, N) = \lim_{\substack{X\to\infty \\ N\to\infty}} \left\{\frac{F(\hat{X})}{\hat{X}} - \frac{1}{N}\left[\frac{F(\hat{X})}{\hat{X}} - F'(\hat{X})\right]\right\} = 0,$$

where (2.11) helps to evaluate the limit. But a value of zero for this limit violates (2.14), which requires the limit to equal $r$. Hence $\hat{X}$ must be bounded from above. Since $\hat{X}$ is monotonically increasing in $N$ and yet bounded from above, we conclude that $\hat{X}$ tends to a finite limit as $N$ goes to infinity.

Since $\hat{X}$ has a finite limit, it is acceptable to treat it as a constant equal to its limiting value in (2.18). It is then easy to evaluate (2.18), and we find that as $N$ grows arbitrarily large

$$\frac{F(\hat{X})}{\hat{X}} = r.$$

That is, the average revenue product equals the rental rate of effort; all excess profits (rents) to the resource are dissipated. Furthermore, each firm introduces only an infinitesimal amount of effort at the open access equilibrium; because $\hat{X}$ tends to a finite value, $\hat{x} = (1/N)\hat{X}$ will tend to an infinitesimal quantity as $N$ goes to infinity.

The results of the mathematical model differ from those of the graphic model in one significant way. The mathematical model predicts an infinite number of firms, each expending infinitesimal effort at open access equilibrium; the graphic model indicates a finite number of firms, each expending a finite amount of effort at open access equilibrium. These differences can be explained by divergent assumptions about the cost function for producing effort. The graphic model uses traditional U-shaped cost curves at the firm level, although industry effort enjoys constant returns to scale (constant marginal costs). Such cost curves lead to a definite number of firms producing at the minimums of their average cost curves in equilibrium. The mathematical model, in contrast, incorporates no explicit assumptions about the form of the cost of effort function. The model assumes constant returns to scale in total industry input $X$ and the size of the catchment area $S$, and that the variable input $x_i$ is perfectly divisible and supplied

[21] $\hat{X}$ being bounded from above means that a finite open access equilibrium input level exists.

by a perfectly competitive (constant price) industry. The model's results depend on a "crowding of vessels" (Dasgupta and Heal 1979: 56) or the population dynamics of the fish, as I have argued. Although it is an assumption, we might take all this to mean that firms in the mathematical model enjoy constant returns to scale in producing effort from $x_i$, even though they face diminishing returns in producing fish when effort is applied to the fishery. Now the presence of constant returns to scale (constant marginal costs) at the firm level leads to the classic indeterminacy problem. The firm has no optimal size nor is there a determinant number of firms in an industry, although industry supply is determinant (Viner 1931; Samuelson 1947: 78–80; Henderson and Quandt 1971: 79–84). Thus, under constant returns to scale, the industry's entire output may be produced efficiently by one, several, many, or, theoretically, an infinite number of firms. Although an assumption of constant returns to scale in effort does not necessitate an infinite number of firms each producing an infinitesimal amount of effort, it is at least consistent with this result.

Despite these differences, both models point to the several identical conclusions mentioned in the body of this chapter: Rent is completely dissipated at open access equilibrium; firms contract their effort as industry effort expands; if the number of firms is limited below open access equilibrium, positive rents accrue—even if inputs are not restricted; and it is necessary to limit both the number of firms and their input levels to attain the socially optimal level of inputs to the jointly used resource.

CHAPTER 3

# Common Property

In Chapter 2, I referred to the problem of unrestricted entry and use of a resource as the problem of open access. Frequently, others have labeled such resource use "common property."[1] I contend, however, that "common property" and "open access" should not be used synonymously. They are two separate resource use regimes, and the distinctions between them deserve to be understood. In this chapter, I make explicit the differences between open access and common property.[2]

This chapter has a second major goal. Some authors in discussing open access offer private property as the best or only solution to the problem (Demsetz 1967; Cheung 1970; Ault and Rutman 1979). Private property is indeed one solution to the inefficiencies of open access. Private property is not the only or necessarily the best solution to open access problems, however. Several other ways to correct open access distortions exist, and a subset of them forms the class of common property. This chapter defends the theory that common property, once defined and distinguished from open access, may represent a solution to open access.

## Definition of Common Property

I will begin by presenting a formal definition of common property, which is characterized by seven points that constitute a set of necessary and sufficient conditions for common property. The conditions are individually necessary because a resource managed under common property must meet all seven of them. The conditions are jointly

[1] The equating of open access with common property is best illustrated by a quotation, of which many similar examples exist. North and Thomas (1977: 234) in their description of hunting and gathering societies state: "The natural resources, whether the animals to be hunted, or vegetation to be gathered, were initially held as common property. This type of property rights implies free access by all to the resource."

[2] I do not claim credit for the distinction between open access and common property. Ciriacy-Wantrup (1971) and Ciriacy-Wantrup and Bishop (1975) made the distinction quite some time ago.

sufficient for common property because all other resource use regimes (in particular, various forms of open access and private property) fail to meet at least one of the conditions.

Let us proceed to the definition. Common property is a form of resource ownership with the following characteristics:

1. The resource unit has bounds that are well defined by physical, biological, and social parameters.
2. There is a well-delineated group of users, who are distinct from persons excluded from resource use.
3. Multiple included users participate in resource extraction.
4. Explicit or implicit well-understood rules exist among users regarding their rights and their duties to one another about resource extraction.
5. Users share joint, nonexclusive entitlement to the *in situ* or fugitive resource prior to its capture or use.
6. Users compete for the resource, and thereby impose negative externalities on one another.
7. A well-delineated group of rights holders exists, which may or may not coincide with the group of users.

### *Bounded Resource Condition*

Point 1 is included because it is necessary in any particular case to know the answer to the question, "What is the resource?" The boundaries of the resource catchment area are sometimes defined by physical or biological parameters, sometimes by social conventions, and sometimes by a combination of these. For example, a fish population is defined by biological characteristics; groundwater and oil pools are circumscribed by physical properties; grazing lands are delimited by the social convention of property lines. An example of physical and social parameters interacting to define the resource is provided by alpine grazing. Sometimes a mountain ridge or the limit of grass growth on a rocky escarpment will provide the property line that humans draw.

The term "common property," it should be emphasized, refers to a social institution, not to a physical or intangible object. The resource is the physical or intangible asset that a group can own and manage by common property. The demarcation of the resource, however, must be included in the definition of the social institution of common property. The institution cannot exist without the resource that it controls.

*Well-delineated Group of Users Condition*

Point 2 in the definition specifies that there are two groups with a relationship to the resource: included users and excluded persons. The first group consists of an identifiable, countable number of users, the second of a set of persons who do not have the right to use. This of course contrasts to open access, where everyone is a potential user. In limiting cases, such as the atmosphere or the oceans, there eventually may be examples of common property in which there are no excluded users. For such cases, however, all of the other criteria for common property must be established, a feat that has not been accomplished by any example of global common property to date.

*Multiple Users Condition*

Point 3 indicates that common property is utilized by two or more people. It excludes the degenerate group of one person. The use or control of a resource by a single person is associated primarily with private property.

*Well-understood Rules Condition*

Point 4 states that rules exist within the included group of users to guide resource extraction. The most important of these rules—important because it helps distinguish common property from open access—is some method to control who may take how much of the resource. Rights to use, however, are not necessarily rights to equal amounts of the resource. Indeed, it is the exceptional case when all users have equal rights to exploit the resource. Other rules may include how rights are transferred, what financial obligation a user has to the group, what work requirement he or she has, and how the rules themselves are changed.

The rules may be formal and explicit or they may be informal and implicitly accepted. In traditional societies, the users themselves may put into place the institutional structure to govern and manage the resource. Such rule structures are often informal and involve implicit understandings, although formal rule structures such as the Swiss grazing commons discussed in Chapter 4 also have evolved in traditional contexts. In an industrialized society setting up a new common property framework, the government may have a hand in implementing rules to govern resource use, where such rules are generally formal, written regulations with legal force.

The rules and conventions of resource extraction under common property always appeal to some authority higher than the individual user or any subset of users. This authority is often explicit, taking the form of a chief, a medieval manor court, a democratic governing body of the commons, a government agency that regulates the commons, and so on. In cases in which the rules of resource extraction are traditional and implicit, however, this authority may be no more (and no less) than the group consciousness and peer pressure.

### *Joint, Nonexclusive Entitlement Condition*

Point 5 inspires two discussions, one about an essential difference between common and private property and the other about the relationship of common property to a public good.

First, let us examine joint, nonexclusive entitlement's implication for the difference between common and private property. Under private property, the *in situ* resource can be said to belong to a particular real or legal person. This person can have secure expectations about possessing particular physical units as well as particular amounts of the resource. Common property resources, however, are fugitive resources. A physical unit of the resource in its *in situ* or fugitive state cannot be associated with a particular user as its owner (Ciriacy-Wantrup 1952: 141–42). Under common property, users may have secure expectations about possessing certain amounts of the resource, but not about possessing particular physical units. The joint, nonexclusive entitlement condition means that participants in a common property arrangement have simultaneous, ex ante (prior to capture) claims on any particular unit of the resource. Therefore, an essential step in the use of common property resources (except those that have a public goods character) is that they be "reduced" to sole ownership through capture. For example, by capturing a fish, a user converts the resource from joint, nonexclusive entitlement to sole ownership.

The distinction between common property and public goods requires a lengthier discussion than is appropriate for understanding joint, nonexclusive entitlement. I will take up this discussion subsequently. For now, two points are relevant. First, some resources that may be managed as common property have a public goods character, such as parks, natural harbors, and so on. They do not exhibit rivalry at low and moderate levels of use. For such resources, reducing the resource to sole ownership through capture does not apply, as it does to resources that exhibit rivalry in extraction. Second, these resources do exhibit joint, nonexclusive entitlement, because all participants who use the resource have an ex ante claim to benefits from the resource, where "ex ante" here means prior to use rather than prior to capture. For these reasons, reduction to sole ownership through capture is not a necessary condition for common property, but joint, nonexclusive entitlement is.

*Competitive Users Condition*

Embedded in Point 6 are two closely related ideas. The first is simply that the multiple users compete for the resource. This does not mean that they may not cooperate to limit resource extraction (see Point 4) or that they may not cooperate in such ways as making mutual capital investments to assist each other in resource extraction. Rather, Point 6 differentiates common property from a corporation, in which two or more users found an enterprise to exploit a resource by pooling their real and financial assets and skills in order to enjoy a common return. Although some aspects of a common property institution may include pooled ownership, for example, buildings, equipment, and other inputs, some inputs and/or outputs remain in the ownership of the individual participant. The model for common property lies more in a cooperative than in a corporation. Competing users under common property come together to cooperate rather than to become corporate.[3]

The second implication of Point 6 is that one user's extraction of the resource generates negative externalities for other users. In this sense, common property is like open access. The difference lies in the extent to which externalities are generated. As I discuss in the section of this chapter entitled "The Private Property, Common Property, Open Access Trichotomy," the well-delineated group of users and the well-understood rules among them, Points 2 and 4, can control the negative externalities at an appropriate level.

Like those under open access, the externalities under common property may be either reciprocal or nonreciprocal. On the one hand, extractors of the resource may impose negative externalities of like kind upon each other. Such reciprocal externalities occur most often in cases where all users of the common property resource are alike in their reason for exploiting the resource. Typically, they are producers utilizing, for instance, a grazing commons, a fishery, a groundwater

[3] A borderline case is the unitized oil pool. Below I include this case as a form of common property, despite exploitation that occurs under unified management. To me, a unitized oil pool is common rather than corporate property, because separate actors with disparate, competing goals *cooperate* to extract the resource.

basin, a common forest, or something similar. On the other hand, common property externalities may be nonreciprocal, as they are between the two essentially different classes of users in such problems as air and water pollution. In the pollution case, one set of users exploits the resource as a sink for pollutants, while the other set of users utilizes the resource for consumption—breathing, drinking, recreating, and so on. Generally, this situation is viewed as one set of users being the generators and the other the receivers of the externality. The incidence of an externality, however, is entirely dependent on who holds the property rights to the resource. Not only can a smoking factory be considered to be imposing an externality on neighboring residents, but neighboring residents can also be considered to be imposing an externality on a factory required to install pollution control devices (Coase 1960). Therefore, the designations "generators" and "recipients" of the externality are in some sense arbitrary, depending entirely on who has property rights to the air. Therefore, users of the resource might be considered all who make some claim on it, and resource systems in which the resource is put to multiple uses could be brought under management schemes in which various types of users become the included group (Point 2 in the definition of common property). The rules they set up for use would constitute the rights and duties of common property.

Unfortunately, expanding common property to include situations of divergent user types and nonreciprocal externalities complicates the analysis considerably. Therefore, as in the analysis of open access in Chapter 2, I will confine myself largely to reciprocal externality situations in discussing common property and contrasting it with open access and private property.

*Rights Holders Condition*

Point 7 recognizes that the resource users and resource owners are not always coincident. Common property rights holders, for instance, may rent their resource use rights to the actual users. Where rights holders and users diverge, however, the rights holders condition requires that the rights holders be a group of people who fulfill the other institutional criteria of common property. Nevertheless, Point 7 is not meant to preclude the situation in which a government entity coordinates or imposes the rules regarding resource extraction on users and rights holders.

Point 7 also differentiates common property from property tenure in which a private owner grants rights to a group to use a resource.

For instance, a private owner does not set up common property in a field when he rents it to a church for its picnic, even if the church as the user group passes all of the other institutional criteria for common property. The contract between the private owner and the group is still the primary arbiter of resource use, not the implicit or explicit rules of the group.

### *An Excluded Condition: Coequal Rights*

Before leaving the definition of common property, I wish to discuss a concept that is related to the definition, but that I have not included in it. Ciriacy-Wantrup and Bishop (1975), pioneers in common property theory, indicate that participants in a common property system have "coequal" rights to use. In practical terms, this means that users share fluctuations in availability of the resource proportionally according to each user's basic right to use or historical pattern of use. It does *not* mean that users have rights to equal amounts of the resource. For example, under coequal rights, a common property fishery regulated by quotas or transferable licenses would follow the rule of proportionate reductions in historical catch rights during bad fishing years. In the commons grazing in the European Alps, where one may graze the same number of animal units from year to year, proportionate adjustments in use for good or bad years are made by lengthening or shortening the grazing season.

S. V. Ciriacy-Wantrup included coequal rights as a necessary condition for common property because he rejected such rights systems as the appropriations doctrine in Western water law from the class of common property (Bishop 1983). This doctrine is based on the principle of first-in-time, first-in-right. The first user to withdraw an amount of water and put it to beneficial use establishes a right to use that amount of water in future periods, as long as the full amount of water continues to be put to beneficial use. Subsequent users may establish rights by withdrawing further water, but the chronological order in which the water is first withdrawn determines each user's right to future water. In particular, in dry years, junior rights holders may be cut off completely, whereas users who established their rights earlier have access to their full amount of water.

Ciriacy-Wantrup excluded this type of allocation system from common property. Yet if members of the resource user group agree among themselves to allocate the resource in an inegalitarian manner, or, in an extreme case, if the group agrees to give only one of its members the entire resource harvest in times of shortage, why should we not call this common property?[4] Users have agreed upon well-defined rules between the group and outsiders as well as within the group, and if the other conditions are met, then one might hold to a definition of common property without an egalitarian allocation rule under resource fluctuations. Although many resources exploited jointly exhibit coequal rights to use, whether they are fisheries or wildlife, groundwater or grazing areas, certain common use resource systems with well-defined rights and duties among users and nonusers exhibit inegalitarian allocation mechanisms, notably irrigation systems. For this reason, I do not include coequal use as a necessary condition for defining common property.

*Synoptic Definition*

In closing this section, I give a less formal definition of common property that includes the salient points from the seven above. *Common property is a form of resource management in which a well-delineated group of competing users participates in extraction or use of a jointly held, fugitive resource according to explicitly or implicitly understood rules about who may take how much of the resource.* There are two reasons for defining common property in this way, in contrast to the frequent usage that equates it to open access. One is historical and one is rooted in the meaning of the word "property." The following two sections elaborate on these reasons.

## The Historical Record of Common Property

Historically, the commons has not represented a system of open access exploitation (Clawson 1974; Juergensmeyer and Wadley 1974; Ciriacy-Wantrup and Bishop 1975; Dahlman 1980). As Clawson (1974: 60) points out:

> Property owned in common, whether land or other kinds, has not by any means always been freely open to any user, nor is property owned in common today in many parts of the world open to any user. Social controls of many kinds have existed, and do exist, to limit and govern the use of property owned in common. Such social controls often regulate the intensity of use. Property owned in common has not invariably been used in an exploitative way.

Examples of natural resources that have been used in common without overuse abound in history and prehistory.[5] Prehistoric hunt-

[4] I am indebted to Robin Cantor for this point.
[5] Besides examples cited in the text, other accounts of historical and modern common

ing and gathering societies used land communally under regulation by tribal heads, closed seasons, social taboos on marriage and lactation, and fission of tribal groups. These institutions managed the resources on a sustained yield basis, and common ownership, far from being the cause of overexploitation, may have been the primary reason for preservation of resources (Ciriacy-Wantrup and Bishop 1975).

Common grazing land and communal forests in Europe offer other long-standing examples of group-managed, limited access resources. Some of the community forests in Europe provided models of good forest management, precisely because they were managed for the community. Grazing commons were often limited to residents of a certain village or hamlet, or only to descendants of original residents from a specific prior date. Further regulation of grazing took the form of opening and closing dates, limitation of animals to the number for which an individual could provide forage through the winter, or outright stinting.

Common grazing also occurred in the open field system of England, a system that we will view in detail in comparisons with the Swiss grazing commons in Chapter 5. English common grazing, rather than a maladaptation, may well have been the most efficient production method that stood alongside individual cropping in the arable, given the economies of scale in cattle grazing relative to crop planting (Dahlman 1980: 7).

The English commons system apparently sprang from previously open access land, because at very early dates all members of a community had equal access to common lands (Juergensmeyer and Wadley 1974). Because of limited resources and growing population, however, such liberties of use changed into exclusive rights to use during prefeudal and feudal times. These rights to use were based on long-standing residency, property holdings, and rights of certain feudal classes, and they excluded outsiders:

The Englishman's rights . . . were the rights he enjoyed as a member of some particular class and community.

> He lived under customs and enjoyed franchises which might be peculiar to his native town or even his native parish. . . . And every village and township would no doubt be as anxious to exclude strangers from its woods and pastures as to preserve its ordinary members' rights in them against encroachment from within or from above. [Pollock 1896: 18]

property resource patterns are given in Hoskins and Stamp (1963), Rhoades and Thompson (1975), Netting (1976), Panel on Common Property Resource Management (1986), and McCay and Acheson (1987).

> . . . Common rights in general, consist of privileges of use, i.e., the liberty of taking sand and gravel, of pasture, of cutting underbrush, etc., according to the customs of the particular neighborhood, and naturally depend upon the resources of the neighborhood. . . .
>
> . . . [I]t was entirely possible that not all the members of a given village with common lands shared equally, or even at all, in the use and enjoyment of the lands. Those to whom the common lands originally belonged (and their heirs) retained their rights over the common. In addition, others, perhaps of another village or even members of the same village who had moved in after the common originated but who lacked rights by descent, might have only one or another of the rights of common, e.g., the right of pasturage, or of turbary. (Juergensmeyer and Wadley 1974: 363–64)

Moving to another time and part of the world, the peasant fishermen of Bahia in northeastern Brazil provide another example of common property resource management (Cordell 1978). Before the technological innovation of nylon nets, they pursued a common property fishery based much more on implicit rules and traditions than on explicit, codified regulations. These traditions had arisen because natural limits had prevented the expansion of estuary fishing. Knowledge of tidal rhythms as influenced by lunar periodicity was very important in locating different fish species in the estuary. The knowledge of tides, fishing grounds, and types of nets to set was confined to a certain number of boat captains and judiciously passed on to only a certain number of apprentices. The possession of this knowledge established implicit but definite property rights claims over lunar-tide fishing areas. Violation of implicit rules was prevented by social pressure from the community of fishermen, and disputes were settled by being aired before this community. Fishing decorum included trading of favors, such as the use of each others' fishing grounds, in a cooperative but controlled fashion.

To summarize, open access has not been the modus operandi of many historical commons. They at least limited the number of users, and some of them limited the amount of exploitation allowed by each individual user. Because of these historical practices, many of which can still be observed to this day, it is incorrect to equate common property with open access.

## The Meaning of Property

The second reason for using "common property" to indicate an institution of joint ownership lies in the meaning of property and its distinction from nonproperty. Property's existence in an object entails rights and duties for property holders and nonproperty holders alike.

In our case, property implies rights and duties for both participants and nonparticipants in resource extraction; the absence of rights and duties means that the institution of property does not exist. As I will show, open access exhibits the complete absence of ex ante (prior to capture) rights and duties, and therefore it constitutes the total absence of property. Common property, on the other hand, as the word "property" implies, involves ex ante rights for the rights holders—even if they are multiple rather than single—and duties for nonproperty holders. It is therefore important to distinguish common property from open access. This section elaborates these ideas by explaining the meaning of rights and duties, the class of rights called property rights, and their application to the distinction between open access and common property.[6]

The first step toward understanding rights is to examine the nature of the connection between persons involved in an ethical or legal relationship. A widely recognized classification of such relationships consists of the four Hohfeldian correlates:

right/duty,
liberty/no right,[7]
power/liability,
immunity/no power.

Each of the four correlate pairs indicates how one person stands in relation to another person in an ethical or legal relationship and what the reciprocal relationship is. The pairs are invariably linked. For instance, the first correlate pair indicates that if one party has a right, the other necessarily has a duty. Where duty is absent, no right exists.

The most important set of correlates for our purposes is the right/duty pair. A *right* is a claim by one individual or institution (the right holder) on another (the duty bearer) for an act or forbearance, such that if the act or forbearance is not performed, it would be morally or legally acceptable to use coercion to extract compliance or compensation in lieu of it (Becker 1977: 11). A *duty*, as the complement (or correlate) to a right, is the obligation of the duty bearer to perform the act or forbearance. Thus, if one agent has the right to expect an act or a forbearance from another, the other necessarily has the duty, in a moral or legal sense, to act or forbear.

[6] This section, up to the application to common property and open access, is based on work on the meaning of property rights by several philosophers and legal scholars, including Hohfeld (1919), Hallowell (1943), Honoré (1961), and Becker (1977: chap. 2).

[7] Hohfeld (1919) uses the word "privilege" instead of "liberty" in the second correlate pair. Becker (1977) uses the term "liberty," which I also adopt.

The liberty/no right correlate pair is also important for our analysis. A *liberty* is a legal or ethical freedom to perform or not to perform an act without any duty incumbent on another person. It also means that others have no right to require the person at liberty to perform or forbear from the act; that is, others hold *no right* as the correlate to the person's liberty. Competitive situations provide an example. Each competitor is at liberty to win; no one has the duty to let another win; each competitor has no right to stop another from winning (if the winner follows the rules of the game) (Becker 1977: 12).[8]

Now I narrow the discussion to *property rights*, in order to show how they exist in common property but not in an open access situation. Whereas rights are relationships between persons, property rights are specifically relationships between persons regarding use of a thing—whether corporeal or incorporeal (Hallowell 1943; Becker 1977: 22). Various rights, duties, liberties, powers, immunities, and liabilities combine to define a person's property rights (ownership rights) in a thing and how another person is morally or legally required to act with regard to the thing (Ely 1914: 106; Honoré 1961; Becker 1977: 19).[9] The existence and observance of these rights, duties, and other relationships distinguishes property from nonproperty, as well as one type of property from another.

One of the most fundamental rights of complete, liberal ownership is the right to possess, which is the right to exclusive physical control or the right to exclude others from the use or benefits of a thing (Becker 1977: 19). Possession is important in the comparison between open access and common property, because fugitive resources under open access are not possessed, whereas they are possessed under com-

[8] The other two Hohfeldian correlate pairs are not important for our analysis of common property. Briefly, however, the power/liability correlates refer to the situation in which one party has the *power* to change the rights, duties, liberties, powers, or immunities of another person at will. An example is a person's power to alter his or her last will and testament. The heirs' *liability* lies in the fact that they must respect their changed legal status toward the bequeathed goods. The immunity/no power correlates refer to the situation in which the first party is *immune* from a power possessed by the second party, who logically has *no power* in that specific case. An example is that creditors generally have power to seize possessions for unpaid debts; a person in bankruptcy proceedings, however, is immune from such power.

[9] The rights, duties, liberties, powers, and immunities that define the degree of ownership are the right to possess; the right to personal use; the right to manage (i.e., to decide how and by whom a thing shall be used); the right to income through forgoing personal use and allowing others to use a thing; the powers to alienate, consume, waste, modify, or destroy a thing; an immunity from expropriation; the power to bequeath; the rights regarding term of ownership; the duty to forbear from using the thing in ways harmful to others; the liability to expropriation for unpaid debt; and rights and duties regarding the reversion of lapsed ownership rights (Honoré 1961; Becker 1977: 19).

mon property. Becker (1977: 21) elaborates on the right to possess as follows:

> The right to possess is to be sharply distinguished from mere protection of possession once achieved—that is, it is a claim right to have possession, not merely a power to acquire or a liberty to keep. If I have a right to possess a thing, others do not merely have "no right" that I not possess it; they have a duty not to interfere with my possession.

This points directly to the property rights distinction between open access and common property. Ownership, if it includes the right to possess, implies the positive right of holding the object and the negative right of excluding others from its possession, even if the object is not yet held. Under open access, however, neither of these rights is present. No one has the right to exclude another from extracting the resource; hence the negative, exclusionary right is not present. Nor is there any security of possessing either particular physical units or a certain amount of the resource; hence the positive right of holding the object also is not present. Thus, there is no ownership, at least not ownership that includes the fundamental right of possession.

This point is important, so I will put it another way. In an open access fishery, no one is secure in the claim to certain fish or even to a certain amount of fish, because someone else may capture them first. Thus, there is no right holder with a claim to possess certain fish or a certain amount of fish. Necessarily, there is also no correlate duty bearer who should forbear capture of fish. With no right/duty relationship in an open access resource, there is *no property* and there are *no owners*. Resources in this situation are *res nullius*, unowned resources (Ciriacy-Wantrup 1971).[10]

Common property, on the other hand, *is* property. It has a definable set of users who have the right to exclude others from possession, use, and enjoyment of benefits. Excluded persons have the duty to observe the rights of the included users to extract the resource. Furthermore, in a well-functioning common property situation, the users have certain rights and duties among themselves with respect to possession, use, and enjoyment of benefits from the resource (Bromley 1989: 205). For example, in a regulated groundwater regime, all participants have the right to pump water at specified rates; they also have the correlate duty of not exceeding their assigned rate so as not to interfere with others' water extraction.

[10] In fact, open access is better characterized by the liberty/no right correlates (Bromley 1989: 203–5). A user is at liberty to catch what he wants. Other users have no right to prevent him. At the same time, however, they have no duty to allow capture. They may possess the fish if they capture them first.

Moreover, the rights and duties in true common property go beyond the right of possession. Under common property, the right to use, the right to manage, the right to income, an immunity from expropriation, the power to bequeath, and the absence of any term of ownership rights all often reside to varying degrees with the individual or the group. With definite right and duty relationships among all parties concerned—both users and nonusers—regarding the object in question, it is possible to talk about owners and their *property* (i.e., their rights in the object). Such property rights represent *res communes,* common property (Ciriacy-Wantrup 1971).

In summary, then, an implicit distinction between open access and common property lies in the concept of property and its requirement of well-defined rights and duties. Open access does not represent property; common property does. An open access resource does not have owners; common property does.

## Limited User Open Access

A qualification is necessary to define common property clearly. Ciriacy-Wantrup (1971) has pointed out that not only has open access been confused with common property but so has a type of resource use pattern that I have called limited user open access (see Chapter 2). Under limited user open access, property rights have been established for a limited number of users, but the property rights among these users remain ill-defined. The most common example of this type of resource is oil and gas pools. Groundwater is also sometimes utilized under this regime, and some forms of limited entry programs in fisheries result in such a property rights structure. The included users are only "quasi-owners" of the resource. They have exclusive rights *to extract* the resource, but not exclusive rights to a certain amount of the resource extracted. Any included user may exploit the resource at any rate desired.

As the models of Chapter 2 indicate, if only the number of users is restricted but not their input levels, the users will expand total inputs beyond the optimal level. The nonoptimality may not be as severe as when complete open access in both inputs and the number of firms is allowed. Nevertheless, limited user open access leads to some expansion of inputs beyond the optimal amount. The lack of individual input controls leaves the property rights structure indefinitely defined, and users are therefore free to follow individual incentives to overexploit the resource. For this reason, I follow Ciriacy-Wantrup (1971) and confine my definition of common property to situations of clearly defined property rights between users and nonusers *and* among the users themselves. This excludes the situation of limited user open access.

As mentioned, unregulated extraction from common oil and gas pools provides an example of limited user open access. Economically excessive extraction rates result from the "rule of capture" prevailing among the limited number of users (Davidson 1963). In order to establish a full set of extraction rights and duties that lead to optimal resource exploitation, compulsory field unitization has long been proposed as an alternative to unrestricted pumping or inefficient government regulation of extraction rates (Davidson 1963; Wiggins and Libecap 1985). Unitization of the fields would

> "require the organization of companies or cooperatives in which all surface owners would share on an equitable basis" [Rostow 1948: 45]. The advantage of such an operation would be to void the rule of capture. (Davidson 1963: 97)

This is a common property solution. The user group would make production decisions to maximize joint profit. Then, by deciding how to divide up the oil or profits among existing users, the group would effectively establish definite property rights.

Another example arises from the establishment of the offshore, two-hundred-mile, exclusive economic zones (EEZs). Before the extension of national claims to two hundred miles, the fish in waters beyond twelve miles (for most countries) constituted an open access resource. Anyone from any country could exploit them. No one had the right to possess the fish before anyone else; no one had the duty to forbear capture. The founding of the EEZs represented the first step toward establishing property rights. There came into being a group of included users (domestic and specially permitted foreign fishers) and a group of excluded users (all unpermitted foreigners). The included users have rights to capture, and the excluded persons have duties to forbear from fishing. Property rights must be defined more strictly, however, to say that full common property has been established. Rights must be set among the included users. This means establishing rights to certain amounts of fish and the simultaneous, correlate duty of not capturing more than permitted amounts.

## Common Property and Public Goods

Understanding common property also requires a grasp of the distinction between common property and a public good. Common property and public goods are similar in that both are held by a group. For common property, the joint, nonexclusive entitlement condition indicates that resource owners have a joint claim on the resource prior to capture or use. The public that supplies a public good similarly has a shared claim on its benefits as a result of providing it through, say, tax collections. However, here the similarities between common property and public goods end.

The essential distinction between a public good and common property lies in a public good's being a type of good or service, while common property is a resource management method. A public good lies among a set of goods types that vary in their degrees of rivalry and excludability in consumption. A public good is the particular case in which consumption of the good is nonrival (two or more may enjoy benefits simultaneously) and exclusion from benefits cannot be enforced.[11] Common property, in contrast, lies on a spectrum of ownership and management forms that ranges from open access to private property. (This ownership spectrum is developed further in the section entitled "The Private Property, Common Property, Open Access Trichotomy.") In fact, because common property is a resource management institution, different types of goods or resources, including public goods, may be managed under it. For example, land, a commodity subject to rivalry in use and exclusion of others from use, may be managed under common property; at the same time, goods or resources with greater public goods character, such as a park or a natural harbor, may also be managed as common property. Nevertheless, as I have discussed, some degree of excludability must be present to define a common property resource adequately.

The conditions of excludability and rivalry both provide contrasts between pure public goods and common property. Pure public goods, with their extremely high costs of exclusion from benefits, are generally supplied under open access conditions rather than conditions that resemble common property. Because it is nearly impossible to

[11] This is not to say that nonrivalry in consumption and nonexcludability from benefits are strictly technical characteristics that define a public good. Exclusion from benefits, for example, can be enforced for almost any good if high enough costs are incurred; conceptually at least, even the purest public goods could be supplied privately. Thus, whether a good is supplied as a public good depends on human decisions about costs and is not strictly determined by technical characteristics. In this sense, the choice between providing a good publicly and supplying it privately can be said to be an institutional choice, just as the choice between managing a resource by common property and managing it by private property can be an institutional one. Still, the probability of a good's being supplied as a public good depends on the costs of exclusion, which *are* a technical characteristic under a given state of technology. Thus, one can classify some goods as more prone to be public and others as more likely to be private.

exclude anyone from enjoying benefits, no attempt is made to define included and excluded user groups. Likewise, complete nonrivalry in consumption, also characteristic of a pure public good, generally does not apply to a common property resource. There are two cases. If the resource can be reduced to sole ownership by capture, then one person's extraction of a unit of the resource clearly precludes another's possession of that unit; there is absolute rivalry in extraction. If the resource exhibits a public goods nature at low and moderate levels of use, but congestion occurs at higher levels of use, users may institute common property–like limitations on use. Significantly, it is precisely the congestion that negates its public goods nature that calls forth common property limitations on use. That is, only the lack of a *pure* public goods nature, nonrivalry at all levels of use, is compatible with the need for common property management.[12]

In contrast to benefits from public goods, benefits from common property resources that exhibit rivalry in extraction can be enjoyed only after the resource has been captured. Joint, nonexclusive entitlement implies that owners of a common property resource possess a *potential* benefit, contingent upon capture or efforts to use the resource. In contrast, beneficiaries of a pure public good, such as national defense, enjoy *actual* benefits even though the good remains under joint, nonexclusive possession.

Another difference between public goods and common property resources lies in the fact that public goods generally are artificially manufactured goods that may be supplied in discretionary amounts. In fact, much of public goods theory relates to how much of a public good to provide. In contrast, common property resources generally are natural resources whose growth or extraction must be managed to obtain optimal use rates. This contrast extends subtly to such examples as parks and natural harbors, which are potential common property resources that traditionally have also been considered public goods. Public goods theory concerns itself with how much to invest in providing these types of amenities—how much of the resource to set aside and how many improvements to provide to make the resource accessible and usable. Common property theory, in contrast, discusses how to manage their use—how intensely to allow use and by whom.

[12] Alternatively, one might say that pure public goods that exhibit no rivalry at any level of use, whose benefits therefore accrue to the whole public, are common property whose user group is everybody. No management of use rates is necessary, because there is complete lack of rivalry in use. At the same time, the whole user group pays for general resource supply and management through taxation and government representation. Admittedly, in this interpretation, the distinction between common property and a public good blurs.

To conclude, not only may goods that can be reduced to sole ownership through capture be managed under common property, but so can some public goods. It is now clear that these are impure public goods, because they are subject to congestion and some form of exclusion. I have given the examples of parks and natural harbors. Potentially, a scenic vista could fall into this category. Because both public goods and goods that can be reduced to sole ownership may be common property, the process of capture that reduces a unit of the resource to sole ownership is not a necessary defining characteristic for common property. Although effort may be needed to capture benefits from a common property resource that has a public goods nature—a person may have to travel to a park, a harbor, or a scenic site to profit from it—deriving benefits does not necessarily compete with others' demands for benefits or exclude others from enjoying benefits, as long as use is controlled below the level of congestion. Thus, reducing the resource to sole ownership to enjoy benefits does not come into the question for a common property resource with a public goods nature. This said, most of the treatment in the rest of this book concentrates on fugitive resources that can be reduced to sole ownership through capture.

## Multiple-Resource Common Property Systems

To round out the definition of common property, I wish to make clear that the institution manifests itself in diverse ways. It may stand alone or be integrated into larger resource management systems. Users in the simplest form of common property employ one technical process to harvest a resource that delivers a single resource commodity or service in one contiguous location. A single-gear, single-species fishery is a good example. More complicated common property systems exist, however. The users may be involved in extraction of several common property resources with one or more techniques simultaneously—as in multiple-gear, single-species or multiple-gear, multiple-species fisheries. The common property resource may deliver multiple services to different types of users. A future example might be the atmosphere, if it is ever fully controlled to accept various pollutants from varying sources at levels that match its varying assimilative capacities. Common property use also can complement other resource management forms in a system. The English open field system was such a system of resource management, in which crop cultivation occurred mainly under individual tenancy intermixed with and complemented by grazing under common property. In all of these cases, however, analysis is eased without loss of generality if the problem is reduced to the harvest of a single resource commodity, although not necessarily by a uniform technology. This is my approach in discussing common property throughout the rest of this book.

## The Private Property, Common Property, Open Access Trichotomy

The preceding sections have concentrated on drawing the distinction between open access and common property in some detail. In the subsequent sections of this chapter, I wish to argue how common property may present a potential solution to the open access problem.

First let us set open access and common property into a larger framework that includes private property. In some ways, common property is like private property: The resource has a definable set of users who may be declared its owners, outsiders are excluded from use, and the users control resource extraction to increase the (joint) net product in order to benefit themselves. Thus, both private property and common property meet the well-delineated group of users and well-understood rules conditions, Points 2 and 4, in the definition of common property.[13] In other ways, common property has properties of open access: Both have multiple users and both contain the incentive for individuals to increase their output beyond the individual share that would produce the joint maximum net product. Thus, open access exhibits the joint, nonexclusive entitlement and the competitive users conditions, Points 5 and 6 of common property's definition, without the controls of the other conditions in the definition. For these reasons, common property might be considered to lie between private property and open access.

The degree of exclusivity in property rights to the *in situ* resource varies under the three systems. Under private property, property rights in the resource (the right to extract it, the right to possess it, the right to alienate it, and so on) are vested in one real or legal person. Under common property, the right to any given physical unit is less well defined. Rather, rights generally are specified in terms of total amounts of inputs or outputs that the user may apply or extract. Which particular units are extracted in fulfilling the quota are immaterial. The next loosest definition of property rights is limited user open access. Under this regime, rights are vested in a certain group of

[13] Of course, for private property an individual user or firm replaces the group of users.

users, but the users have no rights among themselves, either to possess specific physical units or to extract a set amount of the resource. Finally, exclusivity of property rights is lost altogether under open access, where there is neither a definable group of rights holders nor any link between users and physical units or amounts of the resource extracted.

Thus, there is more than just a dichotomy between open access and private property. If limited user open access is grouped with complete open access, there is at least a trichotomy. Common property should not simply be lumped with other group use situations.

Not only is common property distinct from open access and from private property, but it can be a solution to the open access problem, even as private property is. Each of the resource use regimes being discussed has two characteristics that govern extraction rates. How each resource use system is defined on each of these characteristics determines whether controlled extraction rates are achievable. The two characteristics are existence or nonexistence of an included and an excluded group, and existence or nonexistence of constraints on included user extraction rates, as is shown in Figure 3.1. Open access is defined by the lack of constraints on both the number of users and the amount that each user may extract. The models of Chapter 2 made it clear that this is a formula for disastrous overuse. Even if only one of the limitation characteristics is left unfettered, as under limited user open access, exploitation expands beyond the desired rate. Under common property, however, both of the problem-causing characteristics of open access are remedied. Group size is limited and rights and duties to limit extraction are defined among the included users. Private property also limits the number of resource managers

PROPERTY INSTITUTION

| | 1 | 2 | 3 | |
|---|---|---|---|---|
| | | | OPEN ACCESS | |
| | PRIVATE PROPERTY | COMMON PROPERTY | LIMITED USER | UNLIMITED USER |
| GROUP LIMITATION | ONE PERSON | MEMBERS ONLY | MEMBERS ONLY | OPEN TO ANYONE |
| EXTRACTION LIMITATION | EXTRACTION LIMITED BY INDIVIDUAL DECISION | EXTRACTION LIMITED BY RULES | EXTRACTION UNLIMITED | EXTRACTION UNLIMITED |

Figure 3.1. A Trichotomy of Resource Use Regimes

(to one) and controls extraction rates (through the individual's optimization decision). Therefore, although common property stands between open access and private property in the ways already mentioned, it is like private property in the two vital areas of having a defined group and having limited individual use rates. Because both of these regimes eliminate the two main problems of open access, common property may stand beside private property as a solution to the open access problem.

## Common Property in the Economics Literature

Some authors, but by no means all, have ignored the existence of common property institutions. This problem has been made no less severe by the frequent confusion of common property with open access. Witness, for example, Demsetz (1967: 354):

> Several idealized forms of ownership must be distinguished at the outset. These are communal ownership, private ownership, and state ownership. . . . Communal ownership means that the community denies to the state or to individual citizens the right to interfere with any person's exercise of communally-owned rights. Private ownership implies that the community recognizes the right of the owner to exclude others from exercising the owner's private rights. State ownership implies that the state may exclude any from the use of a right as long as the state follows accepted political procedures for determining who may not use state-owned property.

Demsetz's "communal ownership" refers to an open access situation, despite his use of the terms "rights" and "ownership," which as we have seen cannot exist in an open access resource. This is clear because he goes on to speak of *everyone's* having the "right" to use the resource, a failure to "concentrate the cost" of extraction on the user, and consequent overuse of the resource. Thus, because Demsetz explicitly ignores state ownership in his subsequent discussion, he recognizes only a dichotomy of tenure systems: private property and open access.

Cheung (1970: 64) is another who, while recognizing the possibility of common property, labels this ownership pattern less than optimal. It purportedly yields lower rent than sole ownership:

> Consider three alternative arrangements. The first arrangement is a group of individuals forming a tribe, a clan or a union so as to exclude "outsiders" from competing for the use of a non-exclusive resource. In this arrangement each "insider" is free to use the resource as he pleases and derive income therefrom. According to our analysis, the fewer the insiders, the greater will be the "rent" captured by each. . . .
>
> The second arrangement involves not only the exclusion of outsiders, but,

as in some cooperatives, there is central regulation of the amounts of work and income for the insiders. The third arrangement is private property rights governing all resources, where the property rights are exclusively delineated and enforced, and where resource use is guided by contracting in the marketplace.

All three arrangements are costly. While it appears that these costs are lowest for the first type and highest for the third, the gains from each arrangement are in a reverse order.

One must agree with Cheung that the first arrangement yields the lowest rent. Both Anderson's graphic model in Chapter 2 and Dasgupta and Heal's mathematical model in its appendix showed that limiting the number of users but not their input levels leads to some excessive inputs and overuse of the resource. Cheung, however, makes no argument to support his contention that the second arrangement, which describes common property, necessarily yields lower benefits than private property. Indeed, as I argue in the next section and the appendix to this chapter, solutions to open access based on quota and licensing schemes prove that proper limitation of inputs via "central regulation" can lead to the same optimal results as private property. Whether central regulation or private property is more costly is an empirical question that depends on characteristics of the resource.

Although it may seem that other authors repeatedly advocate private property as the sole private solution to open access, many mention, or at least leave room for, common property as a solution. Since definition of property rights is a characteristic of common property, just as it is of private property, many authors might admit to the common property solution even though they primarily had private property in mind when writing. Ault and Rutman (1979: 173) provide an example of this. They describe the transition in many tribal African land use systems from open access when land was plentiful to the division of land into private property when land scarcity emerged and go on to state:

> In order to insure that the individual invests in the land and limits the size of the herd, the land tenure system must change so that individual rights to land are defined, assigned, and transferable.

Not all common property systems would meet Ault and Rutman's requirement of transferable property rights (e.g., strict quota systems do not). Some common property systems, however, do define and assign individual, transferable rights to use. Even though Ault and Rutman were probably trying to describe private property, they might assent to the appropriateness of certain common property arrangements.

Other authors acknowledge the possibility of common property solutions much more freely. Even Gordon (1954: 134), who began the modern theoretical debate on open access resources, has this to say:

The older anthropological study was prone to regard resource tenure in common [i.e., open access], with unrestricted exploitation as a "lower" stage of development comparative with private and group property rights. However, more complete annals of primitive cultures reveal common tenure [i.e., open access] to be quite rare, even in hunting and gathering societies. Property rights in some form predominate by far, and, most important, their existence may be easily explained in terms of the necessity for orderly exploitation and conservation of the resource. Environmental conditions make necessary some vehicle which will prevent the resources of the community at large from being destroyed by excessive exploitation. Private or group land tenure accomplishes this end in an easily understandable fashion.

Scott (1955: 116), who went so far as to subtitle his article "The Objectives of Sole Ownership," recognizes the possibility of common property:

The mere existence of the institution of private property is not sufficient to insure the efficient management of natural resources; the property must be allocated on a *scale* sufficient to insure that one management has complete control of the asset. In this paper, for example, I shall show that . . . sole ownership of the fishery is . . . necessary. . . . [An] immense sole ownership organization [might be] . . . a cooperative, a government board, a private corporation, or an international authority.

Bottomley (1963: 94) also advocates a couple of tenure systems for Tripolitania that have common property character:

Attempts to violate hallowed rights regarding common [i.e., open access] land will, no doubt, run into considerable resistance. It may be that the only politically feasible solution lies in a grafting of the characteristics of private holdings on to common [i.e., open access] land without actually forcing enclosures upon the Arab tribes. In other words, a way must be found of ensuring investors a full return on the capital which they expend regardless of the land tenure system which obtains.

Perhaps the existing tribal structure can be adapted to some cooperative orcharding venture but the formation of such organizations may prove difficult and growth will probably be more rapid if it occurs on the soil of individual enterprise; if, that is to say, the tribesmen, and even outsiders, are able to exercise their entrepreneurial ability to direct self-interest rather than through the cooperative alone. But this requires the alienation to the individual of certain rights pertaining to the common land; the right for the individual to plant trees upon the common land and to harvest them for a predetermined period, subject only to a payment for the use of the land to the members of the tribe, or to some pre-arranged agreement for repurchase by the tribe. In other words, *secure* mutual agreements need to be made between the tribe and the individual so that the fruits of investment will belong to the individual and the rents for the land whereon the investment has been made will belong to the tribe as a whole.

I wish to emphasize that the cooperative orcharding arrangement is not the only example of common property here. The proposed arrangement in which trees would be privately held also exemplifies a common property arrangement *in the land.* Although the capital inputs, the trees, would remain private—much as have cows and other livestock in traditional common property systems of Europe—the land would remain under group control—again like common property in Europe.

Finally, Weitzman (1974: 230–31) illustrates that common property schemes might be considered variants on private property rights. He contrasts two systems: free access and private ownership. His "private ownership" category, however, is not exhausted by cases of sole ownership. Rather, he seems to include various common property schemes:

> There is even a way of envisioning PO [private ownership] in terms of producer cooperatives which take a lease on property at the competitive rental price and determine their membership size by maximizing the dividend of net revenue (after payment of rent) per variable factor member. The solution is the same as before [under individual private ownership of the resource] if rentals have been accurately determined.
>
> It is also conceptually irrelevant to the determination of an optimal allocation whether PO is regarded as based on competitive *private* ownership of property or on efficiently organized government *public* ownership. . . .
>
> Thus, for the model building purposes of theoretically characterizing efficient allocation, who owns property and what factor is thought of as hiring the other in the economic system we are calling PO is somewhat arbitrary. Which arrangement is in fact to be employed would largely depend on institutional considerations and on tradition.

In summary, some economists have not recognized the existence of common property as an institutional form between private property and open access, but have acknowledged only private property as an alternative to open access. This is by no means true of all economists, however, not even some of those steeped in neoclassical traditions. Some of these call only for some type of property rights arrangements in open access resources, which common property as well as private property can provide. Others outwardly admit to the possible success of certain group solutions. Perhaps the war being waged between advocates of private property rights and the proponents of institutional alternatives to private property is unnecessary.[14] Both sides support the vesting of some type of clearly defined property rights in the resource to prevent the "tragedy of open access." Since there is agreement on this point, it is only one more step to realize that the particular form of property rights might best be designed to match the characteristics of the resource being exploited and the people doing the exploiting.

## Neoclassical Justifications of Common Property

Until now, justification of common property's adequacy has been confined to citing characteristics that it shares with private property and its persistence in history. In this section, I defend common property by referring to neoclassical proofs of group solutions. In subsequent sections, we will look at property rights and institutional arguments.

Six neoclassical solutions to the open access problem have been suggested: private property, input quotas, input rights, output quotas, output rights, and taxation. Four of these—the ones involving quotas and rights—can be considered common property solutions. Although an appendix to this chapter offers formal proofs, in this section I give some intuitive grounds for the optimality of these solutions and explain how they can be considered common property.

### *Input Quotas*

In a system of quotas on inputs, participants collude to limit their total inputs for resource extraction to the amount that yields the maximum sustainable net revenue, $E^*$ in Chapter 2. The participants use some nonmarket, nonprice mechanism to allocate individual quotas. In the simplest case, individual quotas are set at $E^*/N$, where $N$ is the number of permitted resource harvesters. The quota on inputs scheme works properly if a rigid production function exists between the inputs applied and the amount of resource extracted. Together, the limitation on inputs and the fixed production relationship effectively vest rights to a certain amount of the resource. The scheme

[14] A group of institutional economists and political scientists has emerged who defend common property as a practical solution to open access. These authors include Ciriacy-Wantrup and Bishop (1975), Runge (1981, 1986), Bromley (1986), and Ostrom (1986), although this is not an exhaustive list. I have not reviewed their work here because it presents arguments that overlap with many of those presented elsewhere in this chapter.

meets the conditions of common property because the number of users has been limited (to $N$) and their individual resource extraction rates have been restricted by limiting inputs. By definition, the arrangement is optimal when the summation of the individual quotas equals $E^*$. The Bahia swamp dwellers described in the section entitled "The Historical Record of Common Property" implicitly followed a quota on inputs scheme.

There are two problems with this solution. First, the incentive remains to cheat on the system by introducing more than $E^*/N$ inputs (or whatever the individual input quotas are) and increasing the personal rent while others hold to their limits. Although the input quotas confine the common property resource users to the optimal solution (figuratively speaking, the southeastern box of the game theoretic diagram of Figures 2.5 to 2.7), there is a constant incentive in this position for some player to cheat on the agreement. The optimal amount of inputs will not be introduced if some members of the commons decide not to be honest and devise a method of hiding extraction effort.

Not only may members cheat on the optimal solution directly, but the second problem with input quotas is that they may expend excess effort indirectly through factor substitution. Until now, the analysis has assumed a composite input, effort or vessels or some other conglomerate variable input. In reality, production processes most often depend on various inputs. Unless the production process is simple and depends heavily or exclusively on only one or two inputs, or unless factor ratios must be maintained in strict proportions for technical reasons, putting quotas on certain inputs can result in factor substitution toward other inputs (Dorfman 1974). For instance, if the number of boats in a fishery is limited, larger boats and crews, or more nets and fuel, may be substituted. In this case, limitation of inputs fails as a viable common property solution.

### *Input Rights*

Input rights, or licensing of inputs, as Dasgupta and Heal (1979) have called them, are also designed to limit resource extraction through limiting inputs. However, they operate differently from quotas. Either the unified user group or the government issues or sells rights for inputs, which in total allow a certain amount of industry effort, say $\bar{E}$. The authority then allows a competitive market to develop for the rights to apply effort. Each of the $N$ firms must decide how many rights it will buy. If $N$ is large enough and if $\bar{E} < E_c$, where $E_c$ is the number of inputs introduced at open access equilibrium, then a competitively determined, positive license price will develop. Call it $\bar{r}$. This price is determined in a market for rights, where the derived demand curve for rights is a function of resource rents obtainable by applying inputs to extract the resource and the supply curve of rights is inelastically set at $\bar{E}$. The cost of the rights $\bar{r}$ is added to other variable input costs, and the higher costs lead to reduced effort. Thus, the cost of a right and a decentralized market mechanism, not a rigid quota, limit effort. Ideally, of course, the authority that issues rights would set $\bar{E}$ equal to $E^*$ and let the market mechanism operate to develop a rights price such that the optimal number of inputs is introduced. A formal proof that this leads to optimal results is contained in the appendix to this chapter.

Input rights also vest a claim to a certain proportion of the resource's productive capacity by virtue of a rigid relationship between inputs applied and resource extraction, and hence they also may be weak if input substitution can circumvent the rights requirement. The solution, however, corresponds closely to the practice of many alpine grazing commons of Switzerland. In this situation, a limited number of users holds grazing rights, where the number of rights held indicates how many animal units may be grazed. These grazing rights are often tradable on the market. This, together with the fact that the cows can be thought of as the capital input, makes the grazing rights identical in principle to the concept of input rights. Because a rather rigid production relationship exists between the primary capital input (cows) and the amount of resource extracted (grass), the limitation on inputs effectively prevents resource overexploitation.

### *Output Quotas and Output Rights*

Two other solutions for the open access problem from neoclassical economics are output quotas and output rights. I make the distinction between nontransferable output quotas and transferable output rights, consistent with the distinction between nontransferability and transferability in input quotas and input rights. The literature has mentioned output limitation schemes for common pool resource extraction much less frequently (e.g., Christy 1973; Crommelin, Pearse, and Scott 1978) than input limitation schemes.[15] To my knowledge

[15] The literature in tradable output rights for pollution control, which might be termed a common property solution for asymmetric externalities, is of course well developed. See, for instance, Dales (1968: 93–97), Montgomery (1972), Atkinson and Tietenberg (1982), Krupnick, Oates, and Van De Verg (1983), and McGartland and Oates (1985).

only Moloney and Pearse (1979) have modeled output rights. The lack of attention in the theoretical literature is odd, because a number of countries and state and provincial governments have implemented output quotas or output rights in fisheries.

Output quotas put a direct limitation on the amount of the resource each user may harvest such that the total amount harvested is socially optimal (maximizes resource rent). More interesting is the output rights system, because of the transferability of the rights. In an output rights system applied to a fishery, the rights-issuing authority determines a total allowable catch $\bar{Y}$, issues rights to individual fishermen, and allows a market to develop in catch rights. Again, the rights-issuing authority sets the total number of rights at the level that maximizes societal net revenues. The price of a catch right will develop to equal the societal shadow price of additional resource extraction, that is, the loss in rent of expanding output beyond the societal optimum. A formal proof is provided in the appendix to this chapter.

Quotas on outputs and output rights constitute direct common property methods of preventing resource overexploitation. There is no need to assume a rigid production relationship between inputs and outputs to get the correct amount of output under this scheme. This has some notable advantages. The users cannot use input substitution to avoid the restriction on exploiting the resource, as they can under input quotas or input rights. In fact, this system encourages producers to determine their own input mixes, and it allows them to install technological changes, both of which encourage efficiency. Firms will use the optimal amount of inputs if they are cost minimizers. Nevertheless, enforcing output rights can be equally as difficult as enforcing input quotas or input rights. Whereas the latter allow input substitution to avoid the restriction, the incentive exists to misrepresent real harvest figures under output limitations. Black markets in the product can also develop. Finally, in some situations—grazing as an example—a limit on outputs (grass harvested) is difficult to implement, and one preferably implements input quotas or input rights.

It is worth noting that a private owner might use any of these quota or rights methods. A sole owner of a fishery, for instance, might use quotas or tradable rights to control lessees in the fishery.[16] The concept of common property, however, does not include the use of quo-

[16] The sole owner would maximize his return from the fishery by limiting the number of lessees and their effort or catch to the optimal levels and charging a rental fee that extracted the resource rent. The lessees would be willing to fish as long as the sole owner left to them at least the normal rate of return on capital and labor.

tas or rights by a private owner, because the possession of the resource and decisions about its exploitation lie in a single person's hands. This violates the multiple users condition, Point 3, and the condition of joint, nonexclusive entitlement prior to capture, Point 5, of the definition of common property. Moreover, as long as a sole owner can enforce limitations, the decisions about external costs that actors in a common property system impose upon each other do not lie with a group of rights holders, Point 7 of the definition. Thus, if a private owner applies a quota or a tradable rights method to a group-used resource, the institution cannot be called common property. When a group or government employs these methods, however, the institution is common property.

## Institutionalist Justifications of Common Property

Since the late 1960s, the property rights and institutional schools of economics have debated the emergence, the efficiency, and the stability of common property. Until Dahlman (1980), the property rights school held a disapproving opinion of group solutions, whereas the institutional school looked more favorably on their potential. In this section, I draw on some of the arguments from both schools to explore the incentives and transactions costs of two phases of a property rights system: establishing it and operating it. Common property may make sense for some natural resources, because the establishment incentives and transactions costs may favor it over private property, while the operating incentives and transactions costs are conducive to common property's stability.

### *Establishing Common Property*

*The property rights paradigm.* Several authors of the so-called property rights school have developed various shades of the idea that economic circumstances can explain the emergence of property rights (Demsetz 1967; Pejovich 1972; Alchian and Demsetz 1973; Anderson and Hill 1977; Dahlman 1980). This notion has been labeled "the property rights paradigm." Its main idea is that new private property rights in objects emerge when the benefits of claiming rights exceed the costs of negotiating and enforcing those rights. The value of assets and the cost of protecting assets vary over time, because of changes in technology, relative factor scarcities, tastes and preferences, governmental regulation, and so forth. As these values and costs change, the marginal benefits and marginal costs of defining property rights shift, so that agents gain or lose interest in defining and enforcing rights in the assets (Anderson and Hill 1977). A reduction in cost, such as the lower cost of enforcing property lines in the nineteenth-century American West caused by the invention of barbed wire, or an increase in benefits, such as land's increased value owing to scarcity, may increase definition and enforcement of property rights.

The majority of supporters of the property rights paradigm believe that more property rights definition and enforcement activity means efforts to increase the level of *private* property. Dahlman (1980), however, has extended the property rights paradigm to show that changes in the benefits and costs of controlling assets that lead to increased incentives to control the assets do not determine the *type* of property rights that emerge. Rather, characteristics of the resources, economies of scale involved in the technologies to exploit them, and other economic factors affect the property rights structure. Depending on resource and social characteristics, one incentive system will yield a better economic outcome than another. Hence, actors choose different property rights systems, depending on their efficiency characteristics, to manage different resources (Dahlman 1980: 3).

For example, in the open field system in feudal England, people used two different property rights structures for farming and grazing land: narrow, scattered strips under individual husbandry for crops and large, undivided commons for grazing. Dahlman (1980: 7) argues that these were not inefficient, anomalous practices undertaken by backward peasants unable to see the error in their ways. After all, people used these methods across northern Europe for centuries. Rather, the key to the property rights structures and the agricultural practices lay in varying optimal scales. In the medieval era, livestock production exhibited greater economies of scale than did crop production. Family-centered production using individual plots could not have exploited the full economies of scale in grazing, whereas it could do so in arable cultivation. Therefore, the peasants left grazing lands in large tracts, utilizing them in common, to exploit the economies of scale in grazing. Simultaneously, they divided the arable into small strips—some just fractions of an acre—to fit the technological capabilities available in crop cultivation.

This then explains the existence of, and even the efficiency of, common property in grazing:

> If the grazing grounds were owned privately, the large-scale grazing areas desired could only be attained by continual transaction between the farmers

involved: collective ownership completely bypasses the problem. (Dahlman 1980: 7)

General economic theory does not imply the universal inefficiency of communal ownership and collective control. On the contrary, correctly applied economic theory will predict that, under certain conditions with respect to transactions and decisions costs, such arrangements will be superior to private ownership and individual control. (Dahlman 1980: 6)

Extending these ideas to the present, we can recognize that the physical attributes and costs of exploitation for at least one class of natural resources preclude private property rights for them. This class is common pool resources, such as groundwater, underground oil and gas, and fish and wildlife.[17] Private property can take two forms: dividing a resource into individual, privately controlled units and sole ownership of the entire resource base. Common pool resources are not physically amenable to the first of these solutions, being divided into pieces and put under private property in their *in situ* state (Dasgupta and Heal 1979: 65; Runge 1981). The technology to control separate units of these resources prior to their capture is extremely costly or does not exist. Therefore, the only private property solution for such resources is sole ownership of the entire resource base. Yet sole ownership for these resources may be impractical for reasons of high cost of instituting and maintaining sole ownership. First, the immense physical scale that some of these resources encompass, such as the wide range of migratory fowl and pelagic fishes or the extent of the atmosphere, makes the control of these resources by a sole owner infeasible, because the costs of control by a sole owner would be virtually infinite. Second, the scale of the resource might not match the optimal scale of production for a single firm; that is, the firm would not be able to extract the rent-maximizing amount of the resource while operating at the minimum on its average total cost curve. In such a case, multiple firms might be able to extract the resource efficiently, but their exploitation would have to be coordinated to avoid the problems of open access. In sum, extending Dahlman's property rights argument indicates that the physical attributes and the costs of exploitation render common pool resources unsuitable for division into individual units on the one hand and unworkable for sole ownership on the other. That is to say, private property

[17] By "common pool resources" I mean the class of resources that are physically unamenable to division into individual, private units prior to capture. *Common pool,* a type of resource, should not be confused with *common property,* a resource management institution. Common pool resources may be exploited under either open access or common property conditions.

rights in general are infeasible for them. In contrast, it is frequently possible to vest common property rights in common pool resources in order to achieve satisfactory use. As examples, input or output rights may be used for fisheries and pollution control; pumping agreements (output quotas) may be applied to groundwater and oil and gas pools.

In addition, some natural resources may be exploited under common property that are not of a common pool nature, resources that could be divided into individual units and used under private control. Land and forests are prime examples. Dahlman's argument at the beginning of this section, playing heavily on the concept of economies of scale, already indicates that certain resource configurations and technological constraints may result in common property's being a preferable arrangement, even when the resource could be privatized. The Swiss grazing commons provide another example. Some Swiss common property grazing areas are found in remote locations, where transportation costs and the risks of individual husbandry favor the scale economies of cooperative use over the incentives of private management.

Thus, whether the resources are common pool or amenable to privatization, particular natural resource configurations, technological constraints, and transactions costs may make common property a superior solution to private property.

*Social and institutional effects.* Besides the physical attributes of the resource and the technological aspects of its exploitation, social and institutional factors influence the establishment of property rights. These include costs of negotiation and institutional and cultural inertia.

Perhaps the most widely recognized barrier to establishing group solutions consists of the costs of negotiation. Establishment transactions costs of this type include (1) uncertainty about one's potential contribution to production without an agreement; (2) the inability to communicate to others one's knowledge about one's reserves of the resource (oil pools, etc.) or one's ability to capture the resource (fisheries, etc.); (3) the costs generated by holdouts and concessions made to them to bring them into the agreement; and (4) the administrative and time costs of negotiating. Often private property advocates contend that these costs of negotiation are a prohibitive deterrent to collective solutions (e.g., Demsetz 1967: 354–55). This is apparently true in some cases. Without government intervention, negotiators for many oil reservoir unitization schemes have failed to reach agreement

(Wiggins and Libecap 1985). As the prisoner's dilemma and the open access resource models indicate, however, negotiations may yield gains to all concerned when the starting point is open access and the resource is about to be or already is overexploited. Given the existence of establishment transactions costs, the question is an empirical one: Do the benefits of collusion—the recovery of lost resource rents—exceed the establishment transactions costs? If so, there are incentives to negotiate and potentially to reach agreement. Common property solutions will emerge in some cases and fail in others. Therefore, failure need not be a foregone conclusion, as some private property advocates maintain. Moreover, where a group solution does not emerge on its own, government intervention to promote it may be an acceptable substitute.

Finally, institutional and cultural inertia may favor converting an open access resource to common rather than to private property. For instance, even if the physical extent of the resource is confined to a space that makes sole ownership theoretically feasible, previous institutional patterns for the resource may make sole ownership unachievable. Even for a resource as large as a fishery on one of the Great Lakes, one can at least imagine a government concession for sole exploitation rights. Yet the history in this area of many independent commercial fishermen makes the political practicality of the idea doubtful. In this case, the administrative and social costs of conversion probably would be prohibitive. As another example, it may be inappropriate to impose certain property rights structures on certain cultures at a particular point in their evolution (Ely 1914: 266, 297–98; Ciriacy-Wantrup 1952: 146). Bottomley (1963) has already provided an example of this inappropriateness, in which he recommends avoiding the violation of "hallowed rights" in land that would occur if a private property approach in tree planting in Tripolitania were undertaken. Instead, he recommends what amounts to a common property solution. In some other cases in the developing world, the attempt to impose private property in other natural resources has not increased efficiency but rather has led to social disruption and even increased resource abuse (Runge 1986). Even in developed countries, historical instances of establishing private property have given rise to rather large costs. The costs associated with legislative acts, disenfranchisement, and social upheaval that accompanied the English enclosure movement provide an example. In sum, there is no a priori reason to believe that establishment costs of converting an open access resource to private property are less than those associated with establishing common property.

*Maintaining Common Property*

As I have mentioned, in the game theoretic formulation of the open access problem, even if collusion leads to the joint-welfare-maximizing solution (the lower right-hand box in Figures 2.5–2.7), there remains the incentive for both players to break the agreement. Similarly, at the optimal total input level in the models of open access, there is always the incentive of increased profits' luring each individual firm to expand inputs and production beyond its allotted amount. How stable, then, is a common property solution?

The answer lies in the transactions costs of enforcing the solution and other incentives that tend to stabilize the solution. Specifically, stability of group solutions requires one or both of two elements—coercive enforcement and assurance of cooperation by other users. Enforcement is a conventional answer, given most often by economists who put limited faith in common property solutions. Assurance is a theme usually found among institutional economists who consider common property a viable alternative to private property in its own right. Here I examine each of these approaches to stability.

*Stability through enforcement.* First, let us consider enforcement. Assume that the problems of reaching a solution have been overcome. Collusion has been allowed and establishment transactions costs are low enough for players to reach and maintain a joint-welfare maximum if they wish. Alternatively, assume that the government can locate the optimal level of inputs and outputs and can allocate these quantities among firms. The question then is, what is to keep the participants at this optimal point? In the context of the conventional wisdom, the answer is enforcement: enforcement tough enough to overcome the incentive to cheat.

I use enforcement in a rather general sense. It can take different forms, depending upon the form of the common property. If the common property system is that of the Bahia swamp dwellers, then enforcement is composed mainly of informal, extralegal procedures and group pressure. If the common property system is that of the Swiss grazing areas, then enforcement means not only group social pressure but policing by an elected overseer and fines for violations as well. If the common property is that of a provincial or state quota-restricted fishery, then enforcement takes the form of a watchdog agency with the full powers of the state and courts to back it up.

In a comparison of common property to private property on enforcement, several points are worth noting. First, whereas the difficulty of enforcing common property rights is explicit in most formulations of the idea, the costs of enforcing private property often remain hidden and implicit in suggestions that it is the best solution. Yet private property rights can be violated just as can common property rights. Trespass or theft violates private property rights; overuse violates common property rights. To be sure, some form of enforcement may be necessary to ensure common property solutions. Large costs, however, both private and social, also are incurred to protect private property rights. Personal costs such as fencing, locks, security guards, court cases, and so on are associated with protecting private property. If these personal measures do not succeed, then the enforcement powers of the state can be brought to bear, a process that also engenders costs. Thus, enforcement is necessary not only to stabilize the unsteady joint-profit-maximizing solution to the prisoner's dilemma, but also to secure private property rights. Criticism of common property for its need to incur enforcement costs to stabilize an unsteady solution is unbalanced if it takes no account of the investment that society and individuals make in protecting private property.

Differences probably do lie in incentives to provide enforcement, however. Whereas under private property individuals are willing to incur some costs of enforcement, under common property the group or outside agents must support a greater proportion of enforcement costs. This is because, even as individuals cannot capture all benefits from investments in improvements to a common property resource, they cannot capture all benefits of enforcement. Still, there is no general reason to suspect that total enforcement costs are greater or less under common property than under private property. In fact, enforcement costs are likely to be less for some resources under private property and less for other resources under common property.

Finally, the costliness of enforcing property rights depends on the type and degree of property rights socialization that takes place in a society. If particular property rights configurations are justified and legitimatized in the prevailing social mores, people will observe them more readily, lowering establishment and enforcement costs. Although private property is the primary form of property rights sanctioned through socialization in most industrialized Western nations, this does not mean that alternatives have not been equally as legitimate in other times or places. For this reason, common property may not require large enforcement costs in certain cultural situations.

*Stability through assurance.* The idea that enforcement is the way to stabilize common property arises from the assumption that individual incentives strongly and invariably lead participants to defect. The idea that stability can occur through assurance questions the validity of this assumption.

Runge (1981, 1986) has attacked the adequacy of the prisoner's dilemma as a model for studying group use, saying that it does not adequately reflect the interdependencies of joint use. As part of the definition of the prisoner's dilemma, the players make decisions independently. Runge argues that real-world commons do not exhibit such independent, separable decisions. Rather, commons users condition their decisions on expectations of others' behavior. A common range ties the users' welfare and decision making together (Runge 1981: 599).

Runge proposes adopting a new model, the "assurance problem" (Sen 1967). He argues that assurance of what others will do allows better decisions, and that the possibility for better decisions gives an incentive to make and keep agreements. Groups, recognizing the advantage to all of capturing resource rents and the potential disaster to the group economy of noncooperation, choose the Pareto optimal solution. This approach also proposes that the incentives involved make the solutions inherently stable, that no incentive remains to defect from optimal solutions once reached.

Runge uses models that reflect interdependencies of decision making and involve no incentives to individuals to defect from the optimum once reached. There is no reason, however, to jump to totally new frameworks to model the benefits of assurance, as Runge does.[18] The problem of assurance can be modeled within the original context of the prisoner's dilemma by allowing adjustment of individual strategies once the other player's move is known. This, after all, is similar to the real world in resource extraction. Assume that each player is assured that the other player will refrain from overexploitation, if he or she also refrains. Let us further assume that maverick behavior on either person's part will simply trigger overexploitation by the other.

[18] To model assurance, Runge uses the "battle of the sexes" (Luce and Raiffa 1957; Bacharach 1977; Runge 1981) and an *n*-person model without strictly dominant strategies (Runge 1986: fig. 2). By using these models to represent real-world interdependencies, however, Runge emasculates another part of the group use problem, the incentive to cheat. In the models of the assurance problem that Runge presents, there is no incentive to cheat once an agreement has been reached. Is there, however, incentive to cheat on the group agreement in a real-world common property solution? Clearly, the answer is yes. The incentive to cheat, if not actual cheating behavior, always persists. The incentive to increase catch in a controlled fishery, to increase pumping from a controlled groundwater aquifer, to graze one more animal on a commons, is ever present. It is just a question of whether the incentive for the individual to stick to the group solution is greater.

What will the solution be? Assuming collusion is possible, the answer is obvious. The joint-maximizing decision will be reached. It is not possible to end up in either the upper right-hand or the lower left-hand box of the prisoner's dilemma payoff matrix (Figure 2.5), where one player is defecting while the other cooperates, because adjustment of strategies is allowed. In addition, both players prefer the lower right-hand to the upper left-hand box, so the former will be chosen. Therefore, given the *assurance* of restraint on the other's part, together with the *assurance* that maverick behavior will simply cause the other to defect as well, each will show restraint. The incentive to cheat is still present, because the lower left- and upper right-hand boxes are still technologically feasible. It is just that the incentive not to cheat is greater. The incentive to obtain a share of the joint maximum profit can be sufficient within the prisoner's dilemma with adjustable strategies to overcome the individual incentive to cheat (Bishop and Milliman 1983). Add to this the real-world desires of individuals to conform to group norms and pressure, and we come to the same conclusion as does Runge (1981: 603):

> The benefits possible in the short term may be more than offset by costs arising within the group from breaking the institutional rule. In the absence of strictly dominant individual strategies, recognized interdependence makes the costs of reputation loss high. Pecuniary costs imposed by the group on its own noncooperative members also may occur. . . . These costs, plus reductions in the attainable set if such antisocial behavior "sets a trend" for others, plus the opportunity costs of innovating new rules, may well exceed the expense of stinting on the range.

These conclusions are strengthened by the fact that a certain amount of uncertainty about others' strategies can lead to cooperation (Kreps, Milgrom, Roberts, and Wilson 1982; Braden 1985). If individuals assign any probability at all to the possibility that others will view cooperation as being in their long-term self-interest, they may experiment with the cooperation strategy, in turn inducing others to follow suit. Experiments with finitely repeated prisoner's dilemmas have shown patterns of cooperation among players, at least for some of the time (Kreps et al. 1982).

In conclusion, then, to the extent that assurance and tit-for-tat strategies obtain, common property can be viewed as a stable solution to open access in and of itself. Runge has moved us forward by taking a close look at the conventional assumption of independent self-maximizers in a noncollusive prisoner's dilemma as an adequate model for the commons. Through his work and the ideas presented here—that a *collusive* prisoner's dilemma can lead to stability—we are closer to understanding how historical common property systems, once they have evolved, have sometimes survived for centuries.

## Summary

I began this chapter by carefully differentiating common property from open access. Both its role in history and its nature as a property institution imply limited use by a definable group of co-owners. Therefore, common property may offer an alternative to private property as a solution to the open access problem. Open access has two characteristics that lead to nonoptimality, and resource users must handle both of them to find acceptable solutions. Both (1) a lack of limitations on the *number of users* who enter into resource extraction and (2) a lack of limitations on the *number of inputs* that each user applies cause inefficiency. Common property addresses both problems. It limits the number of users who are allowed to exploit the resource, and in a well-functioning common property situation, some mechanism is used to limit the amount of inputs that each user may apply or the outputs that each may extract.

As a resource management institution, common property lies between open access and private property. Like open access, it exhibits the incentives inherent in group use, but it imposes the resource control characteristics of private property. It differs from a public good, which also involves group use, because it is a resource use regime whereas a public good is a type of good or service. Some resources that display a public goods character can be managed as common property.

The rules for controlling common property may be imposed from outside or generated within the group. They range from the neoclassical solutions of input or output quotas and rights to far less formal solutions embodied in a set of customs among users. Common property is the preferred solution to open access when the resource is unamenable to being split into individually controlled units, the control costs of sole ownership are prohibitive, or the technological characteristics of production (e.g., economies of scale) favor it over private property. It may also be preferred when social or cultural factors favor a group over an individualistic solution. Once common property is established, enforcement and assurance are elements that can secure its stability. Whereas enforcement may arise from inside or outside the group, assurance arises from inherent incentives within the group to keep agreements.

In view of all this, one is encouraged to ask: Does common property empirically provide an adequate solution to the open access problem? After a look in Chapters 4 and 5 at how the Swiss and English constructed common property institutions, I will take up this question. Chapters 6 and 7 describe and draw conclusions from empirical work comparing common property with private property in Switzerland.

## Appendix: Proofs of Solutions to Open Access

This appendix includes formal proofs of the optimality of the input quotas, input rights, and output rights schemes. A proof of private property's optimality is also included, since it is the standard against which we measure common property's adequacy. Much of the treatment is an adaptation of the approach in Dasgupta and Heal (1979: chap. 3). The output rights proof is a variation of the approach in Moloney and Pearse (1979).

### *Private Property*

Private property as a solution to the nonoptimality of open access can take two forms: (1) putting the entire resource recovery area under a sole owner or (2) splitting the resource grounds into private plots. We will examine both cases.

If there is only one firm in the industry, it will introduce the optimal number of inputs. We can see this by noticing that for $N = 1$, competitive equilibrium conditions (2.13) and (2.14) in the appendix to Chapter 2 reduce to the optimality conditions (2.15) and (2.16), respectively. Thus, a sole owner manages the resource optimally, and the problem of unrestricted inputs arises only if $N > 1$. The sole owner allocates correctly, because he or she considers all costs and benefits of additional resource extraction and internalizes the costs that were imposed on other users under open access.

An assumption of constant returns to scale in producing effort, which, I argued in the appendix to Chapter 2, is consistent with the results of the mathematical model, also facilitates the conclusion that a sole owner can operate an entire fishery optimally. If constant returns to scale do not obtain, scale diseconomies may make the costs of sole ownership prohibitive. For larger fisheries, it is difficult to imagine a single firm producing all industry effort under the U-shaped cost conditions that Anderson (1977) assumes. On the other hand, if increasing returns to scale were to prevail, the other private property solution of splitting the resource into private plots would not be optimal. Thus, private property solutions are not as straightforward as simple mathematical models present them.

Nevertheless, to show mathematically the optimality (under constant returns to scale) of splitting the resource grounds, let us assume that the resource grounds can be divided into $N$ equally productive plots. We must now explicitly introduce the size of the resource catchment area into the production function. Define the production function as

$$Y = H(X, S),$$

where $S$ denotes the size of the entire resource grounds. Our earlier analysis ignored $S$ because it was a constant $\bar{S}$. This, along with an implicit assumption that $H$ exhibits constant returns to scale in $X$ and $S$, allowed us to reduce the production function to a single variable:

$$Y = H(X, \bar{S}) = H\left(\frac{X}{\bar{S}}, 1\right) = H(X, 1) \equiv F(X),$$

where the second-to-the-last step is taken by normalizing $\bar{S}$ to 1.

We now alter $S$ by dividing the resource area up into $N$ plots. Note that this is the crucial assumption for this solution, particularly because some resources, such as fisheries, large oil pools, and wildlife, do not lend themselves to being divided up. By making this assumption, we essentially assume away the reciprocal externality. If, however, it is possible to divide the grounds into $N$ plots, the production possibilities facing a particular user would be

$$y_i = H\left(x_i, \frac{\bar{S}}{N}\right).$$

Here $x_i$ denotes the input level of user $i$. Recalling the assumption of constant returns to scale for $H$ and the normalization $\bar{S} = 1$, we have

$$y_i = H\left(x_i, \frac{\bar{S}}{N}\right) = \frac{1}{N} H(Nx_i, \bar{S}) = \frac{1}{N} H(Nx_i, 1) = \frac{1}{N} F(Nx_i).$$

If we use these production possibilities for the individual firm and take the recovered resource to be the numeraire good, the individual firm's profit is given by

$$\frac{1}{N} F(Nx) - rx,$$

where again $r$ is the rental rate for inputs (boats) and the $i$ subscript has been suppressed because all firms are identical. Maximizing this function with respect to $x$ gives

$$F'(Nx) = r. \tag{3.1}$$

Condition (3.1) is identical to the optimality condition (2.15) in the appendix to Chapter 2. This proves that competitive profit maximization under the regime of $N$ private plots leads to optimal results.

### *Input Quotas*

Another solution to open access is a system of quotas on inputs. The formal proof of the optimality of this solution is implicit in the derivation of the optimality conditions (2.15) and (2.16) in the appendix to Chapter 2. There it was noted that the socially optimal (Pareto efficient) amount of inputs is the solution to the maximization with respect to $x$ of resource rent:

$$\max_{x} F(Nx) - rNx.$$

The first-order condition for this problem is

$$F'(Nx) = r. \tag{3.2}$$

Again, let $\tilde{x}$ be the value of $x$ that satisfies equation (3.2). The quota on inputs system consists of participants in resource recovery colluding to limit themselves to $\tilde{x}$ units of input each. (Alternatively, the government may impose this limit on them.) If each firm introduces $\tilde{x}$ units of input, by the definition of $\tilde{x}$ and condition (3.2), the optimal resource rent will be realized. Each firm will extract $F(N\tilde{x})/N$ amount of the resource and enjoy $(1/N)^{\text{th}}$ of the maximal rent.

### *Input Rights*

The third solution sometimes mentioned for the open access problem is input rights. This too is a scheme to limit inputs, although unlike quotas, rights are assumed to be tradable.

To formalize an input rights scheme, assume that (1) the management agency issues $\bar{X} < \hat{X}$ rights, where $\hat{X}$ is the amount of inputs introduced at open access equilibrium; (2) there are $N$ firms; and (3) the firms are identical. To find the inverse derived demand function for rights—that is, the competitive license price $\bar{r}$ as a function of $x_i$—we need to find an expression for the $i^{\text{th}}$ firm's profit function. This profit function will take the standard form of revenues minus costs. On the revenue side, the $i^{\text{th}}$ firm must make an assumption about how many vessels all other firms will introduce, because its average product is affected by the open access externality from other firms. If it assumes that all other firms will introduce $\bar{x}$ inputs each, its revenues will be

$$x_i \frac{F[(N-1)\bar{x}+x_i]}{(N-1)\bar{x}+x_i},$$

where $x_i$ is the number of inputs it introduces, the ratio term is its average product, and the output (captured resource) price equals one. On the cost side, an operator will regard the equilibrium price of a right as an expense to be added to the purchase price of the input. Hence total costs are

$$(r+\bar{r})x_i.$$

The profit function then is

$$\pi = x_i \frac{F[(N-1)\bar{x}+x_i]}{(N-1)\bar{x}+x_i} - (r+\bar{r})x_i. \tag{3.3}$$

To maximize profits, equation (3.3) is maximized with respect to $x_i$. As a result, the operator will chose $x_i$ such that

$$\frac{(N-1)\bar{x}F[(N-1)\bar{x}+x_i]}{[(N-1)\bar{x}+x_i]^2} + \frac{x_i F'[(N-1)\bar{x}+x_i]}{(N-1)\bar{x}+x_i} = r+\bar{r}. \tag{3.4}$$

Since all firms are identical, in equilibrium $x_i = \bar{x}$, and (3.4) reduces to

$$\frac{(N-1)\bar{x}F(N\bar{x})}{(N\bar{x})^2} + \frac{F'(N\bar{x})}{N} = r+\bar{r}. \tag{3.5}$$

Equation (3.5) implicitly defines the demand for rights $N\bar{x}$ as a function of their price $\bar{r}$ and the cost of a unit of effort $r$. The supply of rights is $\bar{X}$. Equating demand and supply, we have $N\bar{x} = \bar{X}$ as a condition of equilibrium that may be substituted into (3.5). Solving for the equilibrium price of a right:

$$\bar{r} = \frac{(N-1)}{N}\left[\frac{F(N\bar{x})}{N\bar{x}} + \frac{F'(N\bar{x})}{N}\right] - r, \tag{3.6}$$

where $N\bar{x} = \bar{X}$.

This shows that the equilibrium price of a right is a function of the number of rights issued $\bar{X}$, and the cost of effort $r$. Presumably, the issuing agency will want to issue rights only for the optimal number of inputs, that is, set $\bar{X}$ equal to $\hat{X}$,where the optimality condition (2.16) in the appendix to Chapter 2 defines $\hat{X}$. Given identical firms, $\hat{X} = N\bar{x}$. Moreover, the cost of effort $r$ can be eliminated from (3.6), because at the optimal level of effort $\hat{X}$, $r = F'(N\bar{x})$ by the optimality conditions (2.15) and (2.16). Equation (3.6), then, can be rewritten to give $\hat{r}$, the equilibrium price of a right when the optimal number of rights is issued:

$$\tilde{r} = \frac{(N-1)}{N}\left[\frac{F(N\tilde{x})}{N\tilde{x}} - F'(N\tilde{x})\right].$$

Faced with this cost of an input right, the individual resource user will introduce the optimal amount of inputs. The rights-issuing agent, however, needs only to determine the correct number of rights $\tilde{X}$ to introduce, and $\tilde{r}$ will develop by market processes. The revenue from the sale of rights may be collected by the government or user cooperative, or it may be capitalized into the value of the firms if the rights are initially issued free of charge.

### *Output Rights*

A fourth solution for open access based on neoclassical economics consists of transferable output rights. The proof of optimality given here is based on a 1979 article by Moloney and Pearse that develops output rights for a fishery. In such an output rights system, the rights-setting authority determines a total allowable catch $\bar{Y}$, issues rights to individual fishers, and allows a market to develop in catch rights. Properly constructed, this market in rights will not only encourage individual and industry efficiency but also lead individual decisions to the social optimum.

To begin, define a net revenue function $R_i(y_i, P)$, where $y_i$ is the catch of firm $i$ and $P$ is the fish population.[19] The function $R_i(y_i, P)$ gives net revenues that accrue to a fishing operation from the resource rent only; it excludes any costs or revenues from the purchase or sale of catch rights. The control variable for the individual fisher is the catch rate $y_i$; independent of any transferable rights scheme, the fisher would want to maximize $R_i(y_i, P)$ by adjusting $y_i$. Define $L_i$ as the number of rights that the $i^{\text{th}}$ firm holds. Further, let $m$ be the market

[19] Moloney and Pearse (1979) use the notation $H_i$ for a firm's catch and $X$ for the fish population level. This would be confusing here, given notation used elsewhere in this book. I have altered $H_i$ to $y_i$ and $X$ to $P$ to make my notation clear. Also, in my equation (3.9), the function $G(\cdot)$ is the same as Moloney and Pearse's $F(\cdot)$.

Population $P$ appears in the net revenue function, because the catch rate for an individual fisher depends not only on input level $x_i$, but also on the population level: $y_i = y_i(x_i, P)$. Imagine, for instance, that the net revenue function takes the form

$$R_i(y_i, P) = py_i - C_i(y_i),$$

where $P$ is the price of fish and $C_i(\cdot)$ is the cost of harvest for the $i^{\text{th}}$ firm. Net revenue depends on the fish population $P$ because $y_i$ (which depends on $P$) appears in both revenues and costs. The influence of the fish population on an individual's catch was incorporated differently into the previous mathematical model (in the appendix to Chapter 2). There the input level of all other firms, which affects population level, was included in the individual fisherman's production function:

$$y_i = x_iF(X_{N-i} + x_i)/(X_{N-i} + x_i).$$

price for a right. Because a fisherman must hold $L_i$ rights to catch $y_i$ fish, $R_i(y_i, P) = R_i(L_i, P)$. It is obvious that the $i^{\text{th}}$ fisher will retain his holdings of rights only if

$$\partial R_i(L_i, P)/\partial L_i = \partial R_i(y_i, P)/\partial y_i \geq m. \tag{3.7}$$

Indeed, if the strict inequality in (3.7) holds, the fisher will be a purchaser of rights. In the event that

$$\partial R_i(L_i, P)/\partial L_i = \partial R_i(y_i, P)/\partial y_i < m, \tag{3.8}$$

the fisher would sell rights, because a right's value in the market exceeds its marginal value in catching fish. The fisher is in equilibrium if and only if there is equality between his marginal net revenues and the price of a right.

Through the operation of the market in rights, an equilibrium price $m^*$ will develop. The market equilibrium will also be characterized by $\partial R_i/\partial L_i = m^*$ for all $i$, because then and only then is each fisher in equilibrium as just described. All fishermen will be maximizing profits subject to incurring the cost of the rights and holding to the overall constraint on output:

$$\bar{Y} = \sum_{i=1}^{N} L_i.$$

Of course, the only problem is setting $\bar{Y}$ optimally. In keeping with this book's emphasis on static models, I will derive the conditions for a static social optimum. Define the population growth curve in Figure 2.1 as

$$\frac{dP}{dt} = G(P). \tag{3.9}$$

When fishing mortality is added:

$$\frac{dP}{dt} = G(P) - \sum_{i=1}^{N} L_i. \tag{3.10}$$

In equilibrium, natural population growth just equals catch, so

$$\frac{dP}{dt} = 0,$$

and (3.10) becomes

$$G(P) - \sum_{i=1}^{N} y_i = 0. \tag{3.11}$$

For the individual fisher, there is no advantage in holding either more or fewer rights than he catches fish, so in equilibrium $L_i = y_i$. Substitute this into equation (3.11) to get the constraint for a static optimization problem,

$$G(P) - \sum_{i=1}^{N} L_i,$$

and also into the net revenue function,

$$R_i(y_i, P) = R_i(L_i, P).$$

Thus, to attain the social optimum, we wish to maximize total net revenues

$$\sum_{i=1}^{N} R_i(L_i, P),$$

subject to the constraint

$$G(P) = \sum_{i=1}^{N} L_i.$$

This can be performed by maximizing the Lagrangean function

$$\max_{L_i, P, \lambda} V = \sum_{i=1}^{N} R_i(L_i, P) + \lambda[G(P) - \sum_{i=1}^{N} L_i].$$

The optimal solution will meet the first-order conditions:

$$\frac{\partial R_i}{\partial L_i} = \lambda \qquad (i = 1, 2, \ldots, N)$$

$$\sum_{i=1}^{N} \frac{\partial R_i}{\partial P} = -\lambda G'(P)$$

$$\sum_{i=1}^{N} L_i = G(P).$$

The Lagrangean multiplier $\lambda$ can be interpreted as the shadow price of a right. Since, as argued above, $\partial R_i/\partial L_i = m^*$, the first-order conditions imply

$$m^* = \partial R_i/\partial L_i = \lambda.$$

That is, $m^* = \lambda$; the equilibrium market price of a right will equal its societal shadow price. Therefore, private actions responding to the price $m^*$ will lead to the social optimum. The rights-setting authority need only set the correct number of rights

$$\sum_{i=1}^{N} L_i = G(P)$$

such that

$$\sum_{i=1}^{N} \partial R_i/\partial P = -\lambda G'(P)$$

and

$$\partial R_i/\partial L_i = \lambda$$

for all $i$. In reality, $\lambda$ cannot be observed and the quantities $\partial R_i/\partial L_i$ for all $i$ would require large quantities of information, especially if $N$ is large. Practically speaking, the number of rights that maximizes social net revenue can be set only by trial and error, perhaps by the rights-setting authority buying and selling into the market.