Human-wildlife conflicts under different management regimes

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Abstract

Integrated Conservation and Development Projects (ICDPs) have been introduced in many parts of Africa, but their performance has so far been hampered by numerous difficulties. This paper reviews existing bio-economic models on the most common instruments of ICDPs, and clarifies their contradicting predictions. In addition, we present a two-agent Gordon-Schaefer model in order to analyse the interaction between a protected area manager and the local people living on the border of the protected area. Depending on the economics parameters of the model, the results suggest that ICDPs relying on money transfers from tourism and game meat distribution to the local people may succeed in promoting wildlife conservation.

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1. Introduction

Protected areas have long been recognized as the single most important method of conserving biological diversity worldwide. For most African countries, this practice dates back to the colonial era. The objective of this management system was to protect wild animals and natural habitats through prohibition or restriction of wildlife utilization, and the strategy centred on the establishment of law enforcement to detect and sentence intruders (Marks 1984, Leader-Williams and Albon 1988, Kiss 1990, Swanson and Barbier 1992).

However, the continuing poaching pressure in African protected areas has led to a growing recognition that the traditional management system has failed in its goal of preserving wildlife (Kiss 1990, Swanson and Barbier 1992, Martin 1993, Barrett and Arcese 1995, Gibson and Marks 1995, Songorwa 1999). Marks (1984), Kiss (1990) and Swanson and Barbier (1992), among others, claim that the establishment of many protected areas worked against the economic interests of the local communities. The exclusion of the local people, usually without compensation for the loss of property, title and traditional hunting rights, has led to increased antagonism and a disincentive to conserve wildlife (see also Brandon and Wells 1992, Milner-Gulland and Leader-Williams 1992b, Wells 1992, Nepal and Weber 1995).

As a response to this, a rethinking of wildlife management schemes has emerged, where the main strategy today is to include the local people to gain their co-operation and support. By stimulating local participation in the planning and management of wildlife, the conservation managers aim at changing the current pattern of exploitation and limiting or preventing uses that endanger wildlife. This has resulted in the Integrated Conservation and Development Projects (ICDPs). While the core objective of these projects is protected area conservation (see e.g. Brandon and Wells 1992), the projects aim to achieve this by promoting economic development and providing local people with alternative income sources which do not threaten to deplete wildlife.

Several ICDPs are based on game meat distribution and a revenue-sharing component where a share of the park fees or other tourist fees is distributed to the local people as cash transfers (see e.g. Brandon and Wells 1992, Barrett and Arcese 1995). These components represent a direct way of improving local income and welfare and are implemented, separately or in combination, in e.g. the Serengeti Regional Conservation Project in Tanzania, the

CAMPFIRE in Zimbabwe, the ADMADE program in Zambia, and SRCP (see e.g. Brandon and Wells 1992, Barrett and Arcese 1995, 1998, Gibson and Marks 1995)[1].

ICDPs can also generate benefits for the local people through, e.g., local job creation in the formal sector and stimulating increased productivity in the agricultural sector. For instance, the Lupande development project and ADMADE in Zambia offers local villagers project related employment as game scouts (Wells and Brandon 1992). Agricultural improvements are implemented in the Luangwa integrated rural development project in Zambia (Wells and Brandon 1992).

Although ICDPs are today preferred to the conservation strategies that preceded them, the potential sustainability of such projects may be limited by possible design dilemmas and trade-offs inherent in linking conservation and development. In a review of existing ICDPs, Wells and Brandon (1992) give a broad and instructive discussion of dilemmas related to buffer zones around protected areas and revenue-sharing components. Buffer zones may provide economic benefit to the local people through, e.g., legal wildlife hunting or game meat distribution, and use of plants. However, Wells and Brandon question the expectation that such benefits to the local people can change their behaviour and promote natural resource conservation. Also Barrett and Arcese (1995) doubt programs of game meat distribution, claiming that such attempts may increase the local people's dependence on game meat, and thereby foster illegal hunting.

Even revenue-sharing components such as income distribution from tourism face potential shortcomings. First of all, as addressed by Wells and Brandon (1992), important questions related to this strategy are who should benefit, how much and for how long. In addition, for such indirect incentives to succeed, Wells and Brandon stress that some explicit agreement is desirable where there is a direct link between the revenue-sharing component and the conservation objective (see also Brandon and Wells 1992). Barrett and Arcese (1995) raise another central aspect, namely the state of the rural markets. For cash transfers to work, the local people must be able to convert this into food or other consumption goods. The opportunity to do this, however, may be constrained by poor access to markets due to, e.g.,

[1] For a broader review of existing ICDP strategies, see e.g. Brandon and Wells (1992), Wells and Brandon (1992), Barrett and Arcese (1995).

high transaction costs (for a theoretical analysis on farmer households and missing markets, see De Janvry et al. 1991).

Also in the literature on bio-economic modelling, several contributors reveal possible unintended impacts of the ICDP components on wildlife conservation. Further, the bio-economic analyses give some contrasting predictions of their impact on wildlife conservation. Therefore, in section 2 we give a broader review of the bio-economic literature on ICDP components. In section 3 we present a bio-economic model to analyse the impact of ICDP components, i.e. game meat distribution, revenue transfers from tourism, and damage control (see below), on wildlife conservation and the welfare of the local people.

2. An overview of the bio-economic literature on wildlife management

2.1. Antipoaching law enforcement

The bio-economic literature on wildlife conservation and management comprises several topics and types of models. In the literature of antipoaching law enforcement and wildlife conservation, Leader-Williams and Albon (1988) demonstrate an inverse relationship between the patrol effort and the rate of decrease of rhino and elephant numbers in Luangwa Valley in Zambia (see also Leader-Williams et al. 1990). However, while the patrols did deter poaching, the effort was too thinly spread to prevent the decline of rhinos. As an implication for Africa as a whole, they recommend low-spending countries to concentrate the anti-poaching effort over small areas, while large conservation areas can only be maintained in high-spending countries.

Also Milner-Gulland and Leader-Williams (1992a), investigate the impact of antipoaching law enforcement on illegal hunting in Luangwa Valley. They model the poachers' decision to hunt black rhinos and elephants and distinguish between the hunting incentives of local subsistence poachers and professional gangs involved in commercial hunting. Subsistence hunting is defined as hunting performed by the local people for the purpose of domestic consumption or to sell wildlife products at the local market. On the other hand, commercial hunting is carried out by professional gangs from outside the local communities. These gangs sell the wildlife products further afield, often at the international market place (Milner-Gulland and Leader-Williams 1992b). In the case of a Schaefer production function, Milner-Gulland and Leader-Williams (1992a) demonstrate that it is not worthwhile for the local poachers to hunt any of the two species, while it is worth hunting elephants for the professional gang. In the same setting, they show that a penalty which varies with a poacher's offtake is a more effective tool against poaching than a fixed penalty.

2.2. The ICDP component of agricultural improvement

While the above bio-economic analysis focuses solely on the hunting activity of the local people, the starting point of others is to focus on the local people as small-scale farmers involved in two production activities: wildlife hunting and agricultural production. This kind of set-up captures the trade-offs in labour- and land use and implements, besides antipoaching law enforcement, the economic conditions in agriculture as detrimental to the hunting activity. A strategy repeatedly proposed in order to promote wildlife conservation is for ICDPs to support policies which improve the productivity in agricultural sector (see above). The understanding is that improved productivity of labour in agriculture will divert labour away from hunting and thereby reduce the pressure on wildlife. The bio-economic analysis by Skonhoft and Solstad (1998) supports this view as they find that better economic conditions in the agricultural sector always works in the direction of more wildlife conservation.

However, Lopez (1998) demonstrates that this argument may be false, depending on for what type of crop the productivity increases; i.e. land-intensive crop or labour-intensive crop. Using a static model with fixed land endowments and no labour market, he shows that an increased price for the land-intensive output is likely to reduce the labour demand for farming, and hence increase the resource extraction.

Also Bulte and van Soest (1999) question the importance of agricultural productivity. Utilizing a dynamic model for a hunter-agrarian household, they demonstrate that the conservation effect of increased agricultural productivity is unclear and critically dependent on whether or not there exist markets for game meat and labour. With such markets present, the household solves the optimal effort in agriculture and hunting separately[2]. Consequently, there is no effect on wildlife exploitation of improved productivity in agriculture. However, with no markets present, they demonstrate that the conservation effect of productivity improvements is ambiguous.

[2] The intuition is that when a labour market is present the household is able to alter the effort use in agriculture by adjusting its labour supply in formal employment, while the effort use in wildlife harvesting is left unchanged, and vice versa.

Other contributors linking agriculture and wildlife hunting are Swanson (1994) and Skonhoft (1999). These analyses differ from those above in that they model two conflicting land uses, where conversion of land for agricultural production displaces wildlife and vice versa. Swanson (1994) and Skonhoft (1999) consider a single agent (the State, a private agent or a group of local people) who owns and allocate land between wildlife conservation and agricultural production. They show that increased profitability in agriculture is a threat to wildlife because it triggers land use conversion.

2.3. The ICDP components of wildlife utilization and income transfers from tourism

Barrett and Arcese (1998) reveal possible unintended outcomes of benefit sharing components of ICDP for wildlife conservation. They present a household model which investigates the effect of game meat distribution from managed harvests and money transfers from tourism to the local people. The model assumes that no market exists for game meat and, hence, the local people perform illegal hunting for own consumption only. Then, the local people respond to game meat transfers by substituting illegal meat for legal meat and, consequently, this policy succeeds in discouraging poaching. However, because the total of the illegal and legal offtake increases, this policy leads to wildlife degradation.

Skonhoft (1998) analyses a similar scheme of game meat transfers but reaches the opposite conclusion regarding wildlife conservation. In principle, what makes these results differ is that Barrett and Arcese consider the local people as the active agent, while the active agent in Skonhoft's model is the park agency. Skonhoft assumes that the park manager earns income from legal safari hunting and non-consumptive tourism services. By forcing the park manager to transfer a fixed share of the wildlife harvest to the local people, the return from safari hunting is reduced relative to the return on wildlife in tourism. Hence, the park manager responds by making further investments in wildlife conservation.

When it comes to income transfers from tourism, Barrett and Arcese (1998) show that this may stimulate increased illegal hunting due to a positive income effect on game meat consumption. Although the mechanism is different, this result is in accordance with Skonhoft's model (1998) of the park manager. If the park manager is instructed to transfer a fixed share of the tourism income to the local people, the return from tourism is reduced relative to the return on hunting. The park manager responds to this by reducing the investments in wildlife conservation. Hence, both of these analyses suggest that ICDPs relying on money transfers fail to conserve wildlife.

In section 3 we utilize a simple bio-economic model of the interaction between the protected area manager and the local people in order to analyse the effect of income transfers from tourism and transfers of game meat to the local people. The unregulated market solution is compared with the social optimum in section 4. A summary and discussion follows in section 5.

3. A bio-economic model of the interaction between the park manager and the local people

In this section we present a simple Gordon-Schafer model of two agents utilizing a wildlife stock. The focus will be on the conflicting interests between the agency managing the protected area and the local people living in the neighbouring area. Wildlife knows no boundaries and moves freely in and out of the protected area. The park agency utilizes the wildlife stock through safari hunting and non-consumptive tourism services. The local people living in the boundary area utilize wildlife through hunting. Hence, the wildlife stock represents a benefit for the local people due to hunting. In addition, wildlife represents a nuisance for the local people because, when being outside the protected area, the game destroys agricultural crops.

Section 3.1 and 3.2 present the non-cooperative Nash equilibrium and in presence of ICDP, respectively. In this equilibrium the park manager does not take into account that its hunting activity influences the economic conditions of the local people, and vice versa. Hence, the externality working through a changing wildlife stock is not internalised in the Nash equilibrium. Section 4 presents the social optimum where the stock externalities are internalised.

3.1. The basic model and the pre-ICDP solution

To formalize the analysis of the interaction between the park manager and the local people, and its impact on wildlife conservation, consider the two agents with hunting effort (e_1, e_2). Subscript '*1*' denotes the park manager, while subscript '*2*' denotes the local people. The population dynamics of the wildlife stock is determined by the natural growth and the offtake of the park manager and the local people (see Appendix). Ecological equilibrium is defined as a constant wildlife stock over time. Hence, in equilibrium, the aggregate offtake equals the natural growth of the wildlife population, a condition which defines the relationship between the wildlife stock and the hunting effort. In general terms, this relationship is expressed as[3]

(1) $$X = X(e_1, e_2)$$

where increased hunting effort e_i reduces the stock size i = 1, 2.

The solid line in Figure 1 gives the *X*-isocline which illustrates the relationship between e_1 and e_2 for a fixed wildlife stock. This line is negatively sloped because an increase in the hunting effort of the park manager must be offset by a reduction of the hunting effort of the local people to keep the stock size fixed at the same level. For fixed hunting productivity and ecological parameters, a movement towards origin represents a higher wildlife stock, while movements outwards represent less wildlife. The steepness of the *X*-isocline is determined by the relative hunting productivity of the park manager to the local people. For a fixed hunting effort, a more productive hunting by the park manager causes the offtake to increase. In order to keep the stock size constant, the park manager must reduce the hunting effort for every level of effort utilized in hunting by the local people. Hence, as the *X*-isocline rotates inwards, its steepness increases.

The next step is to outline the profit function of the park manager. We assume that the park manager earns income from wildlife hunting and the production of tourism services in the protected area. The income from hunting is a function of the hunting effort and the stock level as $H_1 = H_1(e_1, X)$. Here, $\partial H_1 / \partial X > 0$ as more wildlife abundance increases the offtake (see Appendix). The income from tourism *W* is an increasing function of the stock level, as more wildlife improves the hunting possibilities and attracts more tourists to the protected area, i.e. $W = W(X)$, $W'(X) > 0$ (see also Appendix). The profit of the park manager is therefore expressed as

(2) $$\pi = H_1(e_1, X) + W(X)$$

[3] The specified formalization of the model is given in the Appendix. Here, we present the model in general terms.

The decision problem of the park manager is to determine the optimal hunting effort so as to maximize the profit, given the effort use of the local people and the ecology in *(1)*. The direct effect of an increase in the hunting effort is increased income from this activity. However, more hunting effort reduces the wildlife stock, which, in turn, lowers the income from hunting and tourism. Hence, the park manager must take this trade-off into account when deciding upon the optimal effort use. The manager will therefore direct effort towards hunting until the marginal benefit of hunting equals the marginal cost working via the stock effect.

As mentioned above, it is the *aggregate* wildlife offtake which determines the size of the wildlife stock in ecological equilibrium. Because the profit of the park manager depends on the size of the stock, the optimal effort use e_1 must depend on the hunting effort of the local people e_2. This relationship is represented in Figure 1 by the park manager's response function $R_1(e_2)$. It is downward sloping because increased hunting effort by the local people increases the pressure on wildlife and, thereby, reduces the optimal use of hunting effort for the park manager. In this figure, π^0 and π^1 represent iso-profit curves for the park manager, with π^1 representing a higher profit level than π^0.

The local people derive positive utility from wildlife through the hunting activity. The benefit from hunting is a function of the hunting effort and the stock level as $H_2 = H_2(e_2, X)$. Again, $\partial H_2 / \partial X > 0$ as more wildlife abundance increases the offtake (see Appendix). However, living with wildlife is twofold, as it also represents a cost due to animals roaming in the vicinity of the protected area cause damage to agricultural crops. The utility of the local people is therefore expressed as

(3) $$U = H_2(e_2, X) - D(X)$$

where $D(X)$ is the damage function, $D'(X) > 0$. In general, we assume that the benefit of the local people is an increasing function of the wildlife stock. That is, the marginal benefit of living with wildlife exceeds the cost, i.e. $|\partial H_2 / \partial X| > |D'(X)|$. See below. Inserting for *X* in *(3)* from *(1)* yields $U = H_2(e_2, X(e_1, e_2)) - D(X(e_1, e_2))$. The partial derivative of the utility function with respect to the hunting effort of the park manager can be expressed as

$\partial U / \partial e_1 = (\partial H_2 / \partial X - \partial D / \partial X)\partial X / \partial e_1$. Hence, the utility of the local people is a decreasing function of the hunting effort of the park manager.

The decision problem of the local people is to decide the hunting effort e_2 that maximizes the utility level, given the effort use of the park manger and the ecology in *(1)*. The direct effect of an increase in the hunting effort is increased benefit from this activity. The indirect effect working through a smaller wildlife stock is, however, twofold. First, it lowers the utility of the local people due to reduced benefit from hunting. Second, it increases the utility level due to more wildlife abundance which results in less agricultural damage. The local people must take these trade-offs into account when deciding upon the optimal hunting effort. They will therefore direct effort towards hunting until the marginal benefit of hunting equals the marginal cost. Throughout this analysis we assume that the marginal cost of living with wildlife is 'low' in the sense that the local people will not drive the stock to extinction (see Appendix).

The curve $R_2(e_1)$ in Figure 1 is the local people's best response function. It will be downward sloping under corresponding assumptions as for the park manager. The Nash equilibrium is given by the hunting efforts e_1^* and e_2^* as illustrated at point *N* in Figure 1.

Figure 1 about here

Recall from above that the utility of the local people is an increasing function of wildlife abundance. Hence, U^0 and U^1 in Figure 1 are iso-utility curves for the local people, with U^1 representing a higher utility level than U^0 since $\partial U / \partial e_1 < 0$.

It is clear from Figure 1 that *N* is not a Pareto-optimal point. For instance, a movement from point *N* to point *A* increases the profit level of the park manager, while the utility level of the local people is left unchanged. The Pareto-optimal points in Figure 1 are all points along the line *L* connecting the tangency points of the iso-profit and the iso-utility curves. Among these Pareto-optimal points, all curves on the heavily drawn portion of *L* are Pareto-preferred, i.e. preferred by both the park manager and the local people, to the Nash equilibrium *N*. The Pareto-preferred points represent less hunting effort for both agents and more wildlife abundance compared to the Nash equilibrium.

3.2. The ICDP solution

So far, we have outlined the Nash equilibrium without transfers from the park manager to the local community. The next step is to investigate how income transfers from hunting and tourism affect the size of the wildlife stock as well as the welfare of the park manager and the local people. Assume that a fraction $0 \leq \alpha \leq 1$ and $0 \leq \beta \leq 1$ of the income from hunting and tourism, respectively, is transferred to the local community. Then the profit of the park manager reads $\pi = (1-\alpha)H_1(e_1, X) + (1-\beta)W(X)$, while the benefit of the local people is given as $U = H_2(e_2, X) + \alpha H_1(e_1, X) + \beta W(X) - D(X)$. From relation *(1)* we know that an increase in the hunting effort of the local people gives, all else equal, less wildlife abundance. Because the transfers from safari hunting and tourism are related to the size of the wildlife stock, there is an indirect impact from the hunting activity of the local people to the amount of transfers received. Hence, in presence of ICDP there are additional costs of increased hunting effort, working thorugh reduced transfers from the protected area. In the ICDP scenario the local people will take this into account when deciding upon the optimal effort use in hunting.

3.2.1. Income transfers from tourism

Consider first the case where the local people receive income transfers from tourism, $0 < \beta \leq 1$. Compared to the pre-ICDP scenario, transfers from tourism increase the marginal cost of hunting for the local people and, hence, for a given hunting effort of the park manager they find it optimal to reduce the hunting effort. This is illustrated in Figure 2 by a downward shift in the response curve $R_2(e_1)$. This shift is stronger for a lower price of game meat, which reflects that the income transfer from tourism enables the local people to do with relatively less wildlife offtake.

By forcing the park manager to transfer a fixed share of the income from tourism to the local people, the return from tourism is reduced relative to the return on safari hunting. Hence, for a given hunting effort of the local people, the park manager responds to this transfer by increasing the effort use in hunting. See also Skonhoft (1998). Consequently, as illustrated in Figure 2, the response curve $R_1(e_2)$ shifts upwards. This shift is stronger for a lower price of safari hunting licences, reflecting the necessity of a higher increase in the wildlife offtake in order to compensate the loss of tourism income. The new Nash equilibrium is characterized by reduced hunting effort of the local people, while the park manager direct more effort towards hunting.

Figure 2 about here

The conservation effect of income transfers from tourism is therefore unclear and strictly dependent on the magnitude of the reduced offtake by the local people relative to the increased offtake in safari hunting. In turn, this depends on the price of game meat on the local market relative to the price of safari hunting. It is reasonable to assume that the price of safari hunting licences exceeds the price of game meat on the local market. In this case, it can be demonstrated that income transfers from tourism lead to a higher degree of wildlife conservation, as illustrated by a new Nash equilibrium below the initial *X*-isocline in Figure 2 (see also Appendix).

Obviously, income transfers from tourism improve the welfare of the local people[4]. Consequently, there is a potential for more wildlife abundance and improved local welfare of ICDPs depending on income transfers from tourism. As stated above, the conservation effect is positive and 'strong' if the price of licences in safari hunting is high relative to the price of game meat on the local market. In addition, such advantageous conditions in safari hunting will strengthen the welfare effect of the local people. Hence, ICDPs relying on income transfers from tourism perform better if the return on safari hunting is 'high'.

Graphically, increased income transfers shift the utility level of the local people up, for a given hunting effort of the park manager. Hence, every point along the $R_2(e_1)$ curve in Figure 2 represent a higher utility level than the corresponding point along the original response curve. The new Nash equilibrium corresponds to a higher iso-utility function compared to the initial utility level. In contrast, every point along the $R_1(e_2)$ curve in Figure 2 represent a lower profit level for the park manager than the corresponding point along the original response curve. It turns out, however, that income transfers may increase the profit level of the park manager. This will be the case if the price of game meat on the local market

[4] Theoretically, the impact on the welfare of the local people may turn out as negative if there is a strong negative effect on the degree of wildlife conservation (see above). However, the local people will not accept transfers that reduce their welfare. Hence, we assume that the welfare effect is positive.

is low, in the sense that a positive and strong conservation effect can offset the negative impact of income transfers.

3.2.2. Transfers of game meat

Assume that the park manager is forced to transfer a fraction $0 < \alpha \leq 1$ of the game meat from safari hunting to the local people. This increases the marginal cost of hunting for the local people, and, hence, the local people will reduce the hunting effort for a given effort use of the park manager e_1. This is illustrated by a downward shift in the response function $R_2(e_1)$ in Figure 3, which is stronger for a lower price of game meat p_2. The latter reflects an increasing willingness to exchange own harvest for game meat transfers when the price on the local market is successively reduced. For the park manager, a higher α means reduced return on safari hunting relative to non-consumptive tourism services. Consequently, the park manager responds by reducing its hunting effort for every effort level employed by the local people. This causes an inward shift in the response function $R_1(e_2)$ in Figure 3. This shift is stronger for a 'low' p_1, which illustrates an increasing dependence of the wildlife as a source of income in non-consumptive tourism as the return on safari hunting reduces.

Figure 3 about here

It is therefore clear that the new equilibrium must be within the feasible region bounded by the original response curves and below the below the original *X*-isocline in Figure 3. Transfers of game meat will therefore unambiguously reduce the aggregate offtake and promote wildlife conservation. Depending on the size of the shifts in the response curves, reduced aggregate offtake is brought about by reduced hunting effort of at least one of the harvesters. Figure 3 illustrates the case where both harvesters reduce their hunting effort. This will be the result if the prices of both safari hunting licences (p_1) and game meat on the local market (p_2) are 'low'. On the other hand, a 'low' p_2 causes a substantial reduction in the hunting effort of the local people (see above). The following increase in the wildlife stock enables the park manager to increase the effort use and offtake in safari hunting. In this case, the new equilibrium will be in the lower right part of the feasible region in Figure 3. Finally, if p_1 is 'low' (see above) the park manager will respond to increased transfers of game meat by reducing its own hunting effort and harvest. In turn, this enables the local people to increase their own wildlife harvest. Then, the new equilibrium will be located in the upper left part of the feasible region in Figure 3.

The summing up is that ICDPs relying on game meat transfers will succeed in promoting wildlife conservation and welfare among the local people. The impact on the welfare of the park manager is, however, unclear and strictly dependent on how the aggregate hunting effort is distributed between the harvesters compared to the initial equilibrium. As argued above, transfers of game meat increases the hunting effort of the local people if the price of safari hunting licences is low. This leads to reduce offtake in safari hunting, which strengthens the negative impact of game meat transfers on the income of the park manager. On the other hand, reduced hunting effort of the local people may result in increased offtake and improved profit of the park manager.

4. Social optimum

To be written.

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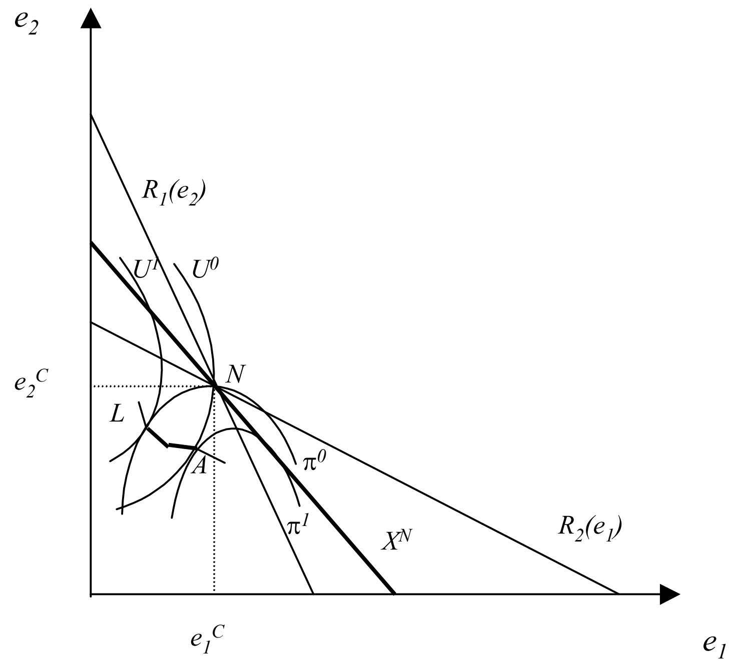
Figures



ure1: The Nash equilibrium.

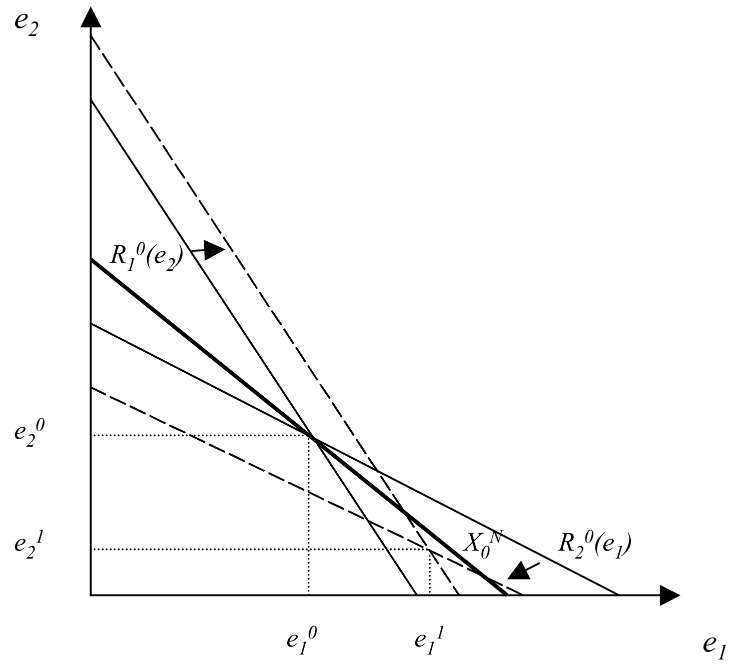


Figure 2: A shift in the transfers from tourism.

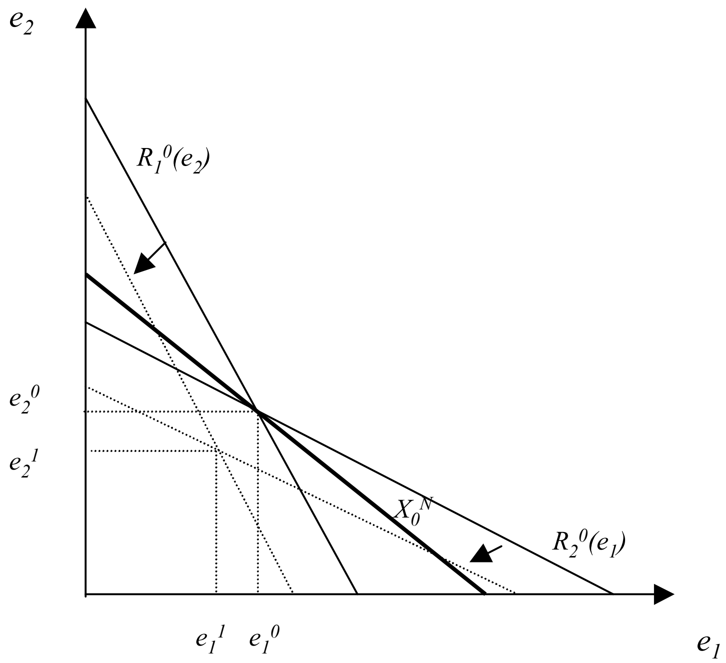


Figure 3: A shift in the distribution of the managed harvest.

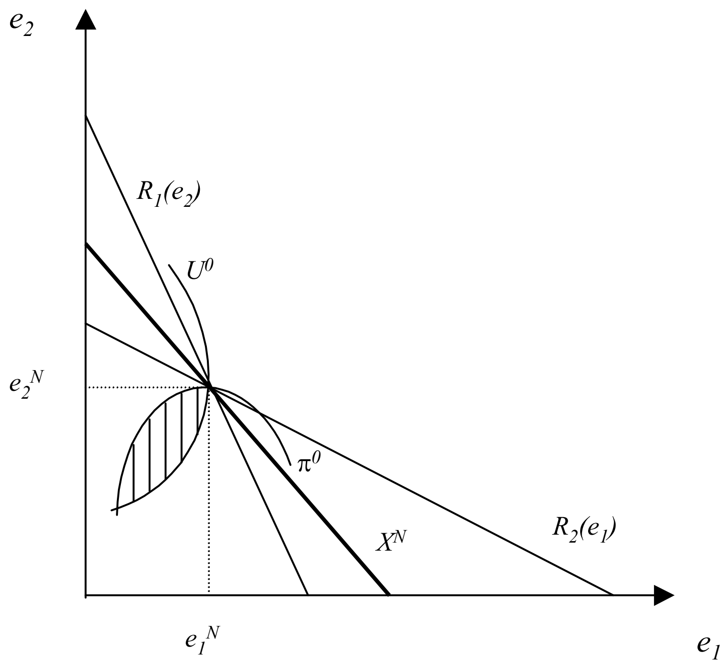


Figure 4:

Appendix

A1. The model

The park manager earns income from hunting and from selling non-consumptive tourism services. The wildlife offtake h_1 is specified as a Schaefer production function $h_1 = q_1 e_1 X$, where q_1 is the catchability coefficient. *V(X)* is the net income from tourism, where it is assumed that *V(X)* is linear and increasing in the wildlife density as the number of tourists increases, $V(X) = vX$, $v > 0$. When assuming that the price of the wildlife offtake is p_1, c_1 is the constant marginal cost of hunting, and ignoring transfers from the park manager to the local people, the profit of the park manager reads

$$(1) \qquad \pi = p_1 q_1 e_1 X + vX - c_1 e_1$$

The local people reap benefit from wildlife through harvesting, where the offtake h_2 is specified as a Schaefer production function $h_2 = q_2 e_2 X$. In addition, wildlife represents a cost to the local people as wildlife roaming in the vicinity of the protected area destroys agricultural crops. Following Zivin et al. (2000) we assume that the damage is proportional to the amount of wildlife. The damage function is therefore expressed as $D(X) = \gamma X$, where $\gamma > 0$ is a fixed constant[5]. Let p_2 be the price of the wildlife offtake and c_2 be the constant marginal cost of hunting. Then, the net benefit of the local people is given in equation *(2)*.

$$(2) \qquad U = (p_2 q_2 X - c_2) e_2 - \gamma X$$

The final step in this section is to present the population dynamics of wildlife. The natural growth of the population is specified as logistic, while the stock shrinks according to the harvesting by the park manager and the local people, as given in equation *(3)*.

$$(3) \qquad dX / dt = rX(1 - X / K) - q_1 e_1 X - q_2 e_2 X$$

[5] We assume that hunting is the only damage control performed by the local people (see below). In addition, and in reality, damage control is also performed through fencing and other measures more directly related to protecting the crop. In the model this would have worked through γ. As we are neglecting such measures, γ is assumed to be constant.

Here, r is the intrinsic growth rate and K is the carrying capacity of the ecosystem. The ecological equilibrium is defined by a constant wildlife stock over time. Solving for X at $dX/dt = 0$ yields

$$(4) \qquad X = (r - q_1 e_1 - q_2 e_2)K / r$$

To obtain $X \geq 0$, the man made mortality must be restricted by $q_1 e_1 + q_2 e_2 \leq r$. For a given stock size, equation *(4)* defines the hunting effort of the local people as a linear decreasing function of the park manager's hunting effort. This relationship is illustrated by the solid line in Figure 1.

A2. The market solution

A2.1. The pre-ICDP solution

Given any hunting effort e_2, the decision problem of the park manager is to determine the hunting effort e_1 so as to maximize the profit in *(1)* given the ecological equilibrium in *(4)*. The first order maximum condition is given by

$$(5) \qquad p_1 q_1 X - c_1 = p_1 q_1^2 e_1 K / r + v q_1 K / r$$

Equation *(5)* together with *(4)* expresses the park manager's best response function $R_1(e_2)$. $R_1(e_2)$ gives the park manager's optimal hunting effort for any given hunting effort e_2. It will be downward sloping as in Figure 1.

In the same way, given any hunting effort e_1, the local people has to decide upon the optimal hunting effort e_2 in order to maximize the utility in *(2)* given the ecological equilibrium in *(4)*. The first order maximum condition is given by

$$(6) \qquad p_2 q_2 X - c_2 = (p_2 q_2 e_2 - \gamma) q_2 K / r$$

Equation *(6)* together with *(4)* gives the local people's best response to any given hunting effort e_1. It will be downward sloping and linear as in Figure 1.

A2.2. The ICDP solution

Assume that a fraction $0 \le \alpha \le 1$ of the income from hunting and a fraction $0 \le \beta \le 1$ of the tourism income are transferred from the park manager to the local people. Then, the net profit of the park manager and the utility of the local people are given by *(7)* and *(8)*, respectively.

$$\text{(7)} \qquad \pi = (1-\alpha) p_1 q_1 e_1 X + (1-\beta) vX - c_1 e_1$$

$$\text{(8)} \qquad U = (p_2 q_2 X - c_2) e_2 - \gamma X + \alpha p_1 q_1 e_1 X + \beta vX$$

Now, equation *(9)* together with *(4)* gives the first order condition for maximum for the park manager, while the first order condition for the local people follows in *(10)* together with *(4)*.

$$\text{(9)} \qquad (1-\alpha) p_1 q_1 X = (1-\alpha) p_1 q_1^2 e_1 K / r + (1-\beta) v q_1 K / r - c_1$$

$$\text{(10)} \qquad p_2 q_2 X - c_2 = (p_2 q_2 e_2 - \gamma) q_2 K / r + \alpha p_1 q_1 e_1 q_2 K / r + \beta v q_2 K / r$$

The differential of *(9)* and *(10)* when taking into account the ecological equilibrium in *(4)* yields

$$\text{(11)} \qquad \begin{bmatrix} 1 & q_2 / 2q_1 \\ q_1 (p_2 + \alpha p_1) / 2 p_2 q_2 & 1 \end{bmatrix} \begin{bmatrix} de_1 \\ de_2 \end{bmatrix} = \begin{bmatrix} v / 2(1-\alpha) p_1 q_1 \\ - v / 2 p_2 q_2 \end{bmatrix} d\beta + \begin{bmatrix} -\left[(1-\beta) v + c_1 r / q_1 K\right] / 2(1-\alpha)^2 p_1 q_1 \\ - p_1 q_1 e_1 / 2 p_2 q_2 \end{bmatrix} d\alpha$$

The determinant of this system reads $1-(1+\alpha p_1 / p_2)/4$ and is assumed to be positive. That is, there is a restriction on the transfers from safari hunting reading $\alpha < 3 p_2 / p_1$.