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Re-telling the Tale of the Commons: A Tale of Rent Seeking, Corruption, Stockpiling and (Even) Tragedy

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ABSTRACT

The tale of the tragedy of the commons is re-told as a problem of vertical governance rather than a problem of horizontal contracting. States make the fundamental determination concerning the amount of management conferred upon resources within their territories, and the groups using these resources are substantially constrained by this prior determination. In particular, it is demonstrated that it is unlikely that institutions might arise endogenously at the user level, when the state has abrogated its responsibility to generate them at the sovereign level. States make the decision to pursue something other than first-best management because institutions require investment and as such must compete against other such investments within the economy. This results in a distinct form of the tragedy of the commons, in which other agents attempt to enter and to exploit the vacated governance positions abrogated by the state, resulting in problems of corruption, waste, and worse.

Keywords: Commons; Governance; Resource Management; Corruption.

JEL Code: K4; N4; Q2

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1 RE-TELLING THE TALE OF THE COMMONS

For many years, the story about the tragedy of the commons has been told as a tale of uncoordinated exploitation by a group of resource users. This analysis was initially developed by Gordon (1954) in his classic on the tragedy of the commons, in his discussion of common lands and animal grazing. It was then generally adopted by many other analysts of the overexploitation problem, often times in relation to fishing boats and fisheries. [see, e.g. Clark (1976)]. Within this framework the problem of resource overexploitation comes down to a failure of horizontal contracting, i.e. some failure to contract and coordinate between users of a common natural resource (Ostrom 1990, Bardhan 2001; Seabright 1994).

We argue here that the horizontal facet is a small part of an overarching problem, which is the failure of the responsible state to institute incentives for resource management. In short, over-exploitation in a commons situation should be viewed more as a governance problem rather than a coordination problem. The problem with the traditional explanation is that it fails to explain why such conditions inhere in regard to certain resources, and not in regard to others, under the control of the same state. All terrestrial resources fall within some state's jurisdiction but not all are subject to the same level or lack of care and management.[1] It is not apparent why the idea of imperfect property rights or management is a useful concept to apply when the same owner-state capably regulates some resources (e.g. tin mines and tea plantations) while failing in regard to others (e.g. wildlife and forests). Given this, it is probably better to view a given management regime as the consequence of societal choice, rather than the cause of collective failures. More fundamental forces are determining the owner-state's decision concerning which management regime to apply to a given resource at a given time.

The declines of many of the large land mammals in sub-Saharan Africa are illustrative of this approach. For example, four African range states (Sudan, Central African Republic, Tanzania, and Zambia) accounted for the bulk of the decline in the populations of the African elephant that occurred during the decade of their greatest decline. These four states alone lost over half a million elephants (nearly half of the continental population) during the 1980s. None of these elephant declines derived from management programmes, as it was illegal to take elephants in each of these states during this period. Rather, it was a classic example of arms length over-exploitation, as unwanted elephant populations were drawn down through largely unregulated access. Leaving the populations unmanaged equated with a tacit endorsement of the over-exploitation that inevitably resulted. The states simply employed tragedy as an instrument of policy (Swanson 1993, 1994). The same sort of institutional arrangement that applied to the African elephant applies, in certain countries, to most wildlife, tropical forests and

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[1] The analysis is not focused on those resources where the state concerned with a particular resource management situation is not readily identified, e.g. fisheries or migratory species. The vast majority of resource management problems, from watersheds to forests to particular species, occur solely or mostly within the boundaries of a given state, just as most governance problems do.

various other natural resources (Repetto and Gillis 1988; Binswanger 1989; Browder 1988).

At base the over-exploitation of all of these commons is the failure of the state concerned to institute governance, and the inefficiency resulting from this failure is broader than the resource concerned. Resources that are left ungoverned within an economy create loads of problems – and these often add facets to the problem worse than the waste of the resource itself. Wasteful rent-seeking, corruption, offshore manipulation and even summary execution become indirect outcomes of the state's governance failure. The most obvious of these is the unmanaged rent-seeking contest that is open access, when the state's refusal to govern results in the non-management of its resource. It is well established that such rent-seeking wastes not only the resource itself, but also other investments made in pursuit of those rents, such as the capital associated with rent capture (e.g. boats etc…). Another form of the problem generated by the state's governance failure is the availability of positions of ownership within the economy left open for exploitation by others. These positions sometimes result in the creation of *shadow* property rights that attach themselves to local officials, power-brokers, or even war-lords who control access to some aspect of the resource. This can result in corruption and distortion in an economy, by reason of the tacit assignment of rights to persons without legal authorization or ownership. Equally troublesome is the instance where the governance failure induces entry by nondomestic agents, whether industry stockpilers or foreign nongovernmental entities (NGEs), each of whom exploits the vacated position for its own benefit without having the capacity or incentive to invest in its management.

In each of these cases, the tragedy arises from the state's abrogation of its responsibility for governing the resource concerned. When the state abrogates its responsibility, it leaves open a certain amount of governance space, into which entry occurs by others in lieu of the state. This substitution for the state by others results in all of the various forms of tragedy indicated in the title. The tragedies are diverse and diffuse in that they affect a much larger part of the economy than does a simple horizontal failure. These are the truest sorts of tragedies. Here we describe the nature of this vertical dimension of the commons problem, by re-telling the tales of these governance problems and why they occur.

2 THE VERTICAL FRAMEWORK FOR THINKING ABOUT COMMONS PROBLEMS

For economists, it is easiest to understand the essence of generalized common resource problems when they are conceptualized within the framework that is more often used for thinking about another vertical governance system – the vertical industry (Tirole 1988).[2]

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[2] This is the arena in which most of the writing on the topic of property rights has occurred in law and economics (Grossman and Hart 1987; Hart and Moore 1990; Hart 1995). In the theory of the firm, the default hypothesis is that the control and rents of the resource remain within the vertically integrated firm, if the firm does not take the explicit choice to delegate them to independent agents

Within this conceptualization, property rights are in general mere instruments for the purpose of incentivizing the efficient flow of resources from outset to endpoint within a vertical structure (such as producer–distributor–retailer). The placement of a property right at any point within this vertical chain is merely for the purpose of incentivizing investments by users at that level (Hart and Moore 1990). This instrumental view of property rights is the key to understanding the source of all problems within resource management – for it places the responsibility for all coordination and management problems initially with the state concerned. Any decentralization of that responsibility is the result of a choice by the state to devolve authority for the purpose of better incentivizing resource management.[3] If the state fails to devolve that authority by failing to create the institutions necessary, this is also a choice of that state.

Clearly this vision of carefully orchestrated management by a lead authority does not match up well with the reality of the many resources that go unmanaged, or at least not well-managed. Why would a state fail to create or invest in the institutions required for effective resource management? In general, it is important to recognize that in every state first-best institutions (from the perspective of natural resource management) would never be targeted.[4] Second-best is the general state of governance in the real world, as monitoring and enforcement is necessarily imperfect and always costly. Truly inferior natural resource regimes can result from the fact that states are constrained to prioritize in their pursuit of objectives, or as an implicit method of resource conversion (Stokey 1998; Swanson 1994). Second-best (or worse) resource management are general outcomes of broader societal prioritization problems, and not just some vestige of nondevelopment.[5]

Therefore, this paper develops a vertical model of the state-determined framework within which individuals operate in the context of natural resource exploitation. The

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(Williamson 1986). One of the interesting issues within the context of any vertical industry (such as producer–distributor–retailer) is: why does the firm not operate as a single fully integrated entity? What advantage is there to a firm (a producer of some good or service) to creating several layers of independent agents or tiers within this industry, for the distribution of the product and the delivery of customer satisfaction? The answer to this question has been provided in several distinct analyses, but always with the same essential message (Williamson 1986). The producer chooses whether to implement a property right at any point in the industry, depending on whether at that point the agent is best incentivized by being a distinct property rights holder. This is the basic argument for a decentralized system of property rights: it provides the best system of incentives for investment at various levels of management (Hart and Moore 1990).

[3] This is now increasingly recognized in the context of land use management (Baland and Platteau 1997, 1998). The increasing use of franchising and rationalized concessions is indicative of the fact that states are recognizing that they are able to own and manage land use via many different forms of vertical arrangements.

[4] See fifth section of this paper. This is the most basic result of the law and economics literature, i.e. that institutions will always be optimized to achieve the efficient level of performance rather than the first-best (Cooter and Ulen 2004).

[5] This is an approach that attempts to address the issues at a more fundamental level than Chichilnisky (1994), where it was argued that inferior institutions (poor property rights) are exogenous variables, and fundamental agents in (trade-induced) resource degradation. Here, sub-optimal institutions are themselves choices, and the results of more fundamental forces, and hence only indirectly result in resource degradation.

regime for the management of natural resources results initially from a governance choice made by the owner-state. Then this choice creates an incentive system that determines the consequential investments by the user-group, which together then determine the resulting outcome for the resources.

In the following diagram, we portray the *generalized commons problem* as a form of two stage game, in which the state moves first in determining whether governance is applied to the resource. The users then operate within the framework that is established by the state. When the state refuses to put in place a framework for governance, it creates an institutional vacuum within which resource management and investment is difficult. If it puts in place some manner of governance, then (to the extent that it invests in this regime) it creates incentives for resource users also to invest in the resources and their management.

Figure 1 lays out the basic framework for this paper. The four regimes on the right are specific outcomes resulting from the combination of the initial choice by the state and consequential investment by the users. The top two outcomes, branching from the state's decision to institute governance, are representative of polar outcomes from a set of possibilities that range (in theory) from first-best management to substantial over-exploitation, depending upon the level of investment resulting under the governance regime elected by the state. The bottom two outcomes, branching from the state's decision to not institute governance, are representative of the potential outcomes when the users are left in an institutional vacuum. These outcomes range from "open access" (where no management of any sort results) to endogenously arising "commons management" (where management arises out of user interaction and investment). The level of aggregate investment, and resulting resource management, is substantially reduced under these outcomes.

To consider further this two-stage approach to the commons problem, we will pursue the problem in stages, working backwards from the resource users' investment decision. In the third section, we will consider the resource users' decision problem – the second

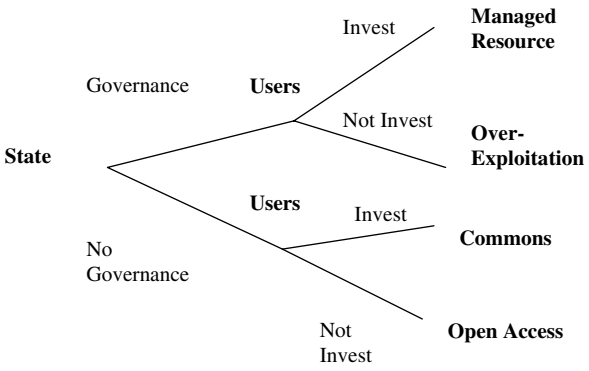

Figure 1. Two stage game of commons management

stage of the game in Figure 1 – first without state governance and then with it. Section 3 demostrates that the analysis of commons problems requires the introduction of an additinal factor, viz. management. In the fourth section we consider the state's optimal choice of governance regarding natural resources – the first stage of the two-stage game in Figure 1. In the fifth section, we discuss what this means for the re-telling of the traditional tale of the commons. In the sixth section we discuss some problems that result from governance problems – new tragedies of the commons. In the seventh section we conclude.

3 THE RESOURCE USERS' PROBLEM: WITH AND WITHOUT STATE GOVERNANCE

Consider the resource management problem from the perspective of users operating within an environment in which basic governance (i.e. the investment in incentive mechanisms) is a prior choice variable by some other decision maker (here, the state). The simplest case is that in which the state simply provides for no governance whatsoever. The alternative is that the state decides to provide some mechanism to encourage the decentralized management of the resource. We will explore both of these options in turn, initially in a pair of examples. Then, we will generalize our argument that the commons problems is a problem that concerns three joint assets: land, resource, and *management*.

3.1 State Failure to Govern: Consequential Noninvestment and the Open Access Regime

We will start by assuming that the state's decision not to govern the commons is determinative.[6] Thus, the state's determination is effective at enabling *free entry* by all potential users to the lands concerned and *free access* to the resource involved. In this situation, there is no capacity for any investments by the resource user group to generate a return, and so there are no incentives for investments in the resource, or in this use of this land. We will demonstrate this result here.

Consider a basic model of resource management, with a resource stock (x) and flow (y) (see, e.g. Dasgupta and Heal 1979). We will assume that this resource resides within the jurisdiction of a given state (s), on lands (R) to which an unlimited number of individuals (n) have access, or potential access.[7] Within this framework, we would like to consider the problem of land use allocation (see, e.g. Swanson 1993), where the issue of resource

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[6] The basic point of this paper is that the state's decision on how to govern a resource will generate responses from others. In the most general framework, the state's decision not to govern may generate the response of entry into the activity of governance (see fifth section *et. seq.* supra). It might also generate the response of endogenous attempts at governance (horizontal contracting in the commons). In this first section, we will assume that the state's chosen level of governance is determinative (i.e. no responsive entry enter into governance). Then the resource user group operates within the context of non-governance chosen by the state.

[7] The assumption of large numbers is crucial, and comes from the belief that current transport technologies make access readily available to all terrestrial environments.

management is considered to be a matter of choosing the level of general resources allocated to this particular use of the lands within the state.[8]

In this first example, we will consider how resource users will choose to allocate resources under their control, in the absence of any governance framework within which they make this decision. The individual resource user's decision regarding resource management concerns the optimal level of individual investment in the resource itself (in terms of foregone harvests) and in the land use (in terms of allocation of land area (R_i) at a price (ρ_R). Investments in the resource potentially yield individual streams of benefits through their impact on both resource growth ($H(x, R)$) and the unit cost of harvesting ($c(x)$). The decision problem concerns the determination of the individual's optimal rate of harvesting (y_i) and the individual's optimal rate of land allocation (R_i). The individual choices are subscripted (i), while the aggregated variables (Σi) are left un-subscripted.[9] Π_i is the present value of the resource to individual i, given the fact of nongovernance.

Definition (Individual Resource Allocation Problem Given Nongovernance)

$$\begin{gathered}
\underset{y_i, R_i}{\text{Max}} \quad \prod_i (y_i, R_i; x, R) \equiv \int_0^\infty e^{-rt} [p(y_t) y_{it} - c(x_t) y_{it} - r \rho_R R_{it}] \, dt \\
\text{subject to } \dot{x} = H(x_t, R_t) - y_t \\
\text{given } x_{t=0}, r, \rho_R \text{ constants} \\
H(x, R), \; c(x) \text{ are continuous, concave and twice differentiable} \\
H'(x, R) > 0, \quad c'(x) < 0 \\
y = \sum_{i=1}^{n} y_i \\
R = \sum_{i=1}^{n} R_i \\
x = \sum_{i=1}^{n} x_i
\end{gathered} \tag{1}$$

In short, the individual resource allocation problem under the state's election of non-governance provides each individual with the choice of the amount of land it would

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[8] One means of conceptualizing the state's land use planning problem is to ask about the optimal allocation of general resources (land, physical capital, human services etc. . .) to the maintenance of a stream of services from a given terrestrial resource (say, a forest). This paper argues that each state solves this problem (at least implicitly) and then institutes the governance framework it elects to implement that solution.

[9] All problems here are dynamic, and solutions are stated in the form of steady-state equilibria. These solutions are assumed to exist, and act as indicators of the outcomes that result under varying institutional structures. Time subscripts are elided at times for purposes of exposition.

allocate and resource it would appropriate under these conditions. The individual user is operating under known biological and technological conditions ($c(x)$ and $H(x, R)$) and given costs of resources (prices, interest rates). The decision devolves to the question of the impact of the governance system – how much investment should be allocated to this given resource under the institutional structure imposed by the state?

The answer to this question requires one further assumption, regarding how users will respond to other users with access to the same resources.

Assumption 1 *[Open Loop Nash Equilibrium Path of Exploitation] Each of the individuals within the user group operates along the Nash equilibrium path of exploitation under open loop conjectures.*[10]

Given the specification of the informational assumptions, it is possible to state the following three propositions regarding the prospects for investments by individuals within the state-determined governance framework of unrestricted access. These investment levels are termed (x^{oa}, R^{oa}).[11]

Proposition 1 *[Resource Rents – State Failure to Govern] If it is assumed that the state's failure to govern results in unrestricted entry, then the incentive to invest is dependent upon the size of the pool of potential entrants. The individually perceived rental value* (λ_i) *of any investment in the common is seen to be a problem of coordination across the pool of all potential entrants* (*of size n*) *as any market-based returns from investments are diffused across all users. Similarly, the industry-wide rents* ($\lambda = \Sigma\lambda_i = n\lambda_i$) *must equal zero as entry is induced by any available but unrestricted rents.*

Proof: **(see Mathematical Appendix)** From the first-order conditions relating to (1)

$$y_i^{OA} : \lambda_i = p(y)\left[1 + \frac{1}{\varepsilon_D n}\right] - c(x); \quad \text{where } \varepsilon_D \text{ is the market's elasticity of demand.}$$

$$y^{OA} : p(y) = c(x), \text{ as } n \to \infty \text{ (unrestricted entry to industry)} \qquad (2)$$

$$\therefore \quad \lambda_i \to (p(y) - c(x)) \to 0 \text{ as } n \to \infty$$

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[10] (See Mathematical Annex for Definitions) To solve this decision problem, it is necessary to specify the nature of the interaction between the various agents with access to the assets. The sort of conjectures which best describe interaction in the context of unmanaged access are known as Open Loop Nash Equilibrium (OLNE) assumptions. Open loop conjectures imply that the only information available or relevant is that arising at the beginning of the programme. This applies well to an open access situation, because there is little opportunity for a feedback-based equilibrium when there is free entry. Enhanced cooperation within the environment will generate additional profits and so more entry, thus returning the group to its original, noncooperative state. In addition, Nash assumptions (that individuals do not respond to other individuals' strategies) apply well in any situation where there are large numbers of players, because it is difficult to develop more sophisticated strategies in this context.

[11] For purposes of simplicity, we report here only the steady-state values of the relevant variables as an indicator of the general incentives for investment under the varying governance frameworks.

Equation (2) establishes the definition of resource rent under free access. If there are large numbers of potential entrants, this implies that individually perceived resource rental value (λ_i) is the residual of the competitive price over the costs of harvest. Resource rent is then equal to the residual of price over input costs.[12] And with free entry, there is no reason for entry to cease before this residual is driven to zero. This is the basic result of free entry within any commons, which translates into zero rents being available from investments into those commons. A simpler way to see this (under assumptions of a symmetrical Nash equilibrium) is the basic insight that stock-related rents from the individual perspective (λ_i) must be channeled through the commons where future returns are received equally by all users. This implies that each user achieves an average return (λ/n) in its use of the common, which must go to zero as access becomes unrestricted.

Proposition 2 (Users' Incentives for Resource Investment – State's Failure to Govern) *Given the state's choice of nongovernance, the averaged return and implicit large numbers of entrants determines that there are no incentives to invest in the resource or in the use of the land. This is because, in the absence of any governance, individuals receive no targeted return to their investments, merely averaged returns. And if access is free and the number of potential entrants is large, then these averaged returns must go to zero.*

Proof: **(see Mathematical Appendix)** From the first-order conditions for (1)

$$\begin{aligned} x_i^* &: \frac{\lambda}{n} H'_x - \frac{c'_x y}{n} = r\lambda \\ x_i^{OA} &\to 0 \quad \text{as } n \to \infty \end{aligned} \tag{3}$$

$$\begin{aligned} R_i^* &: \frac{\lambda}{n} H'_R = r\rho_R \\ \therefore R_i^{OA} &\to 0 \quad \text{as } n \to \infty \end{aligned} \tag{4}$$

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Proposition 2 and Equations (3) and (4) demonstrate the impact of the state's failure to manage on the user group's incentives to invest: there can be no perceived rate of return to investments in the ungoverned resource or in the land use so long as entry is free. This is reflected in the terms on the left-hand side of Equations (3) and (4), where

[12] The value of λ is itself an indicator of the level of investment in the natural resource. This is because, under normal circumstances of declining demand elasticity, the return from successively harvested units is declining. The individual harvester might choose to harvest each unit so long as there is a positive average benefit; however, this is equivalent to noninvestment. Halting exploitation prior to this point (i.e. with $\lambda > 0$) is equivalent to the investment of the unaccessed potential rents back into the resource. (Cheung 1970). Therefore, a positive value of λ (a positive rent) denotes the recognition of the value of the resource as an asset. The higher the value of λ, the more investment the asset is attracting.

investments in the resource receive averaged returns. As entry is unrestricted, the large number of potential entrants drives the incentives for investment to zero.[13]

A classic example of such a combined resource conversion/institutional outcome would be the instance of many traditional wildlife species throughout Latin America and Africa. In many of these regions, the indigenous wildlife was in use for centuries, but then replaced by other forms of livestock when institutions favored investments in other species. With the arrival of the European colonizers, these wildlife species were claimed as state resources but without any attendant governance regime. In many cases, the only governance applied was an absolute ban on all local usage, with no other attempt to implement incentives for the management of the resource.[14] This assertion of sovereignty absent investment in governance ended all incentives for investment in the resource and in the land use at the local levels, hence resulting in conversion of much traditional land (and attendant resources) to uses deemed to be more amenable to investment, such as domestic livestock and especially cattle. The outcome for traditional indigenous species has been the conversion of much of the land formerly associated with them.[15] In fact, in many instances the institutions are tied explicitly to the conversion decision.[16]

In sum, the state's choice not to engage in governance of the resource concerned has been assumed to enable free entry by a large number of potential entrants. As a consequence of the large pool of potential entrants and the prospect of averaged returns, user groups have little or no incentive to invest (i.e. there is a poor set of institutionalized management incentives). The outcome is that there are no investments by users in the resource stock or in the land use. This is the set of outcomes that together are usually termed the open access regime. It is precisely the regime which obtains when the state abrogates its responsibility for governance, there is a poor set of management incentives generated, and the resource users then fail to invest in response.

3.2 With State Governance: Consequential Investments by User Groups

Now let us assume that the state concerned has instead taken the prior choice to engage in some manner of governance. To make this concrete, we will consider a particular example of governance: the idea of the institution of a decentralized system of individual property rights in land. Here, we wish to use the simplest possible example to illustrate

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[13] In both Equations (3) and (4), the LHS of the equations represent the potential benefits from investments and the RHS the opportunity costs. As entry driven higher, the perceived benefits from investment go to zero.

[14] This sort of conflict between traditional local usage and state assertion of sovereignty was rife throughout many parts of the colonial world (see, e.g. S. Marks 1984).

[15] There is very little evidence that the species usually associated with converted lands are in fact better suited biologically to the lands in question. Conversion of land uses to domesticated livestock is an economic decision, and more often driven by institutional factors than market-based forces (Eltringham 1986).

[16] For example, many "homesteading acts" required removal of the indigenous species and replacement with European domesticated ones before property rights would vest. Also, in many parts of the world, property rights were expressly disallowed with regard to any species termed "wildlife."

the difference in investment incentives. Under this institution, it will be assumed that the state pursues the objectives of: (a) undertaking an authoritative allocation of the land to individuals, together with (b) providing sanctions for apprehended interlopers, while (c) leaving the ongoing implementation and monitoring of the system to the user group.[17]

Assumption 2 (State Determination to Govern – by Decentralized Property Rights Institution (PR)) *The state's determination to govern is assumed to take the form of the allocation of an individual parcel of land* (R_i) *and an individual allocation of the resource* (x_i) *to each individual* (i) *in the common. The state does not monitor or enforce that allocation, but merely offers to sanction those individuals caught violating other user's allocations.*

How will the state's decision to govern impact upon the user group's incentives for investment? In general, the function of a decentralized incentive system is to move away from an averaged and toward a targeted set of returns, so that investments by individuals engender returns to those same individuals. This is the definition for management given by Alchian and Demsetz (1972). To see how returns become targeted, we will specify further how governance relates to the management of the resource by the users. Given the state's intervention (by assigning allocated parcels and offering courts to punish identifiable trespassers), resource management by the user group will be assumed to be of the nature of legitimized fence-building around the allocated parcels. Each owner will have the right to fence off its state-allocated parcel and to invest in "fence-building" — to prevent access by others. This manner of investment dovetails nicely with the state's governance mechanism, enabling the users to channel returns increasingly toward themselves via monitoring (by themselves) and punishment (by the state). The question here concerns how much height each user will purchase.

Assumption 3 (Individual Investment in Management under Property Rights Institution) *Given the governance mechanism outlined in Assumption 2, each user has the right to invest in management* (M_i) *relating to its individually allocated land parcel. Management spending has the effect of increasing the targeting of returns away from averaged returns.*

This mechanism operates by reason that the more that is invested in management by the user (i.e. the higher are the fences), the more often that unlawful entrants will be identified (by the user group) and sanctioned (by the state).[18] However, if it is assumed that such investments can never be perfectly effective,[19] then increasing management

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[17] The general situation in most decentralized institutional contexts (property rights, civil liability, and contracts) is that the state will provide a standard-making authority (judiciary) and maintain a monopoly on the use of force (sanctions), while leaving the matter of monitoring and enforcement to users of the institution (Cooter and Ulen 2004).

[18] This conceptualization enables us to portray the investment in management as the determination of an asset level (i.e. the amount of fence acquired) and then to determine the flow of costs deriving from this choice.

[19] The distribution of potential entrants will be assumed to cover a wide range of fence-climbing abilities and motivations, and thus exclusionary investment would need to go to infinity for all

will keep an increasing proportion of the entrants out of the allocated areas, but at a decreasing rate.[20]

Definition (Management) Given state governance, individual management has the impact of enabling the targeting of the returns from the resource. The management function $m(M_i)$ achieves this purpose by means of increasing targeting (away from averaged return) toward full appropriation, as investment in management increases away from zero.

$m(\bullet)$ is defined to be the *management function,* concave and twice differentiable, with:

$$\frac{1}{n} \leq m(M_i) \leq 1,$$

where

$$m(0) = \frac{1}{n}; \quad m(\infty) \to 1.$$

The overall impact of the introduction of such a basic property rights institution may be summarized by the introduction into the resource user's decision problem of this instrument for value appropriation $m(M_i)$. Under the assumptions outlined above, this appropriation mechanism is a concave function of management spending, and represents the manner in which the flow from the designated parcel is shared between its owner and the pool of potential entrants. Thus, this targeting function determines the rate at which returns are appropriated by the individual investor. As management expenditures by the user increase, the share of the stream of benefits appropriated by the designated owner of the land parcel increases monotonically away from an averaged return but at a declining rate.

Under these assumptions, the institution of governance has a very specific sort of impact, by creating the capacity for individuals to undertake management. The individual resource management problem, (1) above, can now be reformulated as follows, under the assumptions of this very basic property rights regime.[21]

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potential entrants to be identified and excluded. Those with exceptional abilities are able to access the parcel with impunity.

[20] Essentially the distribution of potential entrants derives from a skewed distribution with a very long tail of highly motivated or highly able fence climbers. This is akin to the model of precaution utilized in the analysis of consequential investment of users subject to a liability regime (Cooter and Ulen 2004).

[21] In physical terms, the essential difference is that each individual is now operating relative to an individually allocated land parcel, with the legal right to build fences to detect entry to those parcels, and to partition between those who are allocated access (i.e. owner) and those who are not. In terms of governance, the state has merely created the conditions under which individual users see an incentive to invest in management.

Definition (User Choice Given State Governance by Simple Property Rights Regime (PR))

$$\underset{y_{it},R_{it},M_{it}}{\text{Max}} \prod_i^{PR}(y_i, R_i, M_i) \equiv \int_0^{\infty} e^{-rt}\left[\{p(y)y_{it} - c(x_{it})\}\, y_{it} m(M_{it}) - r\rho_R R_{it} - \rho_M M_{it}\right] dt$$

$$\text{subject to: } \dot{x}_i = H(x_{it}, R_{it}) - y_{it}$$

$$\text{given } x_{i,t=0}, r, \rho_R, \rho_M \text{ constants}$$

$$m(M)_i, c(x_i), H(x_i, R_i) \text{ continuous, concave and twice differentiable}$$

$$m'(M_i) > 0, \quad c'(x_i) < 0, \quad H'(x_i, R_i) > 0. \tag{6}$$

In this version of the problem, the state has acted to make an authoritative allocation of the resource stock and land to each individual in the user group. Now each user perceives an individualized return from investments in the resource, as represented by the specification of the growth function as generating individually allocated increases in the resource stock (x_i).

This leads to the following propositions.

Proposition 3 (Resource Users' Incentives to Invest in Management – Given State Governance) *If the state elects to govern the resource in accord with Assumption* 2 *above, each individual within the user group then has the incentive to invest in management as defined in Assumption* 3. *The optimal level of investment in management will be determined by equating the marginal benefit from enhanced rent appropriation to the marginal costs of additional units of management.*

Proof: **(see Mathematical Appendix)** Derived from the first-order conditions to (6).

$$M_i^{PR}: \frac{m_i'(M_i)\lambda_i^* y_i}{m_i(M_i)} = \rho_M \tag{7}$$

$$m^*: m(M_i^{PR}); \quad 0 < m^* \leq 1 \text{ given } M_i^{PR} > 0$$

■

The optimal level of investment in management will equate the marginal impact on appropriation to the price of management services. So long as the appropriation function (m_i) is reasonably responsive to investment, and the cost of management is not too high, Equation (7) states that individuals will now invest in some level of management services for those land parcels for which they have been allocated rights by the state.

The results in terms of incentives for investments in resources are set out in Proposition 4.

Proposition 4 (Resource Users' Incentives to Invest in Resources – Given State Governance) *Assuming that the state chooses to engage in governance and individuals in the*

user group respond with some level of investments in management (*as set out in Proposition* 3), *the resource user group then has enhanced incentives to invest in the subject resources and the land concerned. The incentives for the user group to invest in the resources are dependent on the level of management undertaken.*

Proof: **(See Mathematical Appendix)** Derived from the first-order conditions for (6) above, the assumption of symmetry across resource users, and comparison with results in Equations (3) and (4).

$$\begin{aligned} R_i^{PR} &: \lambda_i^* H_R' = r\rho_R \\ x_i^{PR} &: \frac{(-c_x y_i)}{\lambda_i^*} + H_x' = r \end{aligned} \tag{8}$$

where λ_i^* is determined by the first-order conditions for y_i^*:

$$y_{it}^* = 0 \quad \text{if } \left(p(y_t)\left[1 - \frac{1}{\varepsilon_D n}\right] - c(x_t)\right) m^*(M_{it}) \leq \lambda_{it}^*$$

$$y_{it}^* > 0 \quad \text{if } \left(p(y_t)\left[1 - \frac{1}{\varepsilon_D n}\right] - c(x_t)\right) m^*(M_{it}) > \lambda_{it}^*$$

(λ_i is the perceived value of a unit of stock invested by individual i) ■

There are now incentives to invest in the resources (x) and the land use (R), so long as there are incentives to invest in their management. Investments in the resource no longer yield an average return (y/n) but an *individualized* return ((m)y), and this targeted return provides the mechanism by which investment incentives are instilled. The expected rental value of the resource was driven to zero by free entry; however, under a basic property rights regime, the rental value is now determined by the level of management spending.[22]

Fundamentally underlying all of the differences in the two equilibria under the two regimes (OA and PR) is the government's choice of institutional framework. The state's decision to govern, and the consequential investments in management by the user group, has the effect of overhauling the investment incentives regarding the natural resources. That is, all of these investments – in governance, management and consequently in the subject natural resource – are the consequence of the state's initial decision regarding the institutional framework, i.e. in altering the individual's perception of the incentive system applying to management.[23]

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[22] That is, the unit rental value will be in equilibrium between the force of potential entrants and the force of the investor's exclusionary investments (see, e.g. Copeland and Taylor 2005, for an example of such a mechanism at work).

[23] Note that the level of investment in the natural resources – given state governance – need not approach first-best resource management. The level of investment by user groups will now be

3.3 The Generalized Commons Problem: Management as a Distinct Asset

The general lesson to take away from the examples in this section is that the fundamental impact of state governance lies in the users' recognition that they may choose to invest in management as a distinct asset, in addition to the resources and the land.[24] The commons problem falls generally within that group of problems which concern the optimal management of joint assets. This is the general nature of many different types of relationships within which there is some manner of joint production: organizations, firms and complicated contracts being other examples. In all of these instances, management is seen to exist as a distinct asset in the production relationship, in addition to the other more tangible forms of assets (such as capital and labor) (Grossman and Hart 1987; Hart and Moore 1990; Williamson 1986; Hart 1995).

The classic commons problem is simply the instance in which at least one of the joint assets in the production relationship is a natural resource. Then it is as important in this context as in others to separate out between the tangible assets and their management, which is another distinct dimension; too often it has been assumed that natural resource exploitation and natural resource management are synonymous, while it is important to recognize that they are very different concepts.[25] This more general natural resource management decision problem is depicted in Equation (9).

Definition (The Generalized Commons Problem – The Commons within a Vertical Governance Framework) The Generalized Commons Problem embeds the

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determined by the individual characteristics of those resources (H_x and H_R), the costs of extraction (c_R), and the costs of management. The resultant outcomes may range from overexploitation to first-best management, and every management outcome in-between, depending on the innate characteristics of the resource concerned. It is a long-established result in the natural resource literature that the outcome in natural resource management may be optimal depletion or even optimal extinction, depending upon the innate characteristics of the resource for growth or management (Clark 1973, 1976; Spence 1975; Dasgupta and Heal 1979; Dasgupta 1982).

[24] The two management regimes considered in the previous section of this paper (OA and PR) are discrete examples of the forms of incentive systems which may exist; however, there is a continuum of possible systems. The range of possibilities concerning this most fundamental layer of incentives is termed governance, and this core problem of the commons will be termed institution-building.

[25] In many relations, it is easy to distinguish between the context and the incentive system. In particular, where the relationships are purely "vertical" (such as the passage of goods through a chain of distribution), there is no point in time when the tangible asset is actually held in common. Then, the only joint asset is the incentive system applying to the various parties in the relationship. For example, consider an insurance company that develops an insurance contract and then distributes it through a network of independent sales and service agents (Grossman and Hart 1987). The joint asset between company and distributor is not the insurance policy (which is the sole property of one party in the chain of distribution at each point in time), but the system of incentives to generate optimal investments by both. An institution must be developed within this purely vertical system that will create incentives for agents at both levels to invest optimally in the maximization of the value of the policy. This system must generate incentives for the insurer to invest in the creation of the value-maximizing terms in the policy and must also generate incentives for the retailer to invest in the value-maximizing sales and service scheme. It is this system of incentives to individual investments ("management") that the two parties hold jointly, not the contract itself.

horizontal relationships of the resource user group within the decision-making framework of the manager of the system. The objective of this decision maker is the maximization of the total value of the resource to the user group, by the selection of the institutional form of governance (M_G) that is capable of generating optimal management and optimal resource use by the user group.

$$M_G^* : \underset{M_G}{\text{Max}} \sum_i \prod_i (y_i, R_i, M_i; M_G) \quad \text{subject to : } \dot{x} = H(x, R) - y. \tag{9}$$

In the generalized commons problem, there are now three assets used jointly by the user group: the stock of resources, the land on which they reside, and the joint management of the system by its users ($\Sigma_i M_i$). The decision maker interested in solving this horizontal problem must consider the form of governance (M_G) that will cause the users to recognize and internalize the management component of the problem, just as we saw when comparing the impact of the regimes OA and PR in this section. At the core, then, the generalized commons problem concerns the introduction of institutions that generate the incentives for resource users to invest in resource management.

4 THE FIRST STAGE OF THE GENERALIZED COMMONS PROBLEM: THE STATE'S GOVERNANCE PROBLEM

It is now time to turn to the first stage of the decision problem set out in Figure 1: the decision by the owner-state regarding the governance of the resource and its users. Since there exists an "owner-state" with sovereignty for every parcel of land, there then exists a regulator *de jure* of the incentive systems extant in every commons. Yet, in practice, it appears that in many cases the regulator abdicates this authority, leaving individuals and resources to reach ostensibly unregulated equilibria.

The standard practice in such situations is to advocate that states do a better job in managing the resources, or in defining property rights (see, e.g. Chichilnisky 1994). However, this prescription assumes that institution-building is a costless activity, whereas in fact the development of institutions requires the investment of resources which are then unavailable to other sectors of the economy.[26] Institutional development regarding natural resources must compete for capital just as does any other form of development (health, education, housing, etc. . .) It is this constraint on investment capital that is the fundamental cause of inadequate management institutions, and hence overexploitation.

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[26] This section is in the same spirit as those authors arguing that endogenously arising property right regimes derive from extant conditions within an economy (Field 1989; van Long and Tian 1998; Stokey 1998; Swanson 1993).

This section investigates this hypothesis, and demonstrates how states make decisions regarding *optimal* investments in natural resource institution-building.

4.1 State's Decision to Manage Resources: Commons Problems as Governance Problems

A state with sole jurisdiction over a common resource has two distinct problems to solve: the problem of first-best natural resource investments and the problem of optimal social investments. To some extent, the two objectives do not coincide on account of the opportunity costs implied in achieving the former. In this section, we will demonstrate this by investigating the state's decision on the choice of the optimal amount of management (M) to be applied in regard to given resource and land use. Since we are investigating the social choice problem in this section, aggregate management costs (M) here will consist of both those expended by users (i.e. $\Sigma_i M_i$) plus those management costs of government (M_G).

Consider initially the problem of first-best natural resource investments in isolation. First-best natural resource investment concerns only the nature of the "first-best" solution to the natural resource portion of the commons problem. This is the problem of determining the first-best aggregate levels of investment in the natural resources (x^{fb}, R^{fb}), *assuming that the costliness of these investments is zero*. Equation (10) defines the level of these first-best investments for the three joint assets, given that the cost of management (ρ_M) is zero.

Definition (First-Best Natural Resource Management (FB)) First-best natural resource management is defined to be that level of management that would have been chosen if the cost of management services was zero (i.e. $\rho_M = 0$).

$$x^{fb}, R^{fb}, M^{fb} : \underset{y,R,M}{\text{Max}} \quad \left[\sum_{i=1}^{n} \prod_{i}^{\rho_M = 0} (y_i; x, R, M) \right] \tag{10}$$

$$\text{subject to} : \dot{x} = H(x; R) - y.$$

First-best management is an ideal – one that exists within a world of costless resources. In a world of scarce resources, the level of governance will have to trade-off conservation benefits against the opportunity costs of using those resources elsewhere within the economy. The governance problem of the commons then is to determine and to implement the optimal aggregate level of investment in all three of these joint assets: *land, natural resources, and management*. The optimal governance problem subsumes the natural resource management problem. That is, the state acts by allocating resources to management to move the system closer to the "first-best targets" provided in Equation (10), and thereby removing the costliness of less than first-best institutions, and trades-off these benefits against the opportunity costs of allocating those resources elsewhere within the economy.

The governance problem of the commons is the minimization of the sum of these two types of costliness: natural resource overexploitation and natural resource

management.[27] This is depicted in the two terms of Equation (11): the first represents the costliness arising from the distance between first-best and the selected institutions, the second represents the costliness of investments to reduce this distance.

Definition (Optimal Management of the Commons)

$$M^* : \underset{y,R,M}{\text{Min}} \left[\sum_{i=1}^{n} \left[\prod_i (x^{fb}, R^{fb}, M^{fb}) - \prod_i (y_{i;x,R,M}) \right] - \rho_M M \right]. \tag{11}$$

The internalization of externalities requires investment in management. The price of that management is unlikely to be zero in any situation. The *optimal institution* is the one which balances the gains from the aggregate impact on individual actions of governmental expenditures on incentive modifications against the costliness of those expenditures.[28] Because the institutional change is a collective good, the correct assessment of optimality considers the sum of the individual benefits (Samuelson 1954). This leads us to Proposition 5.

Proposition 5 (Optimal Investment by State in the Commons) *So long as the cost of management is not zero, the optimal level of investment in the management of the commons will not target first-best management. States will target a level of management that will trade-off the costs of imperfect management institutions against the costs of management. Under decentralized management of resources, the efficient provision of management services should satisfy the condition for the provision of any Samuelsonian public good, i.e. the sum of the marginal benefits from investment in management should be set equal to its marginal costs.*

Proof: The optimality condition for state investment in management may be derived by differentiation of Equation (11).

$$M^* : \left(\sum_{i=1}^{n} \frac{\partial \prod_i (M)}{\partial M} \right) = \rho_M . \tag{12}$$

■

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[27] For the purposes of the governance problem, the state should be indifferent as to whether management resources are expended by the private sector (M_i) or the government sector (M_g), and so no distinction is made within this portrayal of the problem.

[28] This constitutes an alternative approach to the analysis of vertical relationships usually undertaken (e.g. the "principal-agent" (P-A) sort of incentive problem), to take into account the costliness of institutional modifications. Under the P-A problem, the principal's object has been assumed to be the installation of first-best incentive mechanisms at minimum costliness, subject to the constraint of maintaining all agents within the principal's jurisdiction (Grossman and Hart 1987). In the context of the commons, the analogous objective would imply that it is the state's role to achieve first-best investment incentives at the minimum possible cost. Such a rendition of the model eliminates the possibility that the societal optimum might lie with investing society's resources in some endeavor other than the refinement of these incentives. The "optimal institution" model provides for this possibility. There is an express trade-off between the costs and benefits of commons management implicit in this model.

This condition states that the current level of investment in governance will equate the present value of expected marginal benefits to the marginal cost of the institutional investment. Although institutional investments are of the nature of public goods and warrant positive levels of investment, clearly the first-best will not be targeted so long as the cost of doing so is greater than zero.[29]

4.2 An Example from the Commons: States' Decisions on Elephant Management

During the decade of the 1980s, it is generally agreed that the population of the African elephant declined by about half, from 1,343,340 in 1979 to 609,000 in 1989 (Douglas-Hamilton 1989). In addition, the trade in ivory, the principal product derived from this species, also doubled between the early 1970s and the early 1980s – from an average of about 550 tonnes to an average of about 1000 tonnes (Barbier *et al.* 1990). On account of these trends, population modellers predicted the imminent extinction of the species (Renewable Resources Assessment Group 1989).

At first glance, the decline of the African elephant appears to be a good example of a classic tragedy of the commons. There is no doubt that the proximate cause of most elephant deaths during this decade was a high-powered weapon, nor that the motivation for the slaughter was the procurement of ivory. During the decade the trade in ivory reached a peak of over 1,000 tonnes per annum, after averaging nearer 600 tonnes in the previous decade (ITRG 1989). It is also clear that the prices of ivory were high. During the 1980s, the price of elephant ivory soared, reaching prices of more than $140/kg in Japan. Nevertheless, the value received by resource users (indicated by the prices paid to poachers) was more in the order of $5–10/kg (Swanson 1989a). This failure to capture rental value is a potential indicator of the existence of a commons problem, as is the continent-wide decline in elephant populations.

The African elephant appears to be a good example of a species endangered through overexploitation. It is important nevertheless to place this species' decline within the context of the various owner-states' determinations on how to manage it. Although the immediate cause of death of each elephant was some hunter's pursuit of its ivory, the more fundamental cause concerns the reasons why these hunters were allowed unmanaged access to the elephant herds, and why the ivory being harvested was not being managed better for the benefit of the elephants' owners.

It is clear that, at least for some of the most important losses of elephants, the implementation of open access has been a choice of the states concerned. This may be seen (in Table 2) from the fact that in the 1980s four countries alone – Tanzania, Zambia,

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[29] It is important to recognize that the management problem and the resource investment problem are distinct but inter-related concepts. If the state decides that it does not wish to invest at all in the resource, then nonmanagement is the means for implementing the chosen disinvestment path (Swanson 1994; and next section). However, even if the state decides that it would like to invest in the resource along a path of positive or increasing stock levels, it will still invest in management in a manner that will be less than perfectly accurate in targeting that path (unless management costs are zero).

Table 1. Estimates of changes in African elephant populations, 1980s

	1979	1989
Central Africa	497,400	277,000
Eastern Africa	546,850	110,000
Southern Africa	282,200	204,000
Western Africa	17,090	19,000
Totals	**1,343,340**	**609,000**

Source: ITRG, 1989. The Ivory Trade and the Future of the African Elephant, Report to the Conference of the Parties to CITES, Lausanne. Barbier, Burgess, Swanson, and Pearce (1990).

Table 2. Park management spending by selected african states (spending levels in $/km^2)

	Date	Management	Pop (1979)	Pop (1989)
CAR	1986	5	63,000	23,000
Kenya	1984	188	65,000	16,000
South Africa	1986	4350	7,800	7,800
Sudan	1986	12	134,000	22,000
Tanzania	1984	20	316,300	61,000
Zaire	1986	2	377,000	112,000
Zambia	1984	11	150,000	32,000
Zimbabwe	1984	277	30,000	52,000

Sources: Bell, R., and McShane-Caluzi, E. (eds.) 1984. Funding and Financial Control, in Conservation and Wildlife Management in Africa, Peace Corps: Washington, DC; Cumming, D., DuToit, R., and Stuart, S. 1986. African Elephants and Rhinos, IUCN: Gland.

Zaire, and Sudan – are estimated to have lost 750,000 elephants between them, equal to the overall continental losses during that period. The other 30 states exhibited no aggregate losses of elephants over the decade, and several demonstrated substantial gains (Swanson 1993). Table 2 further demonstrates the manner in which these states implemented their decisions not to manage; these states spent $2, $11, $12, and 18$/km^2, respectively, on park management in the year surveyed (compared to several hundreds of

$/km by Zimbabwe and South Africa). The decline of the elephant was a straightforward result of these states' determinations to implement an open access regime.

Why would these states elect to implement open access in regard to an obviously valuable resource? In short, the elephant was not perceived to be worthy of investment, in regard to land, stocks or the management services required to manage them. Each elephant requires about one-half square kilometer of good grazing land for its sustenance (Caughley and Goddard 1975). Average life expectancy is about 55 years (Hanks 1972). Therefore, it represents a substantial commitment of resources to provide for a single elephant's livelihood. The resources required for the sustenance of the millions of these creatures that recently roamed Africa would represent a substantial portion of that continent's land area. In addition, few elephants are stationary within an area of a few hectares; they travel widely in search of food, and crops are at particular risk. For these reasons, there are substantial negative externalities experienced by those living in the rural areas of a country that has a significant elephant population. Also, the management of access to the population would not be as inexpensive as with a more sedentary animal. Combined with its slow growth rate and the perceived absence of significant international markets for its products, the pressures for the removal of a substantial portion of the African elephant population from the lands of Africa must have been intense.

Unofficial open access policies were then a good method for mining the vast numbers of surplus elephants, from the perspective of aid-sensitized African government. The criminalization of the off-take of ivory preserves international appearances, while the absence of resources applied to elephant protection allows the mining to continue apace. There is, in addition, the side benefit of the revenues derived from sales of seized ivory. Virtually the entirety of the trade in ivory during that decade (ranging between 500 and 1000 tonnes per annum) was derived from poached ivory sales that were licensed after seizure. This arms-length approach to the industry preserves appearances while fostering the removal of the species from the land.

In short, the elephant's decline has been largely the result of an implicit decision to undertake mining on the part of a few of the range states. The decline of the African elephant during the 1980s, and the ivory trade it spawned, was a direct result of these disinvestment decisions by the state and the management regime that was chosen to implement disinvestment in certain states (Swanson 1993, 1994).

5 RE-TELLING THE TALE OF THE COMMONS AS A GOVERNANCE PROBLEM

The commons problem is at base a governance problem.[30] The state's failure to institute first-best incentives for resource management necessarily determines that there will be

[30] We will now focus on the case where the state is failing to follow the path it would like to target, on account of the cost of the management that accurate targeting would imply. This is distinct from the case in which the state is targeting substantial disinvestment (as in the case of elephants). The latter is just as interesting but covered elsewhere (Swanson 1994).

inadequate investment in management at the user level. Consequently, the resource itself suffers from lack of investment. Clearly, states must prioritize in their investments, and so at times they will under-invest in governance – effectively choosing a regime that results in underinvestment in the resources of the commons. The state's failure to govern adequately is the fundamental cause of waste and inefficiency within this framework.

The strict determinacy within this statement implies that there are certain functions of the state that cannot be devolved or transferred, i.e. there can be no substitution by others for governance by the state. If this were not the case, then it would be possible for private agents to evolve governance by means of complicated (horizontal) contracting at the resource user level, or to institute governance by means of "entry" at the sovereign level.[31] We argue here that the former is extremely unlikely and that the latter is highly undesirable. The problem with the endogenous evolution of institutions at the horizontal level is that, if no prior governance exists, the returns from investing (even in governance) will be untargeted, and so little individual incentive to commence investment exists. The problems associated with the dispersion of sovereign functions across (or even outside of) an economy are much more serious than the simple underinvestment in resource management. They will be discussed in more detail in the sixth section below. Now we turn to discussing why it is unlikely that resource users will be able to substitute for the state, when governance is missing.

5.1 The Traditional Telling of the Tale: The Unlikely Event of Endogenous Governance

There is a substantial literature that has developed around the idea of institution building that is exclusively horizontal in nature, i.e. endogenously generated and enforced institutions arising out of joint production relationships (Seabright 1993, 1994; Ostrom 1990; Ostrom *et al.* 2002). These authors argue that it may be possible for resource user groups to evolve governance within an institutional vacuum. It is important to recognize that, although community management within governance frameworks is possible, horizontal institution-building is not able to substitute for vertical governance.

First, there is the fact that the vertical framework already exists. There is little remaining terrestrial habitat which remains un-claimed territory. This means that a specific state is designated as responsible for the governance of the generalized commons problem [(9) above] for every parcel of land on the earth. Therefore, the vertical form of the institution already exists *de jure*; the important question is why there is so little investment in governance in so many parts of the world, resulting in its virtual nonimplementation *de facto*.[32]

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[31] In terms of the generalized commons model, we are asking why the state need necessarily supply M_G rather than having either the resource users or other entrants supply management services in its stead.

[32] This is not intended to detract from those instances in which the endogenous evolution of governance is of the essence of the problem, viz. where the resources concerned fall either outside of the boundaries of any given state or across the boundaries of many states (e.g. marine resources, atmo-

Second, in the absence of state determination to govern, there are insufficient individual incentives for the commencement of individual investments into governance. This is because the same incentive system applies to the investment in the underlying assets (of management services and institution-building) as applies to the other (natural) assets. Therefore, starting from the initial position of little or no governance, there is little individual incentive to commence investing optimally.

This may be demonstrated by the introduction of the fundamental asset of management into the individual's decision problem set out in (1) above; this is done below in Equation (13). Now the individual must decide how much to invest in initial "fence-building" (management), under conditions in which the state has failed to introduce management institutions. Under these initial conditions, individuals will only invest in this core asset to equate marginal private benefits with marginal private costs, where marginal benefits are averaged rather than targeted.

Definition (Horizontal Institution Building in the Commons) Horizontal institution building may exist within the commons when the state concerned has abrogated responsibility for governance regarding the subject resources. In this context, the user group is then attempting to solve the generalized commons problem for itself, subject to the constraint that any returns from the solution must be channeled initially through an institutional framework in which there is no governance.

Conjecture on the Commons: Incentives to Invest in Management Absent Governance

If the state abrogates its responsibility to build management institutions, then the user groups operating within that commons receive returns to individual investments in management starting from the level of nonmanagement ($M_G = 0$). This implies that the initial returns to management will approach those under an unmanaged regime (such as free entry), and so returns to those investments will be averaged rather than targeted upon the investor. If there are large numbers of potential entrants, then the returns will go to zero. For this reason, if the state fails to manage, endogenous incentives to invest in management are unlikely to arise. In terms of the generalised commas problem ((9) above), horizontal institution building comprises the decision to invest in individual management (M_i) given that vertical institution building is absent ($M_G = 0$).

$$\begin{aligned} M_i^* : \underset{M_i}{\text{Max}} \prod_i^{M_G=0} &\equiv \prod_i (M_G = 0) - \rho_M M_i \\ M_i^* : \frac{\partial \Pi_i / \partial M_i}{n} &= \rho_M \\ \therefore M_i^* \to 0 \quad &\text{as} \quad n \to \infty. \end{aligned} \tag{13}$$

spheric resources, and global resources). This is another topic, clearly important and disassociated from the classic instance of the commons problem (Barrett 1993, 2003; Swanson 1994).

Equation (13) states that the returns from the initial investments in commons management will not be targeted on those who invest, but rather averaged across all users of the resource. This implies underinvestment in management services, precisely because management is a joint asset. Ironically, when the underlying incentive systems are weakest (and institution-building would potentially yield its greatest aggregate returns), the individual incentives to invest in institution-building are also at their weakest. This is the essential reason why horizontal approaches to institution-building are the exception rather than the rule. When the state has refused to manage the commons, there is little incentive for individuals to invest to generate the required institutions.[33]

This discussion also indicates why open access regimes are very stable institutions – in the absence of governmental intervention. If the initial position is one of low aggregate investment in management institutions, there is virtually no individual incentive to commence such investments. This means that an open access regime, once prevailing (and without intervention), will remain a stable equilibrium. This is the reason that fisheries management regimes do not evolve in areas devoid of governance. Although the entire user group would benefit from the evolution of a management regime, the efforts by any one user to create the institution would generate untargeted benefits to the entire user group. So long as that user group is unrestricted by any form of governance institution, there is little incentive for any one user to commence those investments.

5.2 Horizontal Management within Governance Frameworks

It is more likely that existing community-based management institutions are effective precisely because they do exist within a simple governance structure provided by the state. Many authors have argued that communities are able to manage (and hence invest in) common resources, so long as the state establishes some minimum framework of governance for community-based management (Baland and Platteau 1996, 1997, 1998; Bardhan 2001; Ostrom *et al.* 2002; Acheson 2003). This is of course true, but it simply reemphasizes the point that governance is the crucial ingredient for the resolution of commons problems, and that the management unit is often an irrelevance. The important thing is that the management unit perceives that it has the capacity to invest in management, not the structure of the unit itself. This invariance to the form of the management unit is obvious when considered within the context of the vertical industry. We would anticipate that a property right could be devolved within a vertical chain to a well-functioning firm just as efficiently as it could be to an individual.

[33] This of course depends on the pool of potential entrants being very large. A technological shift in transport and communications has occurred everywhere in recent decades that makes it very likely to be the case. This has rendered most terrestrial resources vulnerable to the forces of free entry. Vast urban populations may reach the frontiers in a matter of hours. With this omnipresent pool of potential entrants, there is no capacity for interdependence and recognition to evolve institutions over time. If the number of interacting, and potentially interacting individuals, is very large, then the transaction costs of such collective management is usually too great for such horizontal contracts to evolve. Then it is necessary to rely more on hierarchy for the provision of management solutions.

The structure of the management unit is irrelevant so long as the incentives to manage inhere.[34]

The explanation provided here indicates the reason why the most effective commons institutions are either historic in nature (Swiss Alpine meadows) or operated under prevailing state governance institutions (Spanish and Philippine irrigation districts) (Ostrom1990). In the past, institutions evolved under entirely distinct technological conditions (e.g. the Alps of the middle ages) were not subject to large numbers of entrants, and hence it was possible to endogenously evolve management through interaction and reciprocity. Today institutions created under state authority, encompassing courts and state-sanctioned enforcement (as is often the case in irrigation districts), provide the basic foundations for governance outlined previously, and so explain how cooperatives can operate successfully. Most commons problems exist on frontiers where courts are nonfunctioning and transport is readily available. Under these circumstances, endogenously generated management institutions are highly unlikely to evolve absent initial government intervention. The state's choice of nongovernance is then determinative of the level of investment in management.

6 PROBLEMS RESULTING FROM PROBLEMS OF GOVERNANCE: CORRUPTION, STOCKPILING, RENT-SEEKING

States will not pursue first-best resource management, because they do not pursue first-best anything. Optimal institutions are necessarily bounded away from first-best on account of the costs of management and the concomitant costliness of attempting to achieve perfection. When this results in relatively unmanaged resources, or less than first-best investment by user groups, the resource-related consequences are regrettable but really unavoidable in a world of constrained resources. This is not a tragedy, just a fact of life.

The more substantial source of tragedy-making in this arena lies in the opening that an absence of governance creates for unauthorized entry by various substitutes for the sovereign.[35] The entrant might be attempting to assert authority over the resource rents, or it might be attempting to claim the right to provide governance itself (and claim a rate of return from providing such management). In any event the entrant is usually a highly inferior substitute for the sovereign, and it is this imperfect fit that generates waste.

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[34] In fact, the state must usually work within the management units that exist, or it may only create systemic conflicts. A classic example is the Namibian government's attempt to introduce wildlife management rights into tribal lands within the Caprivi strip. It would be inconsistent, and possibly incoherent, to attempt to devolve wildlife management at the individual level rather than through the extant community-based management system, even though the government has conferred individual-based rights in wildlife to individual owners on lands that are nontribal (Jones 1999).

[35] If $M_G = 0$, this implies complete surrender of the sovereign's position in the hierarchy, and so long as it is very far from first-best, there is some governance space available for entry (as the sovereign is not performing its function to the extent required to fill the core functions).

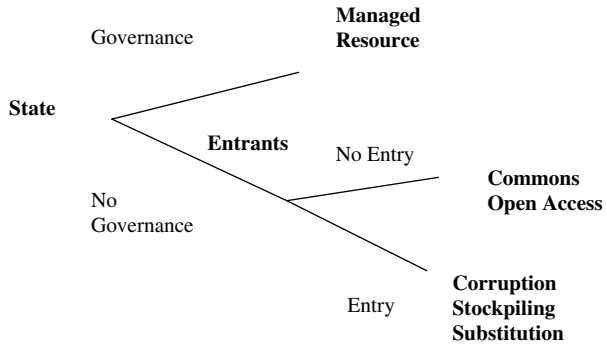

Figure 2. More tragedies of the commons – entry into vacated governance space

We may conceptualize this as a more generalized version of our two-stage game that was set out in Figure 1. In this version of that game, we now allow entry by others, in response to the state's decision not to govern.[36] These agents enter to fill the governance space available to appropriate the rents available from the resource, the land, or from the position itself. In Figure 2, we set out this broader version of the generalized commons problem – the problem of entry into governance – and the broader range of tragedies that may result.

Why is it problematic for others to enter into the space vacated by the sovereign? Clearly, many of the functions associated with governance may be devolved to others without adverse impacts and with potentially significant gains in efficiency; however, it is critical to distinguish between the core functions which need to be undertaken by the state and those which may be devolved.[37] Some of these functions are fundamentally distinguishable from one another, and should be the sole preserve of the state. These *core governance functions* consist, at a minimum, of the two functions indicated at the beginning of section three: (1) some means of authoritatively identifying insiders and outsiders with regard to any given resource (the state as the exclusive source of entitlements), and (2) some means of authoritatively identifying those events where outsiders are attempting to invade insider territory, and the penalization of the same (the state as the exclusive source of police power).[38]

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[36] In the first version of the game, it was assumed that the state's decision regarding governance was determinative, i.e. no responsive entry was possible. We now generalize this to allow for the possibility that the state's decision not to govern creates an opportunity for entry by others interested in exploiting the vacated position.

[37] It is possible to model most of the various governmental functions (policing, protecting, and penalizing) as functions potentially performed by users rather than the state, but it is problematic to do so (Acheson 2003; Hotte 2001, 2005).

[38] In regard to property rights, these core functions are indicated by the fact that property owners are usually allowed to monitor boundaries and to identify interlopers to police, but not given the

These are core functions which the state should not devolve, as the transferability of such functions signals the opening of a very broad and wide-ranging contest regarding state powers. There are large costs associated with enabling these additional (nonpolitical) contests for core sovereign functions, such as is evident in civil wars, corruption, and kleptocracy (Acemoglu Robinson, and Verdier, 2004; Overland, Simons, and Spagat, forthcoming; Collier and Hoeffler 1998). One of the primary functions of the state is to be the sole repository of these rights, and the political contest the sole means of contesting them. Opening up competition for these core functions would generate very broad and costly contests, and should be assiduously avoided.

These contests and their costliness are readily seen in the context of the commons, and we will survey a few here. There are several examples of potential entrants that illustrate the problem of induced entry into vacant governance space: (a) the local government official, (b) the distant resource stockpiler, and (c) the nongovernmental entrant. Any one of these entities might attempt to exploit the opening left relatively unmanaged by the owner-state, resulting in rents for the entrant but without the capacity for instilling incentives for investment in the resource. This occasions waste, corruption, and disinvestment; it can be a real source of tragedy.

We will briefly discuss each of these in turn.

6.1 Shadow Property Rights of Local Officials

The most obvious potential entrant, in the event of the state abrogating responsibility, is the local official with control over some facet of the local institutional complex. Such an official might, for example, have control over the local roads, or other infrastructure, but no real authority to manage the forests. This authority to determine access to the local roads might then be extended to tacitly determine which firms might illegally access an area of forest. This local official is then able to capture a substantial part of the current rental value of the forest, by marketing the rights to forest access, without ever having any capacity or authority to manage the resource itself.

Definition (Shadow Property Rights) A local official is said to hold *shadow property rights* over a resource and its rents when it holds authority over some medium or means by which to access that resource, while not holding any actual rights or authority over the resources or the land.

Conjecture 1 (Impact on Investment – Shadow Property Rights in Local Officials) *A shadow property rights holder who maximizes the capture of short-term rents (by means of a charge for access) will not generate incentives for investment in either land or resource.*

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power to levy punishment themselves upon trespassers. The monitoring function may be devolved to users, but the ultimate governance functions (identification of wrongdoers and their punishment) is not transferable.

Consider a shadow property rights holder who is able to charge each user in the group a fixed charge per person for the ability to access the land (R). Once this fixed charge is assessed, each member of the user group is in the situation of unmanaged access (conditions as in Equations (3) and (4) above) and the investment incentives are as in Propositions 1 and 2. The shadow property rights holder would have some incentive to restrict access to generate investment (reduce n), but this would come at the cost of sharing rents with the resource users. If the shadow property rights holder feels insecure about the ability to capture future rents from the resource or land, then there would be no reason to restrict access and no investment in management would occur.[39]

The occurrence of this situation is so common that it really should not be necessary to list examples. The village elder, park ranger, or local forest administrator will often have some small pieces of authority (access to roads or rights to select employees) which then are able to be administered in such a manner as to generate additional rents for the local official but without generating incentives for investment in the resources from which the rents are derived. These shadow property rights are property rights in the sense that they generate some flow of revenues to the holder, but without the concomitant incentives for investment that property rights should provide. The office holder feels secure enough to make a current charge for access (thereby capturing rents) but not secure enough to feel that the rights provide incentives for investment in the resources concerned. The essential difference between property rights and shadow property rights is that the former generate rents and incentives to manage, while the latter generate only rents.

There is additional waste that occurs in the case of shadow property rights. Of course there is the waste occasioned through the resource, but this is the consequence of the abrogation by the state. The additional costs resulting from shadow property rights are the consequence of the unnecessary empowerment of local officials, in ways that are not intended by their legal scope of authority. The enhancement of the local officials' powers results in all of the waste and distortion associated with corruption. It becomes difficult to determine the real prices of resource rights and the real prices of access, as they become bound up in informal rights and authorities of local officials. In addition, it becomes difficult to define and transfer real property rights in these same resources and lands, as the local officials have incentives to inhibit such institution-building and transfers. The state's abrogation of its responsibility for management generates inferior sets of rights, and vested interests in retaining them.

6.2 Rent Seeking by Industry Stockpilers

The converse situation of shadow property rights is the incidence of industry stockpiling; the industry stockpiler has no capacity to control access to the lands concerned, but

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[39] If the shadow property rights holder is able to assess a variable charge, and does so efficiently (at the level of the shadow value of the stock, for example) it would then be able to create investment incentives in the stock (x) but not in regard to the land use (R) (Mason and Polasky 1994). This would be adequate in the case of non-terrestrial resources, but merely provides incentives for conversion of land.

absolute authority over the resource at some level of the industry. This occurs whenever the resource flows into a bottleneck within the industry, and the agents at that level of the industry are able to capture rents by managing flows from that point onwards.[40] As in the case of shadow property rights, this capacity generates rents without the capacity for investment. In fact, it is even possible that the stockpiler's incentives will be to encourage the decline of the living resource, while it continues to hold substantial stocks at its level of the industry (Bulte, Mason and Horan 2003); Kremer and Morcom 2000).

Definition (Industry Stockpiler) In some industries, it is possible to acquire control over the natural resource at a level distinct from the lands on which it is produced, such as at the wholesale or worked product level. A stockpiler has the capacity to capture rents by means of controlling both the rate of harvesting by the resource harvesters (by determining the rate paid per unit of the harvested resource) and the rate of final consumption (by determining the rate of release from the stockpile). Stockpiles result as a consequence of the agent's capacity to determine different prices (flows) at the resource harvesting level and the resource consumption level of the industry.

Conjecture 2 (Impact on Investment – Stockpiler's Rent Appropriation) *A stockpiler that maximizes the capture of short-term rents – by means of causing rates of harvest to differ from rates of consumption – will not generate incentives for investment in either the land or the resource.*

By reference to Conjecture 1, a stockpiler is equivalent to a shadow property rights holder who is able to make a "piece rate" for access to each unit of the resource. This per unit charge may be used to generate incentives for investment in the resource stock – if the rents are shared with the resource users – but there is no capacity to generate incentives for investment in the land use.

An example of this situation would be the live bird trade as it has existed between various parts of Latin America and Miami, in which the trade flows from numerous uncontrolled harvesters through hundreds of purchasers but finally to a small group of dealers controlling the trade in Miami and the US. The dealers there have been able to receive a flow of hundreds of parrots from Latin America at a price of a few dollars per bird, while delivering a far smaller number of birds onto the North American market at prices of several hundred dollars per bird. A half dozen wholesale firms in the southeastern US handled the vast majority of the exotic bird trade, creating the bottleneck that generated the rents for these stockpilers. To generate this outcome and these rents, several forms of waste occurred. First, the birds were harvested by small armies of peasants working under open access conditions and receiving payments that barely compensated for the labor they invested in the enterprise. Second, since

[40] One of the consequences of the agent's control over the resource at a later stage in the industry (such as the wholesale level) is that the agent must be able to stockpile the resource to assert that control. Stockpiles enable the agent to cause the rate of flow onto the later stages of the industry to deviate from those flowing in from earlier stages.

the rents of the birds were captured by stockpilers in the US, no incentives existed at the production level for investment in the resource stock, the land use, or the management thereof. Finally, the birds were not durable goods and thus were difficult to stockpile, and so the constriction of the trade at the wholesaler level resulted in the deaths of the majority of the birds within the trade. Another tragedy of the common (Swanson 1992).

6.3 Direct Entry into State Management: Entry into Vacated Policy Space

An even more obvious opportunity for rent seeking arises out of the direct entry by other governance units into the space left vacant by the abrogation of the state. There exists a group of agents which act as potential direct entrants into the governance arenas in which states decide not to govern (Slaughter 2004; Coen and Thatcher 2005). These nongovernmental entities are in effect competitors for the state's resource rents, and do so by marketing the supply of management services in situations in which the state does not supply first-best. There are constituencies which are willing to pay these nonstate agents to enter and to supply management, while they are not willing to supply funds to the states concerned to supply the same. In many cases, the nongovernmental entity is unable to supply incentives for investment in the land or the resources, although it is being paid precisely for that purpose.

Definition (Non-Governmental Entrants) A nongovernmental entrant is able to capture rents associated with unmanaged resources by reason of marketing its services as surrogate governor to those concerned whose resource management is less than first-best.

Conjecture 3 (Impact on Investment – Nongovernmental Entrants Appropriation of Rents) *Nongovernmental entrants* (*NGEs*) *may capture rents by offering to provide management services when states do not provide first-best resource management. Nongovernmental entrants may generate incentives for investment in resources* (*by means of introducing mechanisms that generate rents for harvesters*) *or they may generate incentives for investment in land uses* (*by means of introducing mechanisms that generate rents to particular land uses*). *In the short run, however, any such investment incentives must come by means of sharing rents with the resource users, and will subtract from the rents available to the nongovernmental entrant. In the long run, the sharing of rents to induce investment in management will reduce the scope for appropriating further rents as a surrogate government. Nongovernmental entrants do not have incentives* (*short-term or long-term*) *to perform the services that they advertise.*

Nongovernmental entrants are certainly capable of supplying the management services that will generate incentives for investment by the resource users. They may do this by, for example, providing mechanisms that provide green premiums on resources harvested by users investing in them. Or they might create mechanisms that certify certain flows of harvested resources as deriving from lands that are being managed. In either case, the nongovernmental entrant is acting to certify when investment or management is occurring, and so providing incentives for that investment and management to occur. The result must be to both transfer rents and management authority to the resource

user group, thus eliminating the vacancy in which the entrant was operating. The problem with this scenario is that the nongovernmental entities providing this service are necessarily putting themselves out of business. Although there is an incentive to advertise this service, there is less reason to perform it.[41]

6.4 Re-Telling the Tale of the Commons Problem – Exploitation of Vacant Governance Positions

This section has argued that the tragedy of the commons lies not in the governance failure that results in resource wastage, but in the opportunities for rent-seeking that result from the creation of these vacancies in governance. The failure of the state to perform first-best management generates rent-seeking opportunities that may be exploited by local officials, distant stockpilers, or even surrogate governmental units (or nongovernmental units). It is possible for any of these agents to both fill the vacancy, and to perform the desired task of supply management of the resources and lands, but it is more likely that the agent will have the incentive to exploit the vacancy without the capacity for investment.

If governments that suffer under severe budget constraints offered concessions in resource management, then it might be possible for entrants to combine the roles of rent-seeking and investment, but it is difficult for uninvited rent-seekers to assume the role of

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[41] A related story appeared on 12 September 2006 in the Financial Times of London. (http://www.ft.com/cms/s/b841d71a-41fa-11db-b4ab-0000779e2340.html) (See also environment.guardian.co.uk/food/story/0,,2032646,00.html in which the NGE claims that the standards set are "aspirational" and little monitoring or enforcement is undertaken by the NGE.)

> "Trading on fairness," Financial Times, 12 September 2006.
> "More and more customers are willing to pay a premium for certified products such as fair trade coffee: according to Fairtrade Labelling Organizations International (FLO), Fairtrade certified product sales were up 37% last year. There are two ways for sellers or producers to enjoy that premium: give the customers what they want, or lie. Which they choose depends on the integrity of the certification process."
> "That integrity is under question. As we reported in this newspaper last Saturday, workers on certified coffee farms in Peru are being paid less than that country's minimum wage, contrary to the requirements of the Fairtrade mark. Industry insiders also claim that non-certified coffee is being passed off as Fairtrade and that certified coffee is being illegally planted in protected rainforests."
> "This is a disappointment but scarcely a surprise. One of the core ideas behind fair trade is to provide rich consumers with a way of passing money to the poor producers who supply them, without resorting to the indignities or uncertainties of charity. That cash has to travel a long way and it should be no shock that some will be lost."
> "Many retailers see organic or fair trade products as a natural choice for premium mark-ups. This is within the rules of fair trade schemes, which offer guarantees to the producer, not the consumer. Yet it is no different from offering customers a discount if they choose more exploitative coffee."
> "Certified ethical products, then, are problematic even when working as promised. Keeping that promise is hard because certification creates a large pay-off to anyone who can subvert the process. It is not clear how widespread violations are, but since coffee supply chains are much simpler than, say, the cotton business, a flaw in coffee certification is hardly reassuring."

resource managers. In most of the cases set out above (local official, distant stockpiler), the crucial facet of the problem is the difficulty of the entrant to claim control over the resources and the lands (as opposed to their rents). If the entrant can be convinced that it is able to capture rents both today and in future, then incentives for investment will be generated. But of course this is equivalent to creating a first-best property rights institution.

So the tragedy of the common as a governance problem lies in leaving resources lying about unmanaged, generating waste, rent-seeking, corruption, and informal property rights regimes. These problems are much broader than the simple waste of the resources concerned.

7 CONCLUSION

Overexploitation occurs in every nation, but there is no state in which every type of resource is overexploited. States that allow wild birds or tropical timber to go unmanaged institute strict regimes of property rights around tea plantations and tin mines. This is because resource overexploitation is simply another way of saying that the resource is not under first-best management, and first-best management will always be a costly objective to target. States deliberately place some resources under more careful management (nearer first-best) and others very far away indeed. These failures to manage resources and lands in a first-best manner are not tragedies but simply a fact of (resource-constrained) life, especially in those states where constraints are most severely binding. The inefficiencies that result are symptomatic of the many suboptimal situations which exist in a state which has many investment (development) opportunities available.

The failure of these commons is a governance failure: a failure to impose first-best management regimes thereby resulting in inefficient levels of investment by local users in the resource, the lands, and especially the management of both. But the real tragedy lies in the opportunities for rent-seeking that result from leaving vacant governance space. Vacated governance space represents opportunities for shadow property rights and rents for local officials, and for distant stockpilers and direct entrants. If these rents come without the authority of the state, then there often are no incentives to invest in the resources from which they derive. More importantly, the vesting of these informal rights and resulting rents can generate broader distortions in the economy that are both wasteful and stable. The waste derives from the corruption and dislocation that derive from rights that exist *de facto* but without the force of law. The vertical tragedies of the commons result from allowing these governance failures – and the rent-seeking opportunities on which they are based – to become embedded within poor societies.

A solution to this sort of problem must commence with the recognition that first-best resource management is not a feasible target for the average state, and that these vacancies in governance space will exist on account of trade-offs involved in economic development. Certain of the resulting failures of the state may be addressed by either devolution (to communities, municipalities, and firms) and certain of the failures of the state may be addressed via substitution (by external or internal governance-supplying

agencies), but it is critical to recognize that there can be no substitution or devolution for certain core functions of the state. The state's core roles – as ultimate authority over its resources and ultimate source of police power – should not be devolved or substituted, to avoid the opening up of broad contests over core governance functions.

In these cases, it is advisable to provide aids to state governance, rather than devolution or substitution. The solution to many commons problems will be the provision of direct aid for the development of the governance systems of those countries that are currently prioritizing carefully in regard to their social investments.

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1 MATHEMATICAL APPENDIX: RE-TELLING THE TALE OF THE COMMONS

1.1 Individual Decision Problem Regarding Investment in the Commons – Equation (1)

$$\underset{y_i,R_i}{\text{Max}} \quad \prod_i^{x,R}(y_i, R_i; x, R) \equiv \int_0^{\infty} e^{-rt}\left[p(y_t)y_{it} - c(x_t)y_{it} - r\rho_R R_{it}\right] dt$$

$$\text{subject to } \dot{x} = H(x_t, R_t) - y_t$$

$$\text{given } x_{t=0}, r, \rho_R \text{ constants}$$

$$H(x, R), c(x) \text{ are continuous, concave and twice differentiable}$$

$$H'(x, R) > 0, \quad c'(x) < 0$$

$$y = \sum_{i=1}^{n} y_i$$

$$R = \sum_{i=1}^{n} R_i$$

$$x = \sum_{i=1}^{n} x_i$$

This version of the commons problem provides that each individual (i) must choose how much land use (R_i) and resource stock (x_i) to keep invested within the common pool (x, R).

1.2 Assuming Open Loop Nash Equilibrium

(a) Open Loop assumptions imply $\mathrm{d}y_i/\mathrm{d}x_t = 0$ as information set at all time $t = \{x_0\}$. (i.e. no feedback).
(b) Nash conjectures imply $\mathrm{d}y_i/\mathrm{d}y_j = 0$, $\mathrm{d}R_i/\mathrm{d}R_j = 0$, $\mathrm{d}x_i/\mathrm{d}x_j = 0$ (i.e. no strategic interaction regarding user choices).

1.3 Formulating the Hamiltonian for (1)

$$H = [p(y)y_i - c(x)y_i - r\rho_R R_i]e^{-rt} + \lambda_i e^{-rt}[H(x) - y]$$

where λ_i is the co-state variable corresponding to the value of a unit of x_i (this is the

value of a unit of stock invested in the common from the perspective of i)

$$\lambda = \sum_i \lambda_i$$

(this is the value of a unit of stock invested in the common from the perspective of all users).

1.4 Using Pontryagin's Maximum Principle to determine conditions for Optimal Path

(1A) $\mathrm{d}H/\mathrm{d}y_i = 0$ *(Static first-order condition on y)*

$$\rightarrow \left[p'(y)\left(\frac{\partial y}{\partial y_i}\right)y_i + p(y) - c(x)\right]e^{-rt} - \lambda_i e^{-rt}\left[\frac{dy}{dy_i}\right] = 0$$

$$\rightarrow [p'(y)y_i + p(y) - c(x)] = \lambda_i \text{ by Nash conjectures and symmetry}$$

$$\rightarrow p\,(y)\left[1 + \frac{p'(y)}{p(y)}\frac{y}{n}\right] - c(x) = \lambda_i \text{ by assumption of symmetry}$$

$$\rightarrow p(y)\left[1 - \frac{1}{\varepsilon_D n}\right] - c(x) = \lambda_i \text{ where } \varepsilon_{\mathrm{D}} \text{ is the elasticity of demand}$$

(1A.1) Complementary slackness implies that the optimal conditions for the level of harvest (y_i) *are*

$$y_{it}^* = 0 \quad \text{if } p(y_t)\left[1 - \frac{1}{\varepsilon_{\mathrm{D}} n}\right] - c(x_t) < \lambda_{it}^*,$$

$$y_{it}^* > 0 \quad \text{if } p(y_t)\left[1 - \frac{1}{\varepsilon_{\mathrm{D}} n}\right] - c(x_t) \geq \lambda_{it}^*.$$

(1A.2) Unrestricted access implies zero profit condition on industry

$$y_t^{OA} : p(y_t) = c(x_t) \rightarrow \lambda_t^* = 0 \quad \text{as } n \rightarrow \infty.$$

Establishing Proposition 11 (combining 1A.1 and 1A.2 above)

$$\begin{aligned} y_i^{OA} :&\ \text{as } n \rightarrow \infty \text{ (assuming unrestricted entry)} \\ &p(y) \rightarrow c(x) \text{ (from 1A.1)} \\ &\therefore\ \lambda_i \rightarrow 0 \text{ (from 1A.2)} \end{aligned}$$

This condition establishes that unrestricted entry drives the resource rent to zero, as entry drives price toward the unit cost of the resource.

(1B) Choice of R_i – Static First-Order Condition (suppressing time subscript)

$$\frac{\partial H}{\partial R_i} = 0$$

$$R_i^* : r\rho_R - \lambda_i[H'(R)] = 0 \text{ (by Nash conjectures in } R_i)$$

$$\rightarrow R_i^* : \frac{\lambda}{n} H'_R = r\rho_R \text{ (by Nash symmetry)}$$

$$\rightarrow R_i^{OA} = 0 \quad \text{as } n \rightarrow \infty \text{ (by assumption of unrestricted entry)}$$

This condition establishes that a unit of land dedicated to use of stock x must generate a flow to cover the cost of that land. The expected return from investments into this land use is the industry average whereas each individual must pay for the land allocated individually. The industry average return goes to zero with unrestricted entry (OA equilibrium).

(1C) Portfolio Balancing Condition

$$\frac{\partial H}{\partial x_{it}} = -(\lambda \dot{e}^{-rt})$$

$$\rightarrow x_i^* : e^{-rt}[-c'(x_t)y_{it} + \lambda_{it}H'(x_t)] = e^{-rt}[r\lambda - \dot{\lambda}]$$

$$\rightarrow x_i^* : -c'(x_t)y_{it} + \lambda_{it}H'(x) = r\lambda - \dot{\lambda}$$

$$\rightarrow x_i^* : \frac{-c'(x_t)}{n} y_t + \frac{\lambda_t H'(x_t)}{n} = r\lambda - \dot{\lambda} \text{ (by Nash symmetry)}$$

$$\rightarrow x_i^* : \frac{-c'(x_t^*)}{n} y_t^* + \frac{\lambda_t H'(x_t^*)}{n} = r\lambda^* \text{ (steady-state)}$$

$$\therefore x_i^{OA} \rightarrow 0 \quad \text{as } n \rightarrow \infty \text{ (unrestricted entry)}$$

This condition establishes that a unit of stock left within the commons generates an averaged return to the individual (the industry return divided by the number within the industry) and hence goes to zero with unrestricted entry.

Conditions (1B) and (1C) demonstrate the results in Proposition 2, viz. the investment of resources into the regime without governance have expected returns that are industry averages, and go to zero if entry is unrestricted.

1.5 Individual Decision Problem Given State Governance Under Property Rights Regime (Solving Problem from Equation (6))

$$\begin{gathered}\underset{y_{it},R_{it},M_{it}}{\text{Max}} \prod_i^{PR}(y_i, R_i, M_i) \equiv \int_0^{\infty} e^{-rt}\big[\{p(y)y_{it} - c(x_{it})\}y_{it}m(M_{it}) - r\rho_R R_{it} \\ - \rho_M M_{it}\big]dt \\ \text{subject to : } \dot{x}_i = H(x_{it}, R_{it}) - y_{it} \\ \text{given } x_{i,t=0}, r, \rho_R, \rho_M \text{ constants} \\ m(M_i), c(x_i), H(x_i, R_i) \text{ are continuous, concave, and twice differentiable} \\ m'(M_i) > 0, \quad c'(x_i) < 0, \quad H'(x_i, R_i) > 0\end{gathered} \tag{2}$$

1.6 Formulating Hamiltonian for (2)

$$H_i = [(p(y)y_i - c(x)y_i)m(M_i) - r\rho_R R_i - \rho_M M_i]e^{-rt} + \lambda_i e^{-rt}[H(x_i) - y_i]$$

where λ_i is the co-state variable corresponding to the value of a unit of x_i (this is the value of a unit of stock invested in the land (R_i) allocated to (i).

2.7 Using Pontryagin's Maximum Principle to determine conditions for Optimal Path:

(2A) $\mathrm{d}H/\mathrm{d}y_i = 0$ *(Static first-order condition on y)*

$$\rightarrow \left[\left(p'(y)\left(\frac{\partial y}{\partial y_i}\right)y_i + p(y) - c(x)\right)m(M_i)\right]e^{-rt} - \lambda_i e^{-rt}\left[\frac{dy}{dy_i}\right] = 0$$

$$\rightarrow [(p'(y)y_i + p(y) - c(x))m(M_i)] = \lambda_i \text{ by Nash conjectures and symmetry}$$

$$\rightarrow \left(p(y)\left[1 + \frac{p'(y)}{p(y)}\frac{y}{n}\right] - c(x)\right)m(M_i) = \lambda_i \text{ by assumption of symmetry}$$

$$\rightarrow \left(p(y)\left[1 - \frac{1}{\varepsilon_{\mathrm{D}} n}\right] - c(x)\right)m(M_i) = \lambda_i \text{ where } \varepsilon_{\mathrm{D}} \text{ is the elasticity of demand}$$

(2A.1) Complementary slackness implies that the optimal conditions for the level of harvest (y_i) are:

$$y_{it}^* = 0 \quad \text{if } (p(y_t)\left[1 - \frac{1}{\varepsilon_{\mathrm{D}} n}\right] - c(x_t))m(M_{it}) < \lambda_{it}^*,$$

$$y_{it}^* > 0 \quad \text{if } (p(y_t)\left[1 - \frac{1}{\varepsilon_{\mathrm{D}} n}\right] - c(x_t))m(M_{it}) \geq \lambda_{it}^*.$$

(2B.1) Choice of R_i – Static first-order condition

$$\frac{\partial H}{\partial R_i} = 0,$$

$$R_i^* : r\rho_R - \lambda_i[H'(R)] = 0 \text{ (by Nash conjectures in } R_i),$$

$$\rightarrow R_i^{PR} : \lambda_i^* H'_R = r\rho_R,$$

$$\rightarrow R_i^{PR} > 0 \text{ so long as } \lambda_i^* H'_R > r\rho_R \text{ for some } R.$$

(2B.2) Choice of M_i – Static first-order condition

$$\frac{\partial H_i}{\partial M_i} = 0,$$

$$\rightarrow M_i^* : \{p(y) - c(x_i)\} y_i \, m'(M_i) = \rho_M,$$

$$\rightarrow M_i^* : \left\{\frac{\lambda_i}{m_i}\right\} y_i m'(M_i) = \rho_M \text{ (assuming a competive market for } y),$$

$$\rightarrow M_i^{PR} : \frac{m'_i(M_i)\lambda_i^* y_i}{m_i(M_i)} = \rho_M.$$

(2C) Portfolio Balancing Condition

$$\frac{\partial H}{\partial x_{it}} = -(\lambda \dot{e}^{-rt})$$

$$\rightarrow x_i^* : e^{-rt}[-c'(x_{it})y_{it} + \lambda_{it} H'(x_{it})] = e^{-rt}[r\lambda_\iota - \dot{\lambda}_i]$$

$$\rightarrow x_i^* : -c'(x_i)y_i^* + \lambda_i^* H'(x_i) = r\lambda_i^* \text{ (steady-state)}$$

$$\rightarrow x_i^{PR} : \frac{-c'(x_i)y_i}{\lambda_i^*} + H'(x_i) = r$$