Banking on Extinction: Ivory Storage and Elephant Conservation*

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1. Introduction

Ivory poachers threaten with extinction the half million elephants roaming the African range states (Said et al., 1995). High prices in international black markets tempt poachers to risk their lives harvesting ivory, despite or because of international agreements banning such sales.[1] In response, Kremer and Morcom (2000) offer a novel solution to reduce the risk of extinction—a local government can stockpile ivory and threaten to dump it on the market if the elephant population falls too low (also see Brown and Layton, 2001, on illegal sales of black rhino horns). This time consistent stockpiling policy works by lowering the expected returns from illegal ivory sales, thereby driving otherwise fearless poachers out of the business.[2]

Herein we explore the downside to this storage policy. We show that ivory stockpiling is detrimental to elephant conservation if sufficiently large stocks trigger strategic extinction by African governments. Three realities of ivory storage and trade increase the odds that strategic extinction could occur. First, most African elephants inhabit a few nations, which opens the door for collusion between governments trying to maximize joint interests.[3] Second, while "avoiding extinction at low cost" is a reasonable goal of the broader international community, the preferences in poverty-struck

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[1] Wildlife policy in some nations empowers wildlife agents to shoot poachers on sight.

[2] Ivory storage matters in international negotiations. Large quantities of ivory have been stored in the past for speculative reasons, at considerable cost (Milliken, 2000). Negotiators at COP 10 (Conference of the Parties) of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), decided to lower these costs by allowing for buy-outs by non-commercial donors. The *North* donors can now buy ivory from the *South* to reduce their financial and security liabilities associated with stockpiles, and to generate funds for elephant conservation purposes. But these buy-outs were conditional on "*none of the [thus traded] ivory could be re-sold in any form at any time in the future*" (Milliken 2000). No buy-outs have yet transpired under this mechanism, and the issue of costly ivory storage arose again at COP 11.

[3] We consider perfect collusion as a convenient benchmark. Alternative specifications may be more apt, including "cartel & fringe models." If African range states behave non-cooperatively, externalities in conservation and exploitation emerge when decisions to lift the trade ban are based on the sum of elephant stocks across countries. If one government pursues a path of extinction, it becomes more costly for the other governments to allow their populations to grow to equal the common threshold. This would likely

African range states might be less lofty. Pressing problems like securing potable water and reducing AIDS can force a nation to worry more about the discounted value of monetary revenues than about the survival of a species considered by many locals as pests.[4] Third, all international sales of ivory, private and public, were banned in 1989 by CITES.[5] Nations should expect the trade ban to be lifted either (i) at a *future date* when the *in situ* elephant population becomes sufficiently abundant, reaching a certain threshold value set in the international arena;[6] or (ii) *immediately* if extinction occurs. Though not guaranteed, the international community might dispense with a costly trade barrier when it serves no purpose.[7]

Governments compare the expected returns from two rules—a conservation and an extinction strategy. The *conservation strategy* means that African nations invest in anti-poaching enforcement and store any confiscated ivory or ivory from culled problem animals. The *extinction strategy* implies the nations forego enforcement and could even promote hunting the species to extinction. Using realistic parameters, our results suggest that conditions exist in which African nations prefer the extinction strategy. With extinction, African nations switch to a Hotelling depletion path for their stockpiled ivory. The extinction interval is shorter than the period it takes for the elephant population to recover to the threshold level, causing the discounted value of the extinction strategy to

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increase the probability of extinction in the other countries as well.

[4] This perspective is consistent with that of Anderson (1992: 42) who writes that conservationists in the North "have been prepared to insist on a ban on raw ivory trade in large part because they have not been required to compensate the losers."

[5] CITES is the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Governments can dump commodities on domestic markets, depressing local prices, but this will not scare off poachers illegally catering to international black markets.

[6] Conservationists argue that a strong link exists between legal sales of ivory and poaching. Legal trade abets the laundering of illegal ivory, lowering transaction costs and stimulating poaching. The alleged link between legal and illegal harvesting is a key reason why the trade ban is in place and makes it difficult to predict when the ban will be lifted.

exceed that of the conservation strategy. This result suggests an alternative strategy to enhance the viability of elephant stocks in Africa—international conservation organizations rather than governments should hold the stockpiles.

2. A Model of Strategic Conservation and Extinction

Assume a government has a store of ivory, *s*, and can increase this store by directly influencing harvesting activities, *h*, associated with elephant stocks, *x*. We simplify the interaction between government and poachers by presuming the government can control poachers at a cost. This allows us to focus on government decision-making as constrained by the exogenously imposed trade ban. Harvests are divided into immediate sales, *q*, and stores, *v*, i.e., $h = q + v$. Due to international agreements, however, ivory cannot be sold until the stock of elephants is deemed safe at a level x^* (then, in CITES terminology, the species is downgraded from Appendix I to Appendix II). Thus, ivory sales, denoted $z = y + q$, where *y* denotes sales from stores, can occur as long as $x \geq x^*$.[8] Assuming no depreciation, ivory stores evolve according to

$$(1) \qquad \dot{s} = \begin{matrix} v & if & x \leq x^* \\ v - y & if & x \geq x^* \end{matrix}.$$

Assume the initial stock of elephants, x_0, is such that ivory sales are not allowed initially, i.e., $x_0 \leq x^*$. When and if sales do occur, revenues from these sales are defined by $p(z)z$, where $p(z)$ is the downward sloping demand for ivory, $p'<0$, where primes denote the relevant derivative.

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[7] Commercial trade in ivory from mammoths is perfectly legal, for example, albeit subject to import certificates.

[8] It may be more accurate to model the trade ban in a probabilistic sense. For example, in times with the trade ban in effect, the ban may be lifted according to the stock dependent probability $\alpha(x)$, and in times with the trade ban lifted, the ban may be reintroduced according to the stock dependent probability $\eta(x)$.

The elephant population grows over time according to the equation of motion

(2) $\dot{x} = g(x) - h$,

where $g(x)$ represents elephant reproduction. Assume $g'' < 0$, and $g(0) = g(X) = 0$, where X is the carrying capacity of elephants in the environment. Harvesting costs are denoted by the well-behaved cost function $c(h,x)$, where $c_h > 0$; $c_x \leq 0$; c_{hh}, $c_{xx} \geq 0$; $c_{hx} \leq 0$, where subscripts denote relevant partial derivatives.

Without trade, net benefits during a trade ban are the sum of stock related benefits and damages, possibly minus harvesting costs,

(3) $NB(t) = F(x) - c(h,x)$,

where $F(x)$ measures the sum of wildlife–related tourism benefits, $R(x)$, agricultural damages and other nuisance effects, $D(x)$, and anti-poaching enforcement, $E(x)$. Assume $F(x)$ can have positive and negative values. This structure implies the government is not simply self-serving, it also accounts the benefits and costs affecting its constituents, as manifested by F.[9] With trade, net benefits now include the demand for ivory, and are defined by[10]

(4) $NB(t) = p(z)z + F(x) - c(h,x)$.

The government considers two strategies to maximize the present value of net benefits over time. First, the *conservation strategy* is defined as when stock, and possibly stores, are allowed to grow until x^* is reached and sales can occur legally. Second, the *extinction strategy* is defined as a purposeful extinction of the stock, with a corresponding

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Such a rational expectations model would complicate the analysis without affecting the primary results.

[9] We explore the case of a self-serving government, $F=0$, in the numerical analysis below.

[10] We consider revenues and not consumer surplus since ivory consumers are mainly outside of the range states. Likewise, we do not consider non-use (existence) values as these are mostly external as well.

increase in stores, triggering an immediate lifting of the trade ban.[11] We now consider when the government will choose the extinction strategy over the conservation strategy. We do so by comparing the present value of net benefits under both strategies. If extinction is rapid, relative to restoration of the population to safe levels, an impatient government may prefer the returns of a finite depletion path—strategic extinction, to the returns of an infinite sustainable culling scenario that starts at a later date—strategic conservation.

First, consider the conservation strategy. Here the elephant stock always remains larger than *x** after some time *T*, which is chosen endogenously.[12] Ivory sales are always legal after *T*. Ignoring illegal ivory sales, the government's problem is

(5)

$$\underset{\text{v,q,y,T}}{Max}\ NPV = \int_0^T [F(x) - c(v,x)]e^{-rt}dt + e^{-rT}\int_T^\infty [p(y+q)(y+q) + F(x) - c(v+q,x)]e^{-rt}dt$$

$$\text{s.t. } (1),(2),x_0,s_0$$

Now define the extinction strategy. This strategy presumes the stock never grows past *x**.[13] The optimal extinction scenario is defined by the solution to the problem

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[11] Alternatively, the government may choose to refrain from antipoaching enforcement, $E(x)=0$, allowing poachers to wipe out the species. Although the distributional consequences are obviously different, the economic intuition is unaffected.

[12] Under the conservation option in which extinction never occurs, there is no reason to temporarily deplete the stock once $x>x^*$ as there are no fixed flow costs in the model. Otherwise, so-called "pulse harvesting" may be optimal (see Clark 1990).

[13] An alternative extinction strategy is that the stock temporarily exceeds x^* and is optimally depleted thereafter. This plan may be optimal if the stock related benefits and costs are sufficiently small (i.e., if $F(x)$ is close to zero) and the discount rate r is sufficiently large. Because of the discontinuities involved with the threshold stock, x^*, the problem for each extinction option is formulated differently. We therefore focus on the first plan. If this second strategy were in fact optimal, the benefits of an extinction strategy would be even greater than what we indicate here. The set of initial elephant stock and ivory store levels for which extinction is optimal relative to conservation would likely be increased if this second plan was considered. For the simplest conceptualization, we would have to choose the optimal time at which $x>x^*$ so that the ban is temporarily lifted, and also the optimal time at which x again falls below x^* on its way towards extinction. The problem is more complex if we allow for additional 'cycles' in which the trade ban is lifted temporarily. Extinction is more likely to be optimal if s_0 is sufficiently small. In this case, there may be gains from allowing the elephant stock to increase in order to increase ivory stores.

$$(6) \qquad \underset{v,y,T_1,T_2}{Max} \quad NPV = \int_0^{T_1} [F(x) - c(v,x)]e^{-rt}dt + e^{-rT_1}\int_{T_1}^{T_2} [p(y)y]e^{-rt}dt$$

$$\text{s..t. } (1),(2),\ x_0, s_0$$

where T_1 is the time at which extinction occurs, and T_2 is the time at which stores are depleted. We now compare the returns from these two strategies with a numerical example.

3. Numerical results

We compare extinction and conservation strategies for the African elephant (*Loxodonta Africana*). Our parameters are derived from existing estimates of biological growth, and the economic characteristics of ivory harvesting costs and international demand (see Milner-Gulland et al. 1992; Bulte and van Kooten 1999). First, consider the biological growth and stock parameters. Recent estimates suggest that about 550,000 elephants exist in Africa (Said et al. 1995). Elephant population growth is given by the logistic function $g(x) = 0.067x(1-x/3{,}000{,}000)$. African governments have been storing ivory for a number of years. A recent report indicates 460 tons of ivory have been declared, and it is believed that another 350 tons remain undeclared (Milliken 1997). We therefore presume that 700 tons of ivory is stored in Africa. Assuming 10kgs of ivory per elephant, this translates into 70,000 elephants. The initial store of ivory, measured in elephants, is s_0= 70,000.

Next, consider the economic parameters. Assume the government can convert living elephants into *ex situ* ivory at a maximum pace of 200,000 elephants per year.[14] This maximum harvest level is only slightly greater than actual harvesting in the 1980s,

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[14] Note that, when harvesting is not allowed, the Hamiltonian is linear in the control variables, hence a most rapid approach path to either extinction or the threshold level must be optimal.

even though illegal poachers were the main harvesters, e.g., some 120,000 elephants were harvested in 1986, of which about 80% were illegal. We use the functional specifications derived in Bulte and van Kooten (1999): tourism value: $R(x) = 2.6\times10^6 \ln(x)$; crop and people damages: $D(x) = 165x$; ivory demand: $P(z) = 6{,}397–0.044z$; harvesting costs: $c(h,x) = 692{,}300h/x$.

Assume the trade ban will be lifted under two conditions: (a) after the elephant population exceeds x^*=1.2 million, or the elephant population in 1980 (Barbier et al. 1990);[15] and (b) if extinction occurs. With extinction, we assume the international community delays lifting the ban until it verifies that the last elephant has been killed. We assume a delay of five years, implying the total delay faced by range states in resuming trade under the extinction strategy is T_1+5. Our choice to include this delay assumption biases the numerical estimate in favor of conservation.[16] Finally, we bias our numerical estimate further towards conservation by setting to zero both the (i) costs to store and guard ivory (see Milliken 2000), and (ii) the costs of anti-poaching efforts.

Consider now our main result. Column 4 in Table 1 shows that that the net present value of the extinction strategy exceeds that for the conservation strategy, given a range of discount rates. Stockpiling ivory creates an incentive for governments to follow the strategic extinction path for two reasons. First, it is faster to kill than to nurture elephants—it takes eleven more years to grow the stock to x^* under the conservation strategy relative to the time required to eliminate elephants under the extinction strategy. Second, the economic benefits of large elephant stocks are on-net negative in our model: while more elephants lead to more tourism benefits, they also cause more damage to

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[15] We will also consider less stringent conservation policies.

[16] Delay can also occur under a conservation strategy to verify that x^* has been reached, but we do not

crops and people in the range states. Tourism benefits dominate only at small stock levels that arise en route to extinction, whereas the damages take charge at the large stock levels that arise under the conservation plan (Bulte and van Kooten 1999).[17]

Next we consider how four changes in the underlying conditions affect the robustness of the strategic extinction result (Table 2). First, since it is faster to kill than to rear an elephant, we make the conservation strategy more attractive by reducing the required time to replenish the stock. Specifically, we reduce the threshold stock level by 40 percent, $x^* = 750{,}000$. Table 2 shows, however, that the extinction strategy still dominates, even though the length of time needed to reach x^* is reduced by nearly sixty percent, to 7 years from 17 years.

Second, we make large elephant stocks more attractive by presuming the government is completely self-serving. It cares only about its ivory revenue, and nothing about tourist benefits or local damages, i.e., $F(x)=0$. Again Table 2 shows that the extinction strategy dominates at the ten percent discount rate. But note the differences in net benefits are smaller than before, and can actually favor conservation at lower discount rates. A five percent discount rate, for instance, reverses the result—now the net present value of conservation exceeds extinction by about $700 million. A more patient government that ignores stock effects might prefer the conservation strategy. The open question is how likely this low-discount rate scenario reflects government actions within the range states given their levels of poverty and capital scarcity. Many experts in

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model this explicitly.

[17] Recall we have excluded the costs of protection; adding these costs, however, would only reinforce the main results because poaching would only prolong the replenishment interval and enforcement costs further depressing the net present value of conservation.

development/resource economics would find this presumption as unrealistic (see for example Pearce and Warford, 1993; Holdren et al., 1998).[18]

Third, would conservation be more attractive if ivory stores started at ground zero, i.e., $s_0 = 0$? Table 2 suggests the answer is no. While the benefits under both strategies are lower, they are only moderately so. Apparently, the contribution of past ivory stockpiling to future profits is modest, swamped by benefits of ivory stockpiling during the extinction phase.

Finally, we explore the effects of ivory stockpiling further by presuming that stocks cannot be increased during the extinction phase. This captures the scenario in which the government, trying to avoid the international political heat of an explicit extinction policy, lets poachers do the work for them. Here the government announces a "no enforcement" policy, which then triggers an inflow of rational poachers who kill off the elephants for private profit (see Burton,1999). Poachers now kill and trade the elephants, rather than the government, i.e., $s_{T1} = s_0$. Because the *ex situ* stock of ivory does not grow during the extinction phase, the profits of successive sales will be substantially reduced, whereas the net revenues from the conservation strategy are the same. Table 2 shows, however, that the net value of the extinction strategy still exceeds that of the conservation strategy by $732 million.

We see that our main result holds up to changes in the underlying conditions—ivory storage by African range states enhances the relative profitability and probability of

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[18] Also see Poulos and Whittington's (1999) contingent valuation survey of individual time preferences in six less developed nations including the African nations of Uganda, Mozambique, and Ethiopia. Their results suggest the respondents attached much less value to lives saved in the future than to lives saved today. Few people in their study attached any value to saving lives ten years in the future. For instance, the median discount rate for Ethiopia was 49 percent for 2 years; 39 percent for 5 years; and 28 percent for 10 years. Also, the median Ethiopian respondent said saving seven lives in five years was equivalent to

an extinction strategy. We now ask what conditions would have to exist to reverse this result? We consider alternative parameters to determine what conditions would have to exist, and considered whether they seem reasonable. First, we find that there is no market price for ivory, either large or small, that causes the conservation strategy to dominate the extinction strategy. Second, we do find that conservation dominates if the coefficient for tourism benefits increases nearly six fold, to at least \$14.4 million from \$2.6 million, such that $R(x) = \$14.4\times10^6 \ln(x)$. Finally, we find that conservation dominates if the coefficient for damages is decreased nearly eight fold, to \$23 from \$165, such that $D(x) = 23x$. Given the data currently available, it is our best judgment that these alternative specifications for $R(x)$ and $D(x)$ are unrealistic.

Here is why. For tourism benefits, the threshold value for the coefficient in which conservation becomes profitable is b_T = \$14.4 million. But consider how this compares to an upper bound estimate of the net gain from elephant tourism within the range nations. We start by noting that the net gain to Kenya of wildlife tourism is estimated to be about \$45 million in 1995 (Earnshaw and Emerton, 2000). Now assume Kenya attracts about 15 percent of the wildlife receipts earned in Africa, and that the relation between receipts and net benefits is equal across the board in different countries. Then, total wildlife benefits in all of Africa equal 6.67 times \$45 million = \$300 million. Let us optimistically assign half of the wildlife benefits to elephants and elephants alone—and divide the other half amongst popular species like lions, rhinos, leopards, buffalos, gazelle, African dog, ostrich, and so on. In this case, tourism benefits from elephants equals, $R(x)$ = \$150 million. But given b_T = \$14.4 million, one would predict that the

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saving one life today, as compared to the median US respondent who said that saving two lives in five years was equivalent to saving one life today (see Cropper et al., 1994).

benefits of elephant tourism alone amount to no less than \$190 million [$R(x)$ = \$14.4 million * ln(500,000 elephants)]. This suggests that the pro-conservation threshold value overestimates our upper bound benefit estimate by \$40 million annually (\$190 million vs. \$150 million).[19] While recognizing this is a rough benchmark based on the best available data, overestimating benefits by nearly 25 percent causes us to suspect that the pro-conservation threshold value, b_T, is too high.

4. Discussion

Kremer and Morcom (2000) used ivory stockpiling to merge the theories of renewable and nonrenewable resources, a valuable contribution to our understanding of the efficiency of natural resource policy. They revealed how a policy of stockpiling and dumping could be used to reduce the risks to species threatened by poachers. But for their strategy to work, African range states should stockpile large quantities of ivory. Recall that range states have accumulated about 700 tons of ivory in stores, the 1989 equivalent. Holding other supplies and demand constant, dumping all stockpiled ivory on today's markets would imply an 1989 price level of about \$300 kg^{-1}. Unfortunately, even without the CITES ivory trade ban, this price is unlikely to be sufficiently low to drive out poachers, as one can illustrate using data on poaching revenues, production and costs from Milner-Gulland and Leader-Williams (1992). Prices must be much lower to discourage entry under open access. We fear current stores are insufficient to push the price low enough to force the exit of poachers.

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[19] Alternatively, one can solve for the coefficient in $R(x) = b\,{*}\ln(x)$ as b = \$150 million/ln(500,000) = \$11.43 million, which is 4.4 times larger than our current value of b = \$2.6 million, and is based on the courageous presumption that elephants generate 50 percent of all wildlife benefits.

But we contend that the price is certainly large enough to make it profitable for governments to deplete *in situ* stocks—facilitating legal sales out of *ex situ* stocks. We have shown for a wide range of plausible scenarios that this strategic depletion could be profitable relative to a conservation strategy. Stockpiling *ex situ* resources may enhance depletion of *in situ* stocks if trade in the *ex situ* stock is restricted due to considerations pertaining to the *in situ* stock, which is true for most species protected by CITES.

In this light, we offer an alternative set of policy measures to enhance the viability of elephant stocks in Africa. First, set the threshold population that allows switching to legal trade (i.e., lifting of the ban) at a relatively low level. Low threshold levels reduce the time during which range states only bear the costs of conservation, thereby increasing the relative profitability of conservation. Tough conservation measures—high threshold values—are counterproductive for conservation.

Second, encourage non-commercial donor buy-outs. The international community could invest in purchasing ivory from range states, both for fairness and for efficiency. Buying stockpiled ivory contributes to conservation, which promotes global welfare since it undermines the profits of the extinction strategy. Similarly, restricted and controlled commercial trade under certain conditions should be encouraged. Recent experiences with non-commercial buy-outs have been disappointing, but COP 11's resumption of restricted trade is encouraging. A conservation-motivated international community could agree to buy all existing stocks and to promise to lift the trade ban should the extant population exceed the relatively modest objective of 600,000 elephants. The international community would have to design an incentive-compatible and individually rational ivory contract for the governments of the range states, such that the contract such that the nations are just as well off or better off relative to their next best alternative—which is the strategic extinction option. Good intentions backed with cash and incentives could better serve to protect treasured species at risk.

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Table 1: Numerical results of the extinction and conservation strategies to elephant management

						Difference in NPV
Discount Rate		Extinction Strategy		Conservation Strategy		(Extinction– Conservation)
(r)	T_1	T_2	NPV ($\times\$10^6$)	T	NPV ($\times\$10^6$)	ΔNPV ($\times\$10^6$)
0.05	6	34	1,215.2	17	-668.0	1,883.2
0.1	6	29	500.0	17	-670.3	1,170.3
0.15	6	27	210.4	17	-543.7	754.1

Table 2: Alternative scenarios (r=0.1): NPV of extinction and conservation strategies

						Difference in NPV
		Extinction Strategy		Conservation Strategy		(Extinction– Conservation)
Scenario	T_1	T_2	NPV ($\times\$10^6$)	T	NPV ($\times\$10^6$)	ΔNPV ($\times\$10^6$)
x^*=750,000	6	29	500.0	**7**	235.4	264.6
$F(x) = 0$	6	29	546.3	17	472.5	73.8
s_0=0	6	28	471.6	17	-685.1	1,156.7
No enforcement	6	16	61.9	17	-670.3	732.2