Modelling Fugitive Natural Resources in the Context of Transfrontier Parks: Under what conditions will conservation be successful in Africa?

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Modelling Fugitive Natural Resources in the Context of Transfrontier Parks: Under what conditions will conservation be successful in Africa?

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Abstract

The conservation of fugitive natural resources across national boundaries poses significant challenges in Africa. This realisation has resulted in the creation of transfrontier parks. While transfrontier parks help de-fragment wildlife habitats, in the presence of governance heterogeneity the same arrangements create uncertainty as they allow a diverse range of park managers to make decisions about wildlife. This paper formulates a bioeconomic model to examine the determinants of successful conservation of migratory wildlife across a transfrontier park with patch heterogeneity. The examination shows three key results. Firstly, it is both ecologically and economically worthwhile to establish a unified transfrontier park rather than have disjointed national ones only if stronger governance institutions exist in higher-resource potential areas. Secondly, the local communities will cooperate with transfrontier conservation effort only if they derive greater benefit flows from transfrontier park-based wildlife conservation than from anti-conservation activities such as wildlife poaching. Thirdly, successful conservation requires transfrontier arrangements that equalise the long-run costs and benefits for all constituent partners. Given the presence of patch and governance heterogeneity, successful elephant conservation in Southern Africa requires that South Africa shares benefits with Mozambique and Zimbabwe despite their weaker institutions to prevent resource leakages from threatening the transfrontier park.

1 Introduction

There has been a growing realisation in natural resource management that the governance boundary should be spread wholly over the ecological boundary in order for management decisions to have complete effects on the ecological system.[1] Furthermore, correspondence between ecological and governance boundaries reduces the likelihood of conflicting management decisions about segments of the same ecological system. In dealing with fugitive natural resources such as wildlife, at an international level in Southern Africa, this realisation has brought in its wake the creation of a good number of transfrontier parks.

A transfrontier park is a protected area that spans across boundaries of multiple countries and includes the removal of physical boundaries which might inhibit the free migration of animals and humans. These areas are also referred to as Peace Parks as they have been promoted as political constructs that can help foster peace between neighbouring countries. In many cases, to effectively

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[1] Thus, one needs to first clearly demarcate ecological boundaries before demarcating governance boundaries.

link previously isolated national parks, additional non-proclaimed land may have to be appended to the amalgamated block of land. The appropriate term to use in such contexts is transfrontier conservation areas (TFCAs).[2]

The first transfrontier park in Southern Africa was formally launched in 2000 with the establishment of the Kgalagadi Transfrontier Park through the joining of the Kalahari Gemsbok National Park and the Gemsbok National Park to create a park of 38,000km^2. The second transfrontier park, the Great Limpopo Transfrontier Park, was established in 2002 between the countries of South Africa, Zimbabwe and Mozambique, covering an area of 35,000km^2. The park will eventually cover 100,000km^2. The only other park to date which has been ratified through a treaty is the Ais-Ais/ Richtersveld Transfrontier Park which was ratified in 2003 between Namibia and South Africa, and covers an area of 6,045km^2, spans some of the most spectacular desert mountain scenery and includes the world's second-largest canyon.

Memorandums of agreement have been signed for four other Parks namely, the Limpopo-Shashe (Botswana/South Africa/Zimbabwe), the Lubombo (Mozambique/South Africa/Swaziland), the Maloti-Drakensburg (Lesotho/South Africa) and the Kavango-Zambezi (Angola/Botswana/Namibia/ Zambia/Zimbabwe). Five other areas are at different stages of transfrontier arrangements: the Liuwa Plain-Mussuma (Angola/Zambia), the Lower Zambezi-Mana Pools (Zambia/Zimbabwe), the Chimanimani (Mozambique/Zimbabwe), the Iona-Skeleton Coast (Angola/Namibia) and the Nyika/Kasungu/Lukusuzi (Malawi/Zambia).[3]

The removal of fences between adjacent international parks might help in the de-fragmentation of wildlife habitats, which has long been recognised as a major cause of biodiversity loss particularly in literature on large mammals. In some cases, transfrontier parks might also create an avenue through which some overpopulated parks could be relieved of their excessive wildlife populations by finding additional habitat in adjacent international parks.[4] This is particularly the case if there is spare capacity in the neighbouring international parks and, in that case, conservation in parks on either side potentially stands to benefit by the mere creation of a transfrontier park. It should also be noted that these areas do not only allow for wildlife migration but encourage tourism, economic development and goodwill between neighbouring countries as well as facilitating travel of indigenous inhabitants of the area.

By giving wildlife access to more land, especially large-range species, transfrontier arrangements are potentially conducive to sound conservation. However, in the presence of governance heterogeneity, transfrontier arrangements create uncertainty about the actual outcome as these arrangements entail that a potentially more diverse range of managers get to make decisions about the wildlife. Some of the key wildlife management decisions relate to interaction with the adjacent local communities who may or may not support wildlife conservation, depending on their perceptions about many issues such as damage-causing animals, ownership of wildlife and sources of livelihood. In cases where ineffective managers get to learn from their effective counterparts how to manage wildlife successfully, or where the effective managers get to take over the bulk of the wildlife management decisions, then wildlife will potentially be better off in aggregate. However, if the dominant group of managers responds to perverse wildlife management incentives, then transfrontier parks could actually open up more areas to wildlife mismanagement and loss.

[2] The Southern African Development Community (SADC) Protocol on Wildlife Conservation and Law Enforcement of 1999 defines a TFCA as "the area or component of a large ecological region that straddles the boundaries of two or more countries, encompassing one or more protected areas as well as multiple resource use areas".

[3] See http://www.peaceparks.org for more details.

[4] In some parks such as the Kruger in South Africa, elephant populations are exceeding carrying capacities. If this situation continues unchecked it will adversely affect the parks ecosystem. This has the effect that the elephant's own habitat will be degraded and the habitats of other species will not be spared. This situation might also have adverse economic consequences; for example, it may affect tourism income opportunities. In isolation, countries with overpopulations would have to take drastic measures such as culling. While such measures solve the conservation problem they may attract the wrath of animal rights activists who vociferously campaign against them, thereby adversely affecting tourism opportunities.

In light of the foregoing possible conflicting circumstances, there are no clear expected outcomes from transfrontier park arrangements. In some cases, where the negative effects outweigh the positive effects, transfrontier parks are undesirable constructs. But in other cases, where the positive effects outweigh the negative effects, they may actually be the good way to go. Thus, there is a need for an appraisal of when conservation might be successful or guidelines as to the conditions under which pro-conservation countries should participate in such arrangements. In order to derive these guidelines one should have answers to three key questions. Firstly, under what conditions is it better to have either a transfrontier park or several disjointed national ones when dealing with fugitive natural resources such as wildlife? Secondly, given that transfrontier parks are usually established in areas with human communities, under what conditions might local communities be expected to cooperate with transfrontier park management? Thirdly, if transfrontier arrangements are indispensable, what threshold of governance institutions guarantee enhanced conservation?

This paper investigates the above-mentioned questions by formulating a bioeconomic model using the context of conservation of a wildlife species such as the African elephant (*loxodonta africana*)[5] in the Great Limpopo Transfrontier Park. The model incorporates key considerations such as patch heterogeneity, wildlife migration, and governance heterogeneity. The paper will show three key results. Firstly, it is both ecologically and economically worthwhile to establish a unified transfrontier park rather than have disjointed national ones only if stronger governance institutions exist in higher-resource potential areas. Secondly, the local communities will cooperate with transfrontier conservation effort only if they derive greater benefit flows from transfrontier park-based wildlife conservation than from anti-conservation activities such as wildlife poaching. Thirdly, successful conservation requires transfrontier arrangements that equalise the long-run costs and benefits for all constituent partners.

The rest of the paper is organised as follows. Section 2 reviews the literature on transboundary conservation. Section 3 explains the methodology to be employed, after which the model is formulated, presented and analysed. Section 4 discusses the policy implications of the model. The conclusion is given in Section 5.

2 Literature Review

As highlighted earlier, TFCAs have gained popularity as a method of preserving and conserving natural resources across political boundaries.[6] TFCAs seek to effectively integrate areas previously segregated by political boundaries, to get them under a common management scheme, with the aim for better conservation effort. Munthali (2007) identifies some of the main reasons for creating TFCAs as the need to protect reserves that span across nations, the need to expand the total area that is being utilised for wildlife activities, and the need to re-establish seasonal migration routes. With poverty levels consistently high in most African countries, wildlife resources have also been viewed as a tool that local communities and governments can use for the betterment of the lives of the people around the reserves. Singh (1998), for example, takes the view that TFCAs offer increasing economic opportunities, diminish cultural isolation and may be used for community integration. Thus, TFCAs can be viewed as vehicles with which to fight for the twin goals of conservation and development. There seems to be consensus that wildlife may impact positively on the lives of the people around it, if it is effectively managed.

While there is consensus and acknowledgement that TFCAs can have a huge impact on the livelihood of communities, how these areas ought to be managed remains debatable. Büscher and Dietz (2005) argue that instead of embracing communities in TFCAs, the older, more exclusionary

[5] In Southern Africa, the elephant is probably the single greatest factor influencing ecosystem conservation in protected areas (DNPWLM 1999). Perhaps this points towards that governance boundaries should be along the ranges of elephants and take refuge in it being both a keystone and umbrella species. Indeed the elephant range was the key consideration in the establishment of the Great Limpopo Transfrontier Park.

[6] This section uses the term TFCA as it is broader and encompasses a transfrontier park.

approach should be taken. They argue that there is irrefutable evidence that African communities have failed to harness the full potential of wildlife resources, with some communities which are well-endowed with natural resources and which have been given ownership, failing to improve their lives. While this view cannot be disregarded, as there indeed are numerous cases of failures by communities, there are also cases of communities which have addressed both the conservation as well as the economic goals. One example is that of the Makuleke clan which benefited from land restitution in the Kruger National Park of South Africa, a member of the Great Limpopo Transfrontier Park.

The management of TFCAs is not without problems by virtue of their structure. One of the main challenges faced is the exclusion of most stakeholders, as governments (or their conservation agencies) generally assume full ownership of TFCAs (Munthali, 2007). Such alienation of other stakeholders tends to prop up conservation objectives and override economic objectives. While conservation is the uncontested main objective, other objectives such as the livelihood of the local communities should also be considered, as these stakeholders potentially pose a threat to conservation effort should they not stand to benefit from the areas. The TFCAs potentially affect the communities by reducing the size of area available for agricultural purposes in cases where rangeland is drafted-in, and by perpetrating damage to crops and property when more animals from a larger animal population wander outside the protected areas. Due to colonial history and different perceptions around access to resources and use between different communities, misunderstandings are bound to arise, resulting in non-cooperation (Munthali, 2007).

While parks may generally face ineffective management capacities, the level of coordination needed in joint operations is higher than when dealing with individually managed resources. In some cases, management capacity for this level of coordination may just not exist. Thus, TFCAs may inherently have collective-action problems as more people have to be consulted and consensus must be reached on all key decisions. In cases where payoff structures are asymmetrical, and one sub-area stands to benefit more than the others, management views and objectives regarding the way forward may be diametrically opposed.

Now consider the Great Limpopo Transfrontier Park (GLTP), in whose context this study is to be shaped. Apart from the above-mentioned general issues that TFCAs face, GLTP has its own challenges, of which the major ones will be revealed. As Saayman and Saayman (2006) point out, there are extreme poverty levels amongst communities living around the TFCA.[7] Such a situation puts pressure on the GLTP from resource use by the local communities. A challenge that crops up is that the management system will have to enhance enforcement against unsustainable illegal off-take. Countries tend to differ in the manner in which they execute their responsibilities. Some countries might prefer to exclude local communities and use a more centralised approach to management, an approach which historically has, in some cases, effectively turned their portions of the TFCA into *de facto* open-access areas due to ill-resourced, ineffective monitoring. Some might prefer to involve local communities as a way to reduce resource-monitoring costs and increase resource protection.

There is a role for communities to play given that wildlife biological processes occur at small, medium and large scales such that their effective management requires that governance systems are organised in multiple scales that are effectively linked (Ostrom 1995).[8] Countries that promote congruence between the governance system and the biological process in wildlife conservation have strong governance institutions. In this context, governance institutions refer to the rules, norms, and strategies adopted by individuals as they interact with the resource, *inter alia*, and exist in the minds of the participants and are sometimes shared as implicit knowledge, rather than in an explicit and written form (Ostrom 1999). Institutions include rules of behaviour, ways and means of enforcing these rules, procedures for mediation of conflicts, sanctions in the case of breach of the rules,

[7] For instance, Limpopo and Mpumalanga provinces in South Africa, the provinces in which the Kruger National Park is situated, are among the poorest provinces in the country.

[8] Thus the governance system must be as complex as the biological process it is trying to manage. It is not uncommon to find smaller-scale organisations that are nested within larger ones, each with its own distinct set of rules (Ostrom 1995).

and organisations supporting transactions. Institutions affect the way in which exploitation of the elephant resource can take place. Poaching is likely to be rampant in countries with weak governance institutions, because poachers hunt without effective restraint. Furthermore, local communities who are adjacent to wildlife are likely to support and shield poachers as a way to protest their exclusion from wildlife management. Of concern to local communities will be whether the creation of the TFCA will entail costs for them in the form of (i) increased human-wildlife conflict given that there is no guarantee that wildlife will not occasionally wander from the parklands into the rangelands, and (ii) loss of traditional hunting and agricultural areas given that local parkland boundaries may have to be redrawn to effectively link the local park to the neighbouring ones. It will be difficult to establish TFCAs adjacent to communities who feel disenfranchised and stand to suffer large losses.

The creation of the TFCA will most likely see the emergence of new wildlife migration patterns particularly across political boundaries, given that the quality of habitats is likely to differ in the different parts of the TFCA. Also, animal instinct could be such that wildlife tends to escape from areas characterised by high risk of illegal resource use, to safe sanctuaries. Thus, wildlife is likely to be concentrated along certain routes or sanctuaries within the TFCA, with the result that access to wildlife hotspots is unevenly distributed amongst the participating countries. Under these conditions, the extent of benefits generated[9] from the TFCA by each party would therefore largely depend on the extent of conscious infrastructural development.[10] Evidence from the GLTP has shown heterogeneity in infrastructural development with serious backlogs in Mozambique and Zimbabwe. On the Zimbabwean side (i.e. Gonarezhou Park), most roads are not tarred, in bad shape and mostly accessible by off-road vehicles (Spenceley *et al.* 2008). The level of other tourist infrastructure such as game lodges, viewing spots, telecommunication systems, road transfer facilities and other recreational facilities is also not well developed, particularly on the Mozambican side. The South African side (i.e. Kruger Park) can be described as the diametric opposite of the descriptions of its two counterparts. For as long as migration is asymmetrical and infrastructural development is heterogenous, benefits and costs in the different areas will not be the same. Furthermore, countries that benefit more from the TFCA are expected to invest more in its sustainability and in infrastructure which consolidates those benefits. The heightened heterogeneous infrastructural development ultimately leads to collective action problems.[11] Thus, all participating countries ought to draw net benefits from the TFCA if conservation is to be enhanced.

These challenges probably explain why, to date, GLTP has fallen seriously short of quantifiable deliverables despite much having been said about the potential of the project in terms of the possible economic gains to the communities and biodiversity enhancement. Sceptics of the project argue that, other than the relocation of a handful of elephants from Kruger to Gonarezhou, GLTP has perhaps not achieved anything else. The motives behind the establishment of GLTP have also been called into question a number of times, with the suggestion that South Africa stands to gain the most and wanted to find areas to where it could translocate excess elephants from Kruger at low cost.[12] Some experts will, however, argue that this is not so much a numbers game but the creation of the opportunity for elephants to be able to move around and it is their use of resources across time and space that results in the success or failure of a TFCA.

Nevertheless, the point has been made that the extent of enhancement of conservation under TFCAs will necessarily depend on the resultant payoff matrix of conservation benefits for the par-

[9] Country benefits from TFCAs usually come in the form of benign tourism. Additional benefits may be existence values.

[10] A country might be better able to counter adverse wildlife migration effects by putting in place mechanisms to navigate to wildlife hotspots. Better still, the country might be able to make the habitat on its side more attractive by, say, sinking waterholes to induce the wildlife to change its range.

[11] Given that wildlife will move to the other countries participating in and benefiting more from the TFCA, why should a particular country make conservation sacrifices given the possibility that it might not eventually benefit from them? The situation which might arise is akin to an international tragedy of the commons.

[12] The Kruger had an excessive elephant population and these had to be rid of, but without taking drastic action such as culling which would have had bad publicity and taken a toll on tourism revenues.

ticipating countries as it is affected by at least two factors. Firstly, the wildlife migration patterns, particularly those of large range and more valuable species given spatial heterogeneity. Secondly, the nature of governance institutions in each of the participating countries, i.e. given the location of most TFCAs, there is a need to craft those scenarios where wildlife conservation actually gains from TFCAs.

3 The Model

The paper uses bioeconomic modelling, which takes into account the biological process of wildlife as well as the economic incentives of people interacting with wildlife. The management actions of humans will affect the wildlife ecosystem and the wildlife ecosystem will in turn give its feedback by changing the economic incentive structure of humans. By formulating a plausible model that captures the biology-economics interactions, one may be able to predict the effects of changing key parameters of the model. Bioeconomic models have been formulated to investigate biology-economics interactions especially for individual country situations, for example in investigating Integrated Community Development Projects (ICDPs) (see Shulz and Skonhoft (1996), Skonhoft and Solstad (1996), Skonhoft and Solstad (1998) and Skonhoft (1998). Where transboundary resource management has been investigated, fisheries have tended to dominate, particularly migratory coastal fish species which move across country borders (for example, Sanchirico and Wilen (2001)). For terrestrial species, bioeconomic models have tended to focus on investigating the effect of creating new protected areas in formerly open-access lands in a particular country (for example, Johannesen and Skonhoft (2004)). The proposed work will extend the discussion in the bioeconomic modelling literature to include fugitive terrestrial resource management situations where countries come together to manage jointly previously isolated national parks, where wildlife migration takes place across country borders and where there is heterogeneity of governance institutions of local communities living adjacent to the TFCA.

This work is inspired by the African elephant in the context of the GLTP. Given that the elephant frequently migrates across large areas, it is imperative to incorporate the dynamics of elephant migration when analysing different management regimes in the underlying sub areas. The model will therefore incorporate the dynamics of elephant migration, elephant population growth, off-take and the economic system under which the transfrontier park operates, to find the effects of interventions on equilibrium values.

We start by discussing the possible modelling of elephant migration. We note that in the absence of transboundary resource management the elephant inevitably migrates within each national park. Since the focus of this paper is on transboundary resource management, we take isolated national park internal migration for granted and instead focus on migration across the different political jurisdictions of the GLTP.[13] There are three main types of animal migration which are potentially of interest to this discussion: (i) seasonal migration, (ii) symmetric density-dependent migration, and (iii) asymmetric density-dependent migration.

With seasonal migration, the species moves from habitat to habitat dependant on the season, in search for food.[14] Even though the African elephant has been known to migrate across vast distances each season it is inconceivable that such migration can take all elephants completely from

[13] This refers to the areas in Zimbabwe, Mozambique and South Africa.

[14] Several terrestrial species show this form of migration in Africa. An example is the seasonal migration of the wildebeest, zebra and gazelle from Serengeti national park to the Masai Mara reserve in search of food depending on the rainfall patterns. The Serengeti-Mara ecosystem as a whole covers some 25,000-32,000 km^2 (Ronald *et al.*, 1989) and there is a significant rainfall gradient throughout the ecosystem, with some areas receiving an annual rainfall of only 800mm and others over 2,000mm. It is this kind of vast difference that then makes it possible for seasonal migration, where the species move from one area completely to the other, as the climatic conditions allow for different vegetation, nutritional value and carrying capacity per unit area. In other contexts outside the Serengeti-Mara migration, these animals stay in the game reserve for most of the year, but all migrate outside the reserve into the surrounding environment in search of better pasture in the dry season (Fryxell et al, 1995).

one political jurisdiction of the GLTP to another. Symmetric density-dependant migration occurs between habitats whose natural conditions are generally identical. Modelling elephant migration as symmetric would imply that, throughout the transfrontier park, the physical quality of the habitat and the quality of food are identical. Therefore, the elephants would be distributed evenly, and there would be a positive flow of animals to that area whose density becomes lower. This however is hardly practical as the geographical characteristics are not the same everywhere within the park. With asymmetric density-dependant migration, species are sensitive to extraordinary circumstances in their habitat, e.g. dangers such as predation and competition, and opportunities such as abundant water and food. In equilibrium, therefore, there would be more elephants per unit area in the preferred habitat, but there will still be some elephants, albeit in lower densities, elsewhere.

Drawing from the work of Sanchirico and Wilen (2005), Skonhoft and Armstrong (2005) and Armstrong and Skonhoft (2006), the mathematical model for asymmetric density-dependant migration of elephants across the different political jurisdictions in GLTP is formulated below. Even though the GLTP comprises of three political jurisdictions, for simplicity, we assume that it constitutes of two spatial patches – patches 1 and 2.[15] The net migration rate from patch 1 to patch 2 at the beginning of each period, denoted by M_{1t}, may therefore be represented as:[16]

$$M_{1t} = m(\alpha \frac{S_{1t}}{K_{1t}} - \frac{S_{2t}}{K_{2t}}) \tag{1}$$

The coefficient of transboundary movement (dispersal), m, shows the intrinsic dispersal rate of the elephant between the two patches. A low coefficient denotes low rates of migration between the patches, while a high coefficient exhibits higher dispersal. The parameter α is used to capture the preferences of the elephant for a particular patch. If $\alpha < 1$ then there is a preference for patch 1 while $\alpha > 1$ indicates preference for patch 2. If $\alpha = 1$ then the elephant is indifferent between the patches and migration follows the symmetric density-dependent pattern. The preferences in this case are assumed to be largely shaped by different levels of non-anthropogenic danger and opportunities in the two patches, e.g. predator-prey relations and competition with other species.[17] The model will designate the preferred patch as patch 1. S_{1t} and S_{2t} are the total stocks of the elephant at time t in patches 1 and 2 respectively, while K_{1t} and K_{2t} are the respective elephant-carrying capacities. The term S_{it}/K_{it}, $i = 1, 2$ captures density-dependent migration while α captures its asymmetric nature. In a similar way, the net migration rate from patch 2 to patch 1 can be defined and denoted by M_{2t} where, simply put, $M_{2t} = -M_{1t}$ because whatever net elephant stock leaves patch 1 will necessarily have gone to patch 2.

The presence of heterogeneity of the physical conditions in the different patches gives the possibility of more favourable elephant growth in one of the patches. Thus, the model assumes that there is a difference in the intrinsic growth rates r_i of the elephant between the two patches. Given that the model labels the preferred patch as patch 1, the difference in intrinsic growth rates between the two patches implies that $r_1 > r_2$. It is assumed that the natural growth of the elephant f_i for patch $i = 1, 2$ is dependent on the post-migration stock $(S_{it} - M_{it})$ and follows the logistic function as follows:

$$f_i(S_{it} - M_{it}) = r_i(S_{it} - M_{it}) \left(1 - \frac{(S_{it} - M_{it})}{K_{it}}\right) \tag{2}$$

Some management will be required to keep the elephant stock within an acceptable range in each patch. It is therefore assumed that, at the end of each period and for each patch $i = 1, 2$, a

[15] Making use of more complex mathematical manipulations, the results from a two-patch model can be extended to the three-patch model.

[16] This model allows for flexibility on the assumptions about migration. The parameter m can be varied from species to species as different species have differing rates of movement. Species with a high degree of spatial movement will have a large value of m as opposed to those with minimal movement, which would record a much lower value. For any species, this parameter would be constant, and determined through empirical studies.

[17] In other cases, the preferences may be shaped by different hunting pressure and other human activities (e.g. culling, poaching, perennial man-made waterholes) in the two patches.

certain amount of elephants H_{it} will be captured and sold off to game farms and nature reserves with the capacity to manage them effectively (this is a common occurrence in the South African wildlife sector).[18] In addition to this official off-take, there is also an off-take P_{ijt} poached by human community $j = 1, 2$ living adjacent to each patch $i = 1, 2$, which is a function of anti-poaching effort A_{it}, poaching effort E^P_{ijt} and elephant stockS_{it} as will be elaborated later.[19] It should be noted that we have deliberately chosen to index patches by i and communities by j as we will demonstrate that community characteristics are not necessarily congruent with patch characteristics, i.e. good communities are not necessarily located adjacent to preferred patches.

Now bringing migration, growth and off-take together, the rate of change of the total stock of the elephant in patch $i = 1, 2$ can be represented as follows:

$$\frac{dS_{it}}{dt} = f_i(S_{it} - M_{it}) - M_{it} - H_{it} - P_{ijt}(A_{it}, E^P_{ijt}, S_{it}) \tag{3}$$

$$\frac{dS_{it}}{dt} = r_i(S_{it} - M_{it})\left(1 - \frac{(S_{it} - M_{it})}{K_{it}}\right) - m\left(\alpha\frac{S_{1t}}{K_{1t}} - \frac{S_{2t}}{K_{2t}}\right) - H_{it} - P_{ijt}(A_{it}, E^P_{ijt}, S_{it}) \tag{4}$$

Legal elephant benefits are in the form of two main sources of revenue: the first arising directly from tourism[20] and the second from proceeds of the sale of live game H_{it} to game farms and nature reserves.[21] It is assumed that benefits from tourism are directly related to the stock of elephants.[22] Thus, the total benefits B_{it} in patch $i = 1, 2$ are a function of the stock levels S_{it} and off-takes H_{it} for $i = 1, 2$ i.e.

$$B_{it} = B_{it}(S_{it}, H_{it}) \tag{5}$$

The costs incurred by the conservation authorities are in the form of habitat management (waterholes, fireguards, etc) and tourism infrastructure (gravel roads, viewing spots, lodges, etc). The main cost of keeping elephants is the regulation of the size of the herd. They would need to be tracked, provided with sufficient waterholes and fenced-off from human settlement areas and so forth. While this involves material provision, it also entails costly anti-poaching enforcement effort A_{it} for $i = 1, 2$ targeted towards the illegal hunting by adjacent human communities. The other cost accruing to the park is that of capturing the live game H_{it} for sale. Thus, total costs C_{it} in patch $i = 1, 2$ are assumed to be directly dependent on the stock of elephantS_{it}, the official off-takes H_{it}, and anti-poaching enforcement efforts A_{it} i.e.

$$C_{it} = C_{it}(S_{it}, H_{it}, A_{it}) \tag{6}$$

[18] Being a keystone species and an umbrella species, elephants are the single most influential species that affects the dynamics of the TFCA. They have the capacity to overexploit their natural habitat if they exceed the carrying capacity, but at lower numbers they can increase biodiversity and spatial distribution of other animals (Baxter, 1996). If stock management is not done on a continuous basis, drastic measures might become necessary in the future. Should the elephant population exceed its carrying capacity, the species will break into neighbouring areas for food, thus costing the parks in terms of compensation. As an extreme measure, the elephants have to be culled, within the context of compensation for damage-causing animal impacts on neighbouring communities. Thus it is in the park's interest to rid of excess elephants.

[19] Poaching is assumed to follow the Schaefer function of the form $P_{ijt} = e(A_{it})E_{ijt}S_{it}$ where $e(A_{it})$ is the off-take per unit of effort, E_{ijt}.

[20] The African elephant continues to fascinate many people and is considered an appealing animal, partly due to its size, charisma and the imminent threat of danger that always comes with being close to one (Reynolds and Braithwaite, 2001). It is because of this special appeal that tourists have continued to flock to the wildlife reserves in Africa.

[21] These proceeds are not derived from hunting, but from translocating live animals to game farms and nature reserves to further their conservation effort. In cases where consumptive use is allowed, this would have included proceeds from trophy hunting, once-off concessionary sales of ivory, sale of game meat and any other wildlife-related products.

[22] It seems plausible to model tourism benefits as depending on the elephant stock for three reasons. Firstly, we abstract from the notion that tourism is a function of an index of biodiversity, because we are dealing with a one-species model. Secondly, more people are likely to be attracted by a larger elephant population, as they would be guaranteed of viewing it. Thirdly, as a keystone and umbrella species, elephants indirectly regulate the total stock of other species in the park through the dispersal of seeds and regulation of veld types. These activities ultimately affect the stocks of all the other animals and thereby improve the index of biodiversity within the range of interest.

3.1 *Managing a unified transfrontier park*

After pulling the fences down, the conservation authorities come up with a shared long-run vision and conservation strategy. They will use the anti-poaching enforcement effort A_{it} and the official off-take H_{it} for $i = 1, 2$ as control variables. It is assumed that the unified transfrontier park is managed to maximise the present value of net benefits NB. Thus, the problem is:

$$\underset{A_{it},H_{it}}{MaxNB} = \int_0^\infty \left(\sum_1^2 \left[B_{it}(H_{it}, S_{it}) - C_{it}(H_{it}, S_{it}, A_{it}) \right] \right) e^{-\delta t} dt \tag{7}$$

$$s.t. \frac{dS_{it}}{dt} = r_i(S_{it} - M_{it}) \left(1 - \frac{(S_{it} - M_{it})}{K_{it}} \right) - m \left(\alpha \frac{S_{1t}}{K_{1t}} - \frac{S_{2t}}{K_{2t}} \right) - H_{it} - P_{ijt}(A_{it}, E^P_{ijt}, S_{it}) fori = 1, 2 \tag{8}$$

The initial elephant stock level is $S_{i0} = S_i^0$ for $i = 1, 2$. The current value Hamiltonian is:

$$\begin{aligned} H^C &= \textstyle\sum_1^2 \left[B_{it}(H_{it}, S_{it}) - C_{it}(H_{it}, S_{it}, A_{it}) \right] \\ &+ \textstyle\sum_1^2 \lambda_1 \left[r_i(S_{it} - M_{it}) \left(1 - \frac{(S_{it} - M_{it})}{K_{it}} \right) - m \left(\alpha \frac{S_{1t}}{K_{1t}} - \frac{S_{2t}}{K_{2t}} \right) - H_{it} - P_{ijt}(A_{it}, E^P_{ijt}, S_{it}) \right] \end{aligned} \tag{9}$$

The maximum principle is:

$$\frac{\partial H^C}{\partial A_{it}} = -\frac{\partial C_{it}}{\partial A_{it}} - \lambda_i \frac{\partial P_{ijt}}{\partial A_{it}} = 0 fori = 1, 2 \tag{10}$$

$$\frac{\partial H^C}{\partial H_{it}} = \frac{\partial B_{it}}{\partial H_{it}} - \frac{\partial C_{it}}{\partial H_{it}} - \lambda_i = 0 fori = 1, 2 \tag{11}$$

$$\begin{aligned} \frac{d\lambda_{it}}{dt} &= \delta\lambda_{it} - \lambda_{it} \left[r_i - 2r_i \frac{(S_{it} - M_{it})}{K_{it}} - \frac{m\alpha}{K_{it}} - \frac{\partial P_{ijt}}{\partial S_{it}} \right] \\ + \frac{\partial C_{it}}{\partial S_{it}} - \frac{\partial B_{it}}{\partial S_{it}}; fori &= 1, 2 \end{aligned} \tag{12}$$

$$\frac{dS_{it}}{dt} = r_i(S_{it} - M_{it}) \left(1 - \frac{(S_{it} - M_{it})}{K_{it}} \right) - m \left(\alpha \frac{S_{1t}}{K_{1t}} - \frac{S_{2t}}{K_{2t}} \right) - H_{it} - P_{ijt}(A_{it}, E^P_{ijt}, S_{it}) fori = 1, 2 \tag{13}$$

The interpretation of condition (10) is that the transfrontier park authorities will invest in anti-poaching enforcement until the value of abated additional poaching is equated to the marginal cost of such enforcement. From condition (11), the size of the official off-take will be set at a level at which the benefit from the additional unit harvested equals its marginal cost. The marginal cost of removing an additional unit of wildlife is made up of two components, harvest cost and opportunity cost. Equations (12) and (13) are the co-state equations. Along the optimal efficient path, the rate of return from patch i is given by:

$$\delta = \left[\frac{d\lambda_{it}}{dt} \diagup \lambda_{it} \right] + \left[r_i - 2r_i \frac{(S_{it} - M_{it})}{K_{it}} - \frac{m\alpha}{K_{it}} - \frac{\partial P_{ijt}}{\partial S_{it}} \right] - \left[\frac{\partial C_{it}}{\partial S_{it}} \diagup \lambda_{it} \right] + \left[\frac{\partial B_{it}}{\partial S_{it}} \diagup \lambda_{it} \right]; fori = 1, 2 \tag{14}$$

From the maximum principle and stock dynamics, one can solve for the steady-state equilibrium values of A^*_{it}, H^*_{it} and S^*_{it} as functions of M_{it} and E^P_{ijt}, *inter alia*, if given specific functional forms. It should be noted that E^P_{ijt} is taken by the parks agency as given from some optimisation algorithm of local communities. How does the solution presented above compare to the steady-state equilibrium values which can be obtained from several disjointed national parks?

3.2 *Managing several disjointed national parks*

Without pulling down the fences, there will be no transboundary migration. However, each park will still be assumed to maximise the present value of net benefits NB_i inter-temporally, by using anti-poaching enforcement effort A_{it} and the official off-take H_{it} as control variables. The nature of the problem can be structured and solved as before. While the objective function remains the same, the stock dynamics in the case of several disjoint national parks becomes:

$$\frac{dS_{it}}{dt} = r_i(S_{it})\left(1 - \frac{(S_{it})}{K_{it}}\right) - H_{it} - P_{ijt}(A_{it}, E^P_{ijt}, S_{it}) fori = 1, 2 \tag{8'}$$

Thus, all terms denoting migration drop out due to its absence. Along the optimal efficient path, the rate of return from patch i is given by:

$$\delta = \left[\frac{d\lambda_{it}}{dt} \diagup \lambda_{it}\right] + \left[r_i - 2r_i \frac{S_{it}}{K_{it}} - \frac{\partial P_{ijt}}{\partial S_{it}}\right] - \left[\frac{\partial C_{it}}{\partial S_{it}} \diagup \lambda_{it}\right] + \left[\frac{\partial B_{it}}{\partial S_{it}} \diagup \lambda_{it}\right] fori = 1, 2 \tag{15}$$

From the maximum principle and stock dynamics, one can solve for the steady-state equilibrium values of A^*_{it}, H^*_{it} and S^*_{it} as functions of E^P_{ijt}, *inter alia*, if given specific functional forms. It should be noted that the above solution assumes that E^P_{ijt} does not change from the level presented earlier. Furthermore, in the current case the steady-state equilibrium values are not a function of M_{it}. In particular, a comparison of equations (14) and (15) shows that it makes a difference whether there is a transfrontier park or several disjointed national ones. In equation (14), there are additional terms accounting for transboundary migration. Even though the net migration across the transfrontier park will be zero, there will be a stock effect with transboundary migration which would not exist in cases without such migration i.e.

$$\sum\nolimits_1^2 2r_i \frac{M_{it}}{K_{it}} - \frac{m\alpha}{K_{it}} = 2r_1 \frac{M_{1t}}{K_{1t}} - \frac{m\alpha}{K_{1t}} + 2r_2 \frac{M_{2t}}{K_{2t}} + \frac{m}{K_{2t}} = 2M_{1t}\left(\frac{r_1}{K_{1t}} - \frac{r_2}{K_{2t}}\right) - m\left(\frac{\alpha}{K_{1t}} - \frac{1}{K_{2t}}\right) > 0 \tag{16}$$

With transboundary migration, elephants are likely to reduce the time they spend running away from danger within a restricted area and spend more time breeding in preferred habitats. Thus, without a unified transfrontier park there would be certain stocks in each patch, which yield a certain aggregate stock. However, with the unified transfrontier park there will be migration to that patch where a greater per unit growth will be experienced. Thus transboundary migration potentially yields additional overall growth, for given levels of E^P_{ijt}.

We can point out a typical case in which a transfrontier park would be a better tool for conservation as opposed to several disjointed parks. If patches 1 and 2 are demarcated along political boundaries, then natural migration patterns and breeding grounds might be compromised. For example, patch 1 might encompass the main breeding habitat, but due to political fencing, the species as a whole may not have adequate access to this. This ultimately affects the rate of growth, which would be lowered since migration patterns and breeding grounds are restricted. A single transfrontier park allows for natural spatial dispersal of species by removing artificial barriers and allowing for management according to ecosystem boundaries. This will result in increased biodiversity and a higher stock of animals.[23]

As we have shown above, transfrontier parks make ecological sense. Economically, whether there is a difference between having a transfrontier park or several disjointed national ones will depend

[23] Furthermore, an effectively managed transfrontier park will result in lower running costs due to the scale effect. In the case of a present-value maximising owner, a larger park will have lower overhead costs per person who visits the park, as the owners take advantage of increasing returns to scale on revenues and proceeds. Instead of incurring the same overheads, overheads are split among the different areas proportionately and this increases the net benefits available for distribution, either to the owners for more conservation benefit, or to the local communities to buy out their poaching activities. Considering this scale effect we conclude from a conservation perspective that a single transfrontier park is better than several disjointed national ones.

largely on governance issues as they determine the threat facing the potential incremental stock growth in a unified transfrontier park. If governance institutions remain the same across a unified transfrontier park and several disjoint ones, as in E^P_{ijt} being fixed at a given level, then one should also favour the unified transfrontier park on economic grounds just like the conservationist would. In the steady state, harvest should be equal to growth. The fact that aggregate growth under a unified transfrontier park is potentially greater, must mean that there would be both a higher elephant stock and off-take, and hence more benefits compared with the disjointed-parks case. However, if the governance institutions differ under the unified transfrontier park, such that E^P_{ijt} differs between the two states, then that will also affect both the stock and off-take, in which case a closer look would be needed to determine which way it goes when compared with the disjointed-parks case.

3.3 *Managing a transfrontier park in the presence of heterogeneity of governance institutions*

The governance system in wildlife conservation inevitably involves a number of stakeholders. The actions of all these stakeholders are important determinants of success or failure of conservation. In particular, one of the key issues that impact the success or failure of conservation effort in Southern Africa is the involvement of the local communities. Local communities are considered to be those people who live within and/or around the boundaries of the transfrontier park. They engage in two main activities, agricultural production and illegal hunting. Illegal hunting usually comes as a natural alternative, because of the history associated with the establishment of national parks where local communities where driven away from their traditional lands. It is assumed that the individual members of a particular community have the same preferences and production capacities and thus can be collapsed into one representative agent.[24] However, there are differences between community groups. For simplicity, we assume that the nature of community groups is shaped by the political jurisdictions within which a community is located.[25]

Communities may or may not support conservation. Communities may disrupt conservation effort because it denies them access to agricultural land. Proclamation of conservation areas may involve relocating people to other areas or reducing the size of their farmland. Damage-causing animals also destroy their crops and, in cases without well-defined property rights, communities may have distaste for any governance system imposed on them, with regards to how they may or may not interact with the wildlife around them subject to a sense of ownership, or a lack thereof. It is therefore crucial that in transfrontier park management, the local communities are involved to the extent that their objectives and those of the conservation authorities are synchronised. Without this synchrony, the conflict of interest that would result may cause the conservation objectives to fall short of their potential. In the case of transfrontier parks, this problem poses a bigger challenge than internally contained reserves as, due to their size, there could be significant populations to consider. Management authorities have to find a way to deal with this possible threat to conservation.

The general consensus in the literature is that local people will cooperate with conservation effort as long as they stand to benefit from the cooperation (see Swanson and Barbier 1992; Mangel *et al.*, 1996; Johannesen and Skonhoft, 2004). What is this level of benefit that they require to cooperate? In other words, what are the necessary conditions that should prevail before the locals may be expected to cooperate with conservation efforts? To consider this, it is initially assumed that property rights solely belong to resource owners who maximise inter-temporal net benefits and the rate of return obtained from the park is as in equation (14), shown earlier.

With no community property rights, all forms of community-perpetrated hunting are illegal, but

[24] The same assumptions have been applied elsewhere e.g. Johannesen and Skonhoft (2004).

[25] Furthermore, the way in which political jurisdictions will shape community groups is not necessarily consistent with the way they shape conservation, i.e. it is possible to have a preferred wildlife habitat adjacent to a community which is not supportive of conservation. As in the case of the GLTP, these people actually belong to different countries and the nature of benefits and costs they face from the transfrontier park would be different.

it is impossible for the park authorities to exclude the communities completely. Thus, each community $j = 1, 2$ has two sources of subsistence; i.e. it can exert effort E^P_{ijt} on illegal hunting (poaching the elephant) in the park or use effort E^Y_{ijt} to carry out agricultural production. As mentioned earlier, the poaching related off-take P_{ijt} is a function of anti-poaching enforcement A_{it}, poaching effort E^P_{ijt} and the stock size S_{it}. The imputed value of poached output is $\pi^P P_{ijt}(A_{it}, E^P_{ijt}, S_{it})$ where π^P is the price of illegal harvest. It is assumed that agricultural output Y_{jt} is a function of agricultural effort only.[26] The imputed value of agricultural output is $\pi^Y Y_{jt}(E^Y_{ijt})$ where π^Y is the price of agricultural output. Whichever way effort is used, it is comes at a cost i.e. $C^Y_j(E^Y_{ijt})$ is the cost of agricultural effort and $C^P_j(E^P_{ijt})$ is the cost of poaching effort, where each of these costs is assumed to differ between communities; i.e. there is a difference in the ease with which agricultural production and poaching can be conducted by each community for the same amount of effort.

In order to investigate the effects of governance institutions on conservation, we start from the premise that there exists heterogeneity in governance institutions in the two communities.[27] In the narrow sense, institutions determine the costs associated with resource exploitation. One way of modelling the effect of governance institutions on costs is $C^P_j(E^P_{ijt}, G_j)$ where G_j is an index of the strength of governance institutions and $dC^P_j \diagup dG_j > 0$. However, for clarity of exposition of the role of governance institutions, it suffices to use the simple case where $G_j \in \{0, 1\}$ and $\Delta C^P_j \diagup \Delta G_j > 0$. Thus, we will categorise institutions as either anti-conservation or pro-conservation based on whether they make it easy or difficult for elephant poaching.

It is assumed that $C^P_1 < C^P_2$, which implies that community 1 has anti-conservation institutions as it is prone to extracting more elephant off-take per unit of poaching effort. Similarly, community 2 has pro-conservation institutions. Furthermore, it is assumed that each of the communities will select that allocation of effort between its two sources of livelihood so as to maximise net benefits subject to the total availability of effort in each period (i.e. $E^Y_{ijt} + E^P_{ijt} = \bar{E}$ which implies that $E^Y_{ijt} = \bar{E} - E^P_{ijt}$). Having no property rights over the elephant and therefore no guarantee for long-term hunting access, the communities will not take the stock dynamics into account. Thus, the problem of each community $j = 1, 2$ is to maximise the net benefit NB_j with respect to effort as follows:

$$\underset{E^{\rho}_{\rho}}{Max} NB \ = \pi^Y Y_{jt}(\bar{E} - E^P_{ijt}) + \pi^P P_{ijt}(A_{it}, E^P_{ijt}, S_{it}) - C^Y_j(\bar{E} - E^P_{ijt}) - C^P_j(E^P_{ijt}, G_j) \tag{17}$$

The first-order condition for a maximum is:

$$\frac{dNB_j}{dE^P_{ijt}} = -\pi^Y \frac{dY_{jt}}{dE^P_{ijt}} + \pi^P \frac{dP_{ijt}}{dE^P_{ijt}} + \frac{dC^Y_j}{dE^P_{ijt}} - \frac{dC^P_j}{dE^P_{ijt}} = 0 for j = 1, 2 \tag{18}$$

This can be expressed alternatively as:

$$\pi^Y \frac{dY_{jt}}{dE^P_{ijt}} - \frac{dC^Y_j}{dE^P_{ijt}} = \pi^P \frac{dP_{ijt}}{dE^P_{ijt}} - \frac{dC^P_j}{dE^P_{ijt}} for j = 1, 2 \tag{19}$$

From the first order condition, one can solve for the equilibrium value of E^{P*}_{ijt} if given specific functional forms. When maximising benefits, each community will allocate extra effort to either agriculture or illegal hunting until the marginal net benefits between illegal hunting and agricultural production are equalised. The inter-community poaching levels cannot be easily compared as they

[26] It is true that agricultural productivity varies from season to season, depending on variables such as rainfall, natural disasters, the area under cultivation, fertilizer and pesticides and agricultural effort used. However, given the prevalence of labour-intensive agricultural production in most of the communities in question, the amount of time spent working on the land, i.e. agricultural effort, is the largest determinant of final agricultural output. This assumption allows us to focus on the impact of the community decisions on conservation.

[27] Governance institutions can be broad so as to encompass actions of all stakeholders. However, for simplicity we only define them in very localised contexts of local communities' interaction with wildlife.

depend on so many factors, e.g. productivity of agricultural effort in each community, unit costs of agricultural effort in each community, productivity of poaching effort in each community and for each patch, and the unit cost of poaching effort in each community. However, if we assume away all of these differences[28] except that relating to unit costs of poaching effort in each community, so as to assess the effect of heterogeneity of governance institutions, the difference in the cost functions of poaching effort will entail that community 1 invests more poaching effort than community 2. Thus, community 1 poses no substantial threat to the elephant resource while community 2 poses a greater threat to the elephant resource.

As mentioned earlier, we have deliberately chosen to index patches by i and communities by j as we will demonstrate that community characteristics are not necessarily congruent with patch characteristics; i.e. good communities are not necessarily located adjacent to preferred patches. Thus, the model describes a favourable patch 1, an unfavourable patch 2, a good community 1 and a bad community 2. The favourable patch has higher stock growth effects, which are beneficial to a unified transfrontier park. The good community has pro-conservation institutions, which are potentially beneficial to a unified transfrontier park. Therefore, the presence of heterogeneity of patches and governance institutions opens up the possibility of two conservation outcomes from a unified transfrontier park, depending on whether or not there exists a complementary matching of patches and communities:

- If community 1 lies adjacent to patch 1 (i.e. $j = i$) then a unified transfrontier park will yield more conservation and economic benefits, as more of the elephant resource is adjacent to a good community, and hence gets more protection. Similarly, if community 2 lies adjacent to patch 2 then a unified transfrontier park will yield more conservation and economic benefits as less of the elephant resource becomes threatened by a bad community.

- If community 1 lies adjacent to patch 2 (i.e. $j \neq i$) then a unified transfrontier park will not be beneficial on conservation and economic grounds as less of the elephant resource gets protection from the good community. Similarly, if community 2 lies adjacent to patch 1, then a unified transfrontier park will not yield more conservation and economic benefits, as more of the elephant resource becomes threatened by a bad community.

The physical conditions of patches, which determine whether they are favourable or not, are generally visible. It is usually the existence of possibilities to partner parks with favourable patches which drives calls for unification of international parks. It is also believed that habitat assessments are always conducted before ratification of any such unification proposals. This is usually the case because calls for unification come from conservationists whose expertise lies in the ecological sciences. In our view, an assessment of the compatibility of joining patches on ecological grounds constitutes only one of at least two layers of conservation which need to be considered. Governance institutions constitute the second layer of conservation which also needs to be assessed, so that unification only gets recommended when it would yield successful conservation, as represented by patches of high-conservation potential only being partnered with pro-conservation governance institutions; i.e. the $j = i$ scenario in the model. However, the nature of community governance institutions is not obviously discernible.[29] In the absence of an assessment of governance institutions, there is a risk of blindly supporting an economically and ecologically unproductive creation of transfrontier parks. The governance institutions that are needed for transfrontier parks to be worthwhile economically and ecologically, are those that engineer a social system which sets the costs of poaching at a prohibitively high level, so as not to reverse the gains brought about by the incremental stock

[28] This is likely plausible since both communities live on marginal land. Otherwise it essentially represents the *ceteris paribus* assumption. The additional conditions required for the guaranteed productivity of the transfrontier park are $\frac{dY_{1t}}{dE^P_{i1t}} < \frac{dY_{2t}}{dE^P_{i2t}}$, $\frac{dC^Y_1}{dE^P_{i1t}} > \frac{dC^Y_2}{dE^P_{i2t}}$ and $\frac{dP_{i1t}}{dE^P_{i1t}} < \frac{dP_{i2t}}{dE^P_{i2t}}$. Otherwise the minimum condition is that the sum of their influence should not negate the potential incremental stock growth in a transfrontier arrangement.

[29] Neither can this be successfully assessed by scientists whose expertise lies outside social sciences.

growth generated by unification of national parks. Obviously, such institutions ought to co-exist with other conditions mentioned earlier, i.e.

$$\frac{dY_{1t}}{dE^P_{i1t}} < \frac{dY_{2t}}{dE^P_{i2t}}, \quad \frac{dC^Y_1}{dE^P_{i1t}} > \frac{dC^Y_2}{dE^P_{i2t}} and \frac{dP_{i1t}}{dE^P_{i1t}} < \frac{dP_{i2t}}{dE^P_{i2t}} \tag{20}$$

4 Policy implications

The reason why effort is allocated to poaching at all is that it yields a return and a better one than not poaching. One way of eliminating poaching would be to displace the illegal wildlife-related incomes with legal wildlife-related incomes. As long as the flow of benefits from the legal wildlife-related activities to each community in each time period is greater than the marginal net benefit from their alternative sources of livelihood, from an economic incentive point of view, each community has no reason to disrupt conservation effort. Thus, as long as the resource owner can transfer to the communities a visibly wildlife-based flow of net benefits per season at least equal to the returns from poaching, then this allows communities to maximise welfare and shift their use of effort from anti-conservation to pro-conservation activities.[30] The key aspect is that the communities should see a direct link between conservation and the income flows.

While the transfrontier park generally gets more revenues from the patch with the preferred habitat, some of these benefits would need to be used in those areas where the stock of the elephant is most threatened from human interaction, e.g. where the community costs of poaching are generally lower. Thus, there is a need for inter-jurisdiction transfer of revenues for use in displacing poaching for the general good of the whole transfrontier area. Transfrontier resource management can therefore not be successful in cases where participating national conservation authorities each seek to maximise their own benefits without regard to revenues earned by other partners.

In the GLTP situation, it seems that South Africa is managing to attract more tourists, getting a higher legal off-take and consequently generating more revenues than its two counterparts, Mozambique and Zimbabwe. Ultimately, the transfrontier park arrangement will only be successful in conserving the elephant if some of those revenues earned by South Africa are used in those jurisdictions where more conservation threats are found, even if it were in the two counterparts to South Africa. Thus, for transfrontier arrangements to really work, the whole park must be managed as a single unit with the possibility of inter-jurisdiction revenue transfers between its constituent sub-units. This does not seem to be happening currently and might be a source of the arrangement's future failure. This is likely to happen because of the weak governance institutions on the Mozambican and Zimbabwean sides. For instance, there have been some reports of human communities living inside the park on the Mozambican and Zimbabwean sides. In the absence of clear incentives systems for these communities, they may actually become the conduit of resource leakage and not only threaten the resource populations in their respective jurisdictions, but also those on the rest of the transfrontier park.

The key requirement for the use of the transfrontier funds should be for them to help increase the costs of poaching. In reality there are many ways through which this outcome can be generated. It seems that making disbursements to local communities as part of payments for ecosystems services (PES), benefit-sharing schemes, etc, to enhance their institutions, might work more directly to solve the problem. Using the funds to enhance anti-poaching enforcement in other jurisdictions might also work, but perhaps not in a cost-effective manner.

Despite our focus on the role of governance institutions at a local level, we have also alluded to the fact that there are other conditions crucial for the success of transfrontier parks. Some of these conditions require actions from actors external to the local communities. For instance, governments

[30] Transfrontier parks should be cheaper to manage in areas whose communities face very limited poaching possibilities as compared to communities who have wider such possibilities.

should primarily ensure congruent legislation between countries involved. Disparities in legislation give rise to unequal benefit schemes and this would result in an imbalance of benefits from the transfrontier park. In cases where this occurs, local communities will benefit unequally and this might lead to a breakdown in cooperation in some areas. In the case of the African elephant in GLTP, governments should ensure that all legislations pertaining to the species is the same in all the three countries. Rules pertaining to the movement, control and export of the animals have to be aligned such that there is a common base for operation between the countries involved. Of particular importance are the rights and responsibilities of the local people and their constitutional rights. In cases where constitutions state that the local people may not be moved, complex implications may arise where the area under management has to be increased for greater conservation, for example.

Governments should seek to restore natural ecosystem boundaries and equalise management capacity between the different countries. Between the three countries involved in the GLTP, infrastructural differences are huge and this affects the conservation effort. It results in habitat quality differences, which in some cases will result in lower stock levels. Using the migration functional form assumed in this paper, a habitat which allows for restraint of poachers will have a higher stock of animals. This will lead to less harvesting costs and increased tourism revenue for the park authorities. The area will thus gain at the expense of the other and a breakdown of the relationship may follow.

Governments should align conservation goals between countries. Conservation ideas and approaches vary and this may lead to conflict when the goals of the transfrontier park are different between countries. A country whose elephant population is thriving may be concerned more about efficient extraction of benefits and less about preservation. In such cases there would be conflict and conservation effort will stall. To this effect, government should ensure identical park management regimes. Governments should ensure that all park authorities in the three countries take this view in their management. The same management regimes will ultimately align cost structures and benefit flow, and this will result in cooperation.

5 Conclusion

The conservation of fugitive natural resources across national boundaries poses significant management challenges. This realisation has brought in its wake the creation of transfrontier parks. Indeed, the removal of fences between adjacent international parks might help in the de-fragmentation of wildlife habitats, which has long been recognised as a major cause of biodiversity loss, particularly in literature on large mammals. However, in the presence of governance heterogeneity, the same arrangements create uncertainty about the actual outcome, as the transfrontier arrangements entail that a more diverse range of managers get to make decisions about these resources. This paper formulates a bioeconomic model to investigate and analyse the factors influencing the successful conservation of migratory wildlife across adjacent international protected areas. The paper begins by an analysis of whether it is better to have a single transfrontier park or several disjointed national ones. From a conservation perspective, a single transfrontier park is better, as it introduces a stock effect from transboundary migration, with potentially higher growth rates of species, due to habitat preservation and maintenance of seasonal patterns and breeding grounds. This ultimately increases conservation and biodiversity. However, it is only better, both ecologically and economically, to have a single transfrontier park rather than several disjointed national ones if strong governance institutions exist in high-resource potential areas.

Local communities are an important stakeholder in this conservation effort, without whose support conservation may be difficult, fail to achieve its full potential or merely be a failure. Local communities will thus have to be included in the benefit stream and the paper shows that as long as the stream of benefits from the park authority is greater than the stream of benefits from the alternative sources of income, they would cooperate as they face an opportunity cost for not cooperating. Implementing this successfully requires that the transfrontier park is managed as a single unit with the possibility of inter-jurisdiction revenue transfers between its constituent sub-units.

Lastly, the paper discusses the threshold of governance institutions required for successful management of fugitive natural resources. The governance institutions that are likely to promote the success of a transfrontier park are those which impose high costs for deviant behaviour and equalise the long-run costs and benefits for all constituencies.

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