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Downward sloping demand for environmental amenities and international compensation: elephant conservation and strategic culling

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Abstract

Conventional wisdom holds that monetary compensation for positive transboundary externalities will promote conservation of resource amenities. We demonstrate that, in the case of elephant conservation, international transfers may also result in strategic behavior by host countries, with adverse implications for global welfare and in situ stocks. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

The economic rationale for preserving environmental amenities and conserving natural resources is often partially, though certainly not always exclusively, based on non-use values. Conservation of wildlife resources in developing countries is likely to involve positive externalities, with non-use values accruing to people in different countries, usually developed ones. Transboundary non-use values (e.g., for preservation of wildlife) for which the “host” country is not fully compensated may lead to sub-optimal provision from a global perspective, as pointed out by Barbier and Swanson (1990) in the context of elephant management. It is often argued that compensating for positive externalities is in the interest of nature conservation,

and should be pursued through international conventions and agreements. It is well documented that the mismatched timing between transfers and conservation investments by the range states may result in renegeing and agreements that are not renegotiating proof. In this paper, we focus on another, less well-known effect of providing transfers. We demonstrate that the alleged positive effects of international transfers may never materialize because transfers may provoke strategic behavior by the host country, resulting in loss of welfare for the international community and excessive depletion of the resource. This is demonstrated for the case of African elephants.

2. Downward sloping demand for environmental amenities

Empirical work on non-use values has largely ignored declining marginal preservation value. Loomis

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and White (1996) and Bulte and van Kooten (1999a) have recently summarized empirical contingent valuation work, concluding that the bulk of research is directed at willingness to pay (WTP) to avoid species extinction. For example, the overview by Bulte and van Kooten indicates that, out of a sample of 30 recent CVM studies, not less than 24 were aimed at measuring WTP for a 100% change in population. (While some studies aimed to establish estimates for the WTP to double the current population, the majority focused on the possibility of extinction.) However, the limited empirical work that has tried to measure downward sloping demand for environmental amenities and resources indicates that the demand for “nature” is indeed subject to diminishing returns (Tanguay et al., 1993; Loomis and Larson, 1994; Montgomery et al., 1994; Brown et al., 1994).

The implications of downward sloping demand for environmental amenities (or, declining marginal preservation value) on optimal stocks has been analyzed by Bulte and van Kooten (1999a) for the case of minke whales in the northeast Atlantic. Not surprisingly, they conclude that optimal whale stocks are highly sensitive to assumptions concerning marginal WTP (MWTP) for preservation of whales. Both strict conservation and extinction can be justified for the same total preservation value (the area under the MWTP or demand function), just by varying the “slope” of the (linear) demand function. Their results also confirm the conventional wisdom that, irrespective of the specification of marginal preservation value, internalizing (positive) external effects is in the interest of nature conservation.

An alternative reason for providing international transfers, especially relevant for the case of elephant conservation analyzed below, is the following. Anderson (1992) argues that people in developed countries were willing to adopt the 1989 trade ban in ivory primarily because they did not have to compensate African countries for the economic losses they would incur (see also Milliken, 2000). Upon comparing optimal stocks of elephants in Zambia with and without a trade ban on ivory, Bulte and van Kooten (1999b) found that, for most discount rates, elephant stocks are greater with the trade ban than without it. However, protecting elephants cost some \$75–700 per

additional elephant, again depending on the discount rate. For the higher rates of interest characteristic of developing countries, the trade ban can protect elephants at the (relatively modest) cost of about \$120 per elephant. As Anderson (1992) argues, preferences for elephant conservation may be especially strong in developed countries, so it seems “fair” that they should compensate Zambia.

The standard result that internalizing positive externalities promotes conservation of nature depends critically on the (unrealistic) assumption that an international governing body exists to ensure a cooperative solution, or that national governments can somehow be tempted to agree to the global optimum (e.g., Sandler, 1997). We do not review cooperative solutions, but, rather, discuss the use of compensation payments for conservation of wildlife. Specifically, we study the role of international transfers to African range states that are an increasing function of the protected elephant population, as advocated by, e.g., Schulz and Skonhoft (1996) and Skonhoft and Solstad (1998). The latter authors, studying pastoralist decision making when wildlife and livestock compete for forage, write “...an international payment for conservation linked to the stock of wildlife will give [...] incentives to increase the wildlife stock and therefore bring the market solution more in accordance to what is socially optimal” (Skonhoft and Solstad, 1998, p. 256). However, we show that international transfers that aim to internalize external effects of conservation may not contribute to wildlife conservation. Indeed, the opposite effect may occur. To show this, we extend an existing model of elephant management by Bulte and van Kooten (1996) to include international payments by developed countries to protect elephants, demonstrating that selfish range states can sometimes improve their welfare by choosing an excessive depletion strategy.

3. Wildlife management and compensation for elephant protection

Assume that the international community derives utility $U(x)$ from elephant conservation, but chooses not to compensate the host country for this externality. To focus the model and discussion we will ignore the problems associated with poaching

ivory (but see Millner-Gulland and Leader-Williams, 1992; Leader-Williams et al., 1990; Bulte and van Kooten, 1999b). The model also simplifies reality by overlooking the possibility to store ivory. While this assumption does not affect the steady state results reported below, it does affect the transitional paths towards equilibria (see Kremer and Morcom, 2000). The management problem for African countries can then be represented by

$$\text{Max} \int_0^{\infty} [R(x) + py - D(x)]e^{-rt} dt \quad (1)$$

subject to

$$\frac{dx}{dt} = \dot{x} = G(x) - y. \quad (2)$$

In the objective function (1), x is the stock of elephants, $R(x)$ the recreation benefits, y the harvest level (i.e., the first two arguments in the objective function represent use values), p the price of ivory on a per elephant basis, $D(x)$ the agricultural benefits foregone as a result of elephant conservation, and r the social discount rate. Non-use values are assumed to exist, but accrue to people in different countries who choose to free ride. Since no compensation for these non-use values is provided they are ignored by range states. In the equation of motion (2), $G(x)$ is the growth function.

The associated current value Hamiltonian is $H = R(x) + py - D(x) + \lambda[G(x) - y]$, where λ is the co-state multiplier measuring the shadow price of the stock at the margin. Assuming an interior solution and that a steady state exists, the maximum principle yields the following well-known equations to describe the steady state (see Clark, 1990)

$$r = G'(x^*) + \frac{R'(x^*) - D'(x^*)}{p}, \quad (3)$$

$$G(x^*) = y^* \quad (4)$$

where $*$ indicates an optimum solution in the case of no compensation for the non-use benefits that accrue to foreigners. From (3), the optimal stock of elephants results when the social discount rate equals the growth rate plus the marginal rate of substitution between leaving an elephant in situ and harvesting it today. Given the standard assumption that $G''(x) < 0$, it follows from (4) that increasing marginal recreation

benefits, $R'(x)$, raises the optimal stock x^* unambiguously, with an increase in $D'(x)$ having the opposite effect. From (4) it also follows that, in the steady state, harvest should equal net growth. This model is readily solved when $G(x)$, $R(x)$ and $D(x)$ are specified, which is done in the next section.

Extending the model by Bulte and van Kooten (1996), assume that the international community ceases to free ride, so that range states no longer bear the burden of protecting elephants alone. Define $\phi(x, z) = U(x) + V(z)$ as the additively separable utility function of the international community, where z is consumption of other goods. Assume that marginal preservation value is declining in stock size (i.e., $U'(x) > 0$, $U''(x) < 0$), and that donor countries pay compensation based on the marginal value of elephants preserved, and not according to the cost of protecting them (as noted above). It is easy to show that this form of compensation unambiguously increases optimal stock size. The reason is that there would now be an extra term, $U'(x)$, in the numerator of the stock term in Eq. (3), which, due to the concavity of the growth function, implies that optimal stocks should go up (since $U'(x) > 0$).

A different solution results if African countries are able to collude in order to maximize the overall transfer payments they receive as compensation for transboundary non-use values. With marginal preservation value declining in stock size, the compensation received per elephant is subject to the discretionary choices of range states with respect to harvesting. Thus, African countries could potentially (and, if possible, should) act as a monopolist, raising the price by restricting supply. (The limitations of monopoly behavior are discussed later in the paper.) The difference with conventional models is that the monopolist does not receive a price for a *flow*, but rather for the *stock* it preserves.

In this case, the objective function for the African range states becomes

$$\text{Max} \int_0^{\infty} [R(x) + py + T(x)x - D(x)]e^{-rt} dt \quad (5)$$

where T represents the transfer received per elephant, with $T(x) = U'(x)$. Consistent with economic intuition we assume $U''(x) = T'(x) < 0$. Maximizing (5) subject to (2) gives the associated current value Hamiltonian, $H = R(x) + py + T(x)x - D(x) + \lambda[G(x) - y]$.

Again, assuming a steady state, this problem is readily solved for the following steady state equations:

$$r = G'(x^{**}) + \frac{R'(x^{**}) + T'(x^{**})x^{**} + T(x^{**}) - D'(x^{**})}{p} \quad (6)$$

$$G(x^{**}) = y^{**} \quad (7)$$

where $**$ indicates an optimum solution for this case. Since $G(x)$ is concave, the optimal stock increases when the stock term on the RHS of (6) goes up. Obviously, $T(x^{**}) > 0$, and thus this term contributes to conservation. This can be termed the *conservation motive* of international transfers. On the other hand, by assumption, $T'(x^{**}) < 0$ (hence also $T'(x^{**})x^{**} < 0$). This is what we call the *depletion motive*. Hence, the stock term of (6) is greater than the stock term of Eq. (3) when $T(x^{**}) > T'(x^{**})x^{**}$, and smaller when the reverse is true. In that case, international compensation for a positive externality reduces African elephant stocks. We now solve both models for various assumptions about preservation value at the margin.

4. Empirical results

Precise data on non-use values are lacking, so it is not possible to rigorously assess optimal elephant stocks. Nevertheless, it is certainly possible to “ballpark” the analysis and to demonstrate the possible effect of strategic culling outlined above in a numerical analysis. The African elephant (*Loxodonta africana*) consists of two sub-species that occupy the forests of west and central Africa (*Loxodonta africana africana*) and the open range (savannah) of east and southern Africa (*Loxodonta africana cyclotis*). Due to their genetic differences, both warrant independent conservation status (Said et al., 1995). The savannah elephant is better known than the forest elephant, probably because they are easier to view and a larger sub-species. The west African elephant tends to be a bit smaller and lives in thick bush. This not only makes it difficult to view, but also to inventory. Thus, Said et al. (1995) estimate that there exist about 82 000 elephants in Gabon, but this is a probable and possible estimate (their terminology), not a definitive

Table 1

The savanna elephant of east and southern Africa, population estimates^a

Country/region	Estimated population
Kenya	25000
Tanzania	98000
East Africa	127000
Zimbabwe	81500
Botswana	80000
Zambia	32500
Namibia	11500
South Africa	10000
Southern Africa	218000

^a Includes “definite”, “probable” and “possible” categories of estimates, but not “speculative”. Source: adapted from Said et al. (1995, pp. 17–19).

estimate. In comparison, Said et al. are definite that there are approximately 13 000 elephants in Kenya. Hence, we focus on the savannah elephant of which there are some 345 000 (see Table 1).

We employ the following estimates of $D(x)$ and $R(x)$ from Bulte and van Kooten (1996, 1999b): $R(x) = \beta \ln(x)$, where $\beta = 42.27$ million; and $D(x) = 165x$ Millner-Gulland and Leader-Williams (1992) indicate that the intrinsic growth rate of elephants is 0.067. Assuming a carrying capacity for the savanna elephants that is double extant numbers and a logistics growth function, $G(x) = 0.067x(1 - x/690\,000)$. Our research indicates that raw ivory prices have fallen from about \$300/kg in the early 1980s to perhaps as low as \$25/kg in the mid 1990s. While the ivory trade ban may have contributed to the price decline, it also forced more ivory into the black market, making it difficult to determine prices. Average tusk size has also decreased over the past several decades from about 6 to 5 kg. By assuming a price of \$100/kg and average tusk size of 5 kg, the price of an elephant is \$1000.

As mentioned above, information about the non-use values of elephant management is lacking. Indeed, there are only a few studies aimed at estimating non-use values for large mammals, but these have focused mostly on whales. We heroically assume that WTP to protect gray whales is roughly comparable to non-use values for elephants. Given that WTP for whales is about \$20 per household (Loomis and Larson, 1994), but that the forest and savanna elephants are near perfect substitutes (as is the Asian

elephant, *Elephas maximus*), we assume household WTP is \$10 annually. Given that there are about 200 million households in the richer, developed countries, this implies that the total annual WTP to preserve savanna elephants is \$2 billion. The accuracy of these assumptions will affect our numerical results (in an unknown direction), but we are less interested in the absolute magnitude of the results than in the qualitative ones.

We assume a linear, downward sloping MWTP curve, $U'(x) = a - bx$. Let $A = \$2$ billion be the area under $U'(x)$. Then $U'(x) = a - (a^2/2A)x$. We analyze the impact of various assumptions about MWTP value by varying a , or the non-use value of the first elephant.

First we solve the no-compensation case and then the case where range states do not behave strategically. The results of the no-compensation case do not depend on the specification of $U'(x) = T(x)$ and are reported in the first row of Table 2 for various discount rates between 0% (no discounting) and 18% (a high rate typical of many developing countries). In the real-world case of no compensation, optimal elephant stocks are well below those currently in existence (345 000 elephants) at all discount rates. Optimal stocks are highly sensitive to the discount rate, as one might expect, with stocks only 40% of current stocks for the discount rate of 18%. If left to their own devices (e.g., without a trade ban or monetary compensation), it is optimal for

range states to reduce their elephant herds below what they are now and below globally-optimal numbers (see below). This might explain why some range states (especially in southern Africa) already cull their elephant herds and have sought ways around the ivory trade ban or its modification (see Bulte and van Kooten, 1999b).

The case of compensation with no strategic behavior is also reported in Table 2, but for various assumptions about $T(x)$, i.e., about the value of parameter a . It is obvious that, relative to the “no-compensation” case, compensation with no strategic behavior results in higher optimal stocks, although stocks decline as the marginal value of preserving the first elephant increases. Note that, even if compensation for non-use values is provided, there are many combinations of parameters yielding efficient stock levels that are smaller than current elephant stocks.

For those in the conservation movement, this is a disturbing result. At the margin, culling elephants and reducing the existing stock can enhance welfare. The reason is that, by culling elephants, those in the range states obtain benefits from sale of ivory and reduced damages to crops (and lives) that exceeds the any potential loss in tourism benefits and non-use values in developed countries. Finally, note that for sufficiently steep demand curves, WTP at the margin is zero for the efficient stock levels in the steady state of the compensation case, hence no compensation is forthcoming (compare the case of $a = 25\,000$ for discount rates lower than 12% with the no-compensation case).

WTP at the margin is lower as the steady-state stock increases. This explains why providing a transfer is “more effective” in promoting elephant conservation when discount rates in range states are high (and their preferred domestic stocks are relatively small). Compare the no-compensation case and the case where $a = 10\,000$. For $r = 0\%$, the transfer increases the extant elephant population by 119 166 animals, whereas the increase for $r = 18\%$ is not less than 251 556 elephants.

The main range states for the savanna elephant are indicated in Table 1. Suppose these countries are able to form a cartel in order to maximize compensation payments from developed countries. They do this by pursuing a joint management strategy that involves stricter enforcement to increase stocks or culling to reduce them. Solving the steady state described by Eqs. (6) and (7) yields the results reported in last four

Table 2
Optimum elephant populations in Africa for various assumptions about compensation, discount rates and marginal values of the first elephant

Item	Discount rate			
	0%	6%	12%	18%
No compensation	266820	212190	168687	138626
Compensation with no strategic behavior				
$a = \$5000$	690000	690000	690000	690000
$a = \$10\,000$	397250	394894	392538	390182
$a = \$15\,000$	278084	265768	264716	263664
$a = \$25\,000$	266820	212190	168687	159716
Compensation with strategic culling				
$a = \$5000$	394599	389973	385349	380727
$a = \$10\,000$	201454	200283	199112	197942
$a = \$15\,000$	135012	134490	133969	133447
$a = \$25\,000$	81300	81112	80924	80736

rows of Table 2. It is clear that strategic responses of African host countries to international compensation schemes for non-use values lower the elephant stocks that would be preserved in the absence of such strategic behavior. While compensation under these circumstances could lead to higher elephant stocks than in the absence of such payments, if the WTP to protect the first elephant exceeds about \$8000, the depletion motive of transfers outweighs the conservation motive and greater elephant protection occurs when there is no compensation.

When international demand for non-use values of elephant conservation is steeply downward sloping (i.e., when a is relatively large), the subsidy that range states receive per elephant is highly sensitive to the extant population and the depletion motive outweighs the conservation motive. Then, stocks are lower when international compensation for non-use values are provided; indeed, they may even be below what range states would be willing to protect without compensation. It is not possible, a priori, to determine if compensation will lead to higher or lower elephant populations than in its absence. Knowing what developed countries are willing to pay to preserve elephants is inadequate; it is also necessary to know the shape of the compensation function or the MWTP function.

To what extent are range states able to behave strategically? It depends to some extent on the degree of substitutability between forest and savanna elephants. Further, given that the range states identified in Table 1 are divided on their approach to the ivory trade ban, it may well be unrealistic to expect them to cooperate by forming a cartel to take advantage of compensation payments. Anything that we might say in this regard is mere speculation, because behavior might

change if compensation was actually forthcoming. It might also change if, for whatever reason, wildlife ministries in various countries were to act in concert (e.g., through creation of a supranational elephant conservation agency). Even in the absence of a cartel, range states might be able to behave as oligopolists. In this case, the outcomes will fall somewhere between the strategic and non-strategic extremes reported in Table 2 (see Varian, 1992, p. 290). Another possible constellation is the model where a dominant cartel operates with a competitive fringe of price taking range states (see Hartwick and Olewiler, 1998, pp. 299–300).

It may be that the utility those in developed countries receive from elephant conservation is independent of elephant numbers, as long as their survival is guaranteed (e.g., herd size remains above minimum viable population). Perhaps WTP for elephant conservation simply represents a “warm glow” that people get from contributing to a good cause. If this is the case the ability of range states to behave strategically is very limited, but compensation might then be regarded as a lump sum payment, in which case the behavior of range states would not be different from the no-compensation case. However, given the very existence of the ivory trade ban when elephants are not in any real danger of disappearing at this time (i.e., there remain sufficient numbers to guarantee their survival), we expect that WTP is indeed a function of in situ stocks.

Finally, Table 3 summarizes some results from a sensitivity analysis. We have considered four alternative scenarios, assuming a discount rate of 12% throughout. First, we compute optimal elephant stocks when African range states are not allowed to trade ivory, consistent with the current CITES trade ban.

Table 3
Sensitivity analysis^a

Optimal stocks	No trade	Increase total WTP ($A = \$4 \times 10^9$)	Increase recreation benefits ($R(x) = 84.6 \times 10^6 \ln(x)$)	Increase agricultural damage ($D(x) = 330x$)
No compensation	256364	168 687	305131	104868
Compensation with strategic culling				
$a = \$5000$	395359	690 000	393648	372651
$a = \$10\,000$	200911	392 541	203179	195898
$a = \$15\,000$	134659	264 717	136662	132537
$a = \$25\,000$	81140	160 097	82531	80408

^a Optimal elephant stocks (discount rate of 12% throughout).

Note that elephant populations benefit from a trade ban when $r = 12\%$ (the in situ stocks are somewhat greater than the stocks reported in the third column of Table 2), but also note that the main result of this paper still holds that international transfers may or may not promote conservation if range states collude and if there are diminishing returns to conservation. This finding appears to be quite robust, and is also apparent from the other three scenarios. Increasing total WTP for conservation A and benefits from wildlife tourism $R(x)$ (agricultural damage $D(x)$) will support thicker (smaller) elephant stocks, but the effect of providing transfers is ambiguous depending on the steepness of the “demand for nature” curve.

Optimal elephant stocks appear to be quite sensitive to the specification of benefits and costs; the recommended stock size may be anywhere between as few as 80 000 elephants and as many as the undisturbed, carrying capacity population of 690 000 animals. This strongly suggests that additional research should be devoted towards estimating the relevant parameters before sensible management policies can be formulated.

5. Concluding remarks and discussion

Non-use values spill over national boundaries creating positive (or negative) externalities. When such values are not compensated in the international arena, sub-optimally low levels of wildlife amenities may result. However, the conventional remedy to overcome this problem may provoke strategic responses by host countries, resulting in loss of global welfare and excessive depletion of valuable resources. Hence, an international program to compensate range states where wildlife are found needs to be carefully constructed. Natural resource economists should progress beyond CVM methods to strategic behavior mechanism analysis to come to grips with these problems.

The strategic behavior modeled in this paper resembles a problem known from the literature on optimal pollution taxes (see Baumol and Oates, 1988, pp. 86–89). Should compensation be paid to range states based on the (globally) optimal population of elephants or on the actual population in existence at any point in time, as advocated by Skonhøft and Solstad (1998)? Analogous to optimal pollution taxes, if compensation is paid according to the stock of

elephants in existence at any given time, a cartel of range states will take into account the effect of their harvest decisions on the compensation to be paid. Alternatively, the developed countries could simply pay the compensation amount per elephant associated with what they consider to be the optimal in situ stock, come what may. While varying compensation (pollution taxes) iteratively over time will result in convergence to the global optimal stock if range states (polluters) act non-strategically, the invariant payment (tax) is preferred when strategic behavior is possible (a cartel or single polluter exists).

There are several reasons why implementing the time invariant payment to international nature conservation is difficult in practice. First, the case of sovereign nations is different from that of a national authority that can impose taxes on (unwilling) firms. Sovereign nations can turn the management problem into a game where the compensation scheme is subject to negotiation. The range states may threaten to cull elephants below the non-cooperative equilibrium, unless compensation according to the iterative approach is forthcoming. (Because this is not a credible threat, the range states should be able to commit themselves to this policy otherwise it would not work.) Second, actual decision making in the arena of international nature conservation appears to be based on a piecemeal approach. For example, the ivory trade ban (moratorium on commercial whaling or trade restrictions on tropical timber) appears to be motivated by short-term concerns and, possibly, pressure by certain interest groups (see Hutton, 2000). The long-run optimum is often not in view, highlighting the relevance of the main lesson of this paper. Our numerical results indicate that failing to grasp this can have detrimental consequences for conservation of elephants in Africa.

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