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ANALYSIS

Opportunistic and conservative pastoral strategies: Some economic arguments

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Abstract

This paper revisits the debate over the relative effectiveness of 'conservative' and 'opportunistic' stocking strategies for African pastoral rangelands. The paper is based on a reassessment of the results of an earlier paper in this journal by Campbell et al. (2000) [Campbell, B.M., Dore, D., Luckert, M., Mukamuri, B., Gambiza, J., 2000. Economic comparisons of livestock production in communal grazing areas of Zimbabwe. Ecol. Econ., 33, 413–438] which argued that the advocacy of opportunistic strategies by the 'new range science' was misplaced. This paper questions some of the assumptions of this scenario modelling effort, both in terms of causal structure and parameter estimates. By developing a mimic model and using data from the same site–a dryland communal area in southern Zimbabwe–this paper shows how the conclusions of the earlier paper were premature. The need for sensitivity analysis in assessing model findings is emphasised if policy conclusions, with potentially major impacts on people's livelihoods, are to be drawn. A brief discussion of the implications of this reassessment, including more broadly the limitations and prospects of economic–ecological modelling in policymaking for rangeland management, concludes the paper.
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1. Introduction

One of the major policy challenges for managers of pastoral rangelands in Africa is what is the most appropriate stocking strategy? This has both ecological and economic implications. There have been numerous contributions to this debate over the past decades, with advocates claiming benefits for both so-called 'opportunistic' and 'conservative' strategies. One recent addition to this has been the paper by Campbell et al., 2000, published in Ecological Economics in the special section on 'Land use options in dry tropical woodland ecosystems in Zimbabwe'. This paper criticised the "new rangeland science" (e.g. Sandford, 1983; Behnke et al., 1993; Scoones, 1995, among many others) on economic grounds, claiming that "opportunistic strategies"

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(ones in which the number of livestock kept by pastoralists or agro-pastoralists fluctuate widely in response to good and bad seasons) do not lead to higher economic returns compared to strategies based on "conservative" stocking rates (in which livestock numbers are kept relatively constant). They particularly criticise the new rangeland science's alleged neglect of the different levels of capital costs of the different strategies.

This paper is written in response, although without access to the original model which was not made available. It identifies several flaws in the Campbell et al. paper and comes to different conclusions. As we show, these are not trivial, and have major implications for rangeland policy. For this paper we have developed a simulation model of the livestock system in the Chivi area in Zimbabwe which mimics as far as possible the model used by Campbell et al. We then alter the assumptions and technical and economic coefficients to ones which, on the basis of a range of evidence from the study area, we believe are more realistic and redo the simulation, comparing its results to the results reported in the earlier paper. Towards the end of the paper, we turn to a discussion of some issues relating to the role of capital costs in the choice between strategies and to the more general question of the limits and potentials of simulation models. We end by drawing conclusions about modelling approaches in rangeland policy and the usefulness of Campbell et al.'s contribution to the debate between proponents of opportunistic and conservative strategies.

2. Methodological approach: comparing scenario models

The basis of Campbell et al.'s paper is a simulation model with four scenarios. In simple terms we can describe their model as follows. The model predicts the size of the livestock herd and the annual value of output from this herd and the associated costs. The simulation model is driven by annual rainfall figures. Costs and outputs are fed into a discounted cash flow calculation to give "present values" both at the start of the period of time, 1981–1995 and for one sub-period within it, 1984–1995. The model is exemplified by data for two sites (a site has a notional 1000 households) and one sequence of years in Zimbabwe. The sites are Mangwende (wetter) and Chivi (drier). For brevity we concentrate on the Chivi case, as it is here that the dynamics proposed by the new rangeland ecology are most likely to apply.

The four scenarios modelled, of which the first two are classified by Campbell et al. as "opportunistic" and the next two as "conservative" are as follows:

i) The "opportunistic scenario". In this case the number of cattle kept is not, as it is in other scenarios, determined only by the rainfall and amount of feed available and by no other consideration (e.g. prices). Instead it mimics the actual numbers kept in the two areas from 1981 to 1995. Otherwise this scenario is modelled in the same way as the others: that is the number of livestock kept determines the output, prices and costs. Outputs, costs and prices are, therefore, "modelled" rather than being the actual ones that pertained during the years simulated.

ii) The "tight-tracking scenario". In this case the numbers of cattle kept are immediately adjusted (by sale/death or by purchase) to the exact rainfall-driven amount of livestock feed available in each year, which is termed "the ecological carrying capacity". Only the ecological carrying capacity and no other consideration determines the numbers of cattle kept.

iii) The "conservative-tracking scenario". In this case the numbers of cattle kept are immediately adjusted downwards when (and to the full extent that) the ecological carrying capacity declines from one year to the next. In this scenario, however, the number of cattle is adjusted upwards, when the ecological carrying capacity increases, to a less extent and less rapidly than in "the tight-tracking scenario". In this conservative-tracking scenario numbers never rise above 80% of the ecological carrying capacity and purchases of animals in any year never exceed 60% of the deficit between the numbers held in and the ecological carrying capacity for that year.

iv) The "conservative scenario" in which the number of animals remains at a constant stocking rate set at 67% of the average herd size permitted by the "ecological carrying capacity".

While use of some sort of simulation model is inevitable in comparing strategies in pastoral areas, there are some particular problems with Campbell et al.'s model, or at least the way they have described and used it. This paper examines these problems systematically through an alternative simulation model. The first problem relates to the nature of the different scenarios. Three of these–the tight-tracking, the conservative-tracking and the conservative scenarios–are homogeneous in the logic of their causal structure. In these scenarios the amount of livestock feed (ecological carrying capacity in their terminology) available is determined, within the model, by rainfall. Livestock numbers are, in turn, determined by these amounts of feed in conjunction with stated rules about how livestock numbers respond to feed availability. Other rules control the relationship between rainfall or livestock numbers and commodity prices, the quantity of outputs and costs.

The opportunistic scenario, however, is of quite a different type. In this scenario the rules controlling the causal relationship between rainfall or livestock numbers on the one hand and prices, output and costs on the other are the same as in the other scenarios, but there is no rule in this scenario about the way that livestock numbers are determined by rainfall. In reality (in contrast to simulation) the livestock numbers were determined in this period not only by rainfall and livestock feed, but also by a number of other factors, including prices and the availability of capital, which are absent from the causal relationship in the other scenarios. Moreover, the supply of livestock feed was, in practice, almost certainly different from that predicted by the crude relationship used in the model. One cannot, therefore, directly compare the results of the opportunistic scenario with those of the others since the ceteris paribus assumptions essential for the validity of such comparisons do not hold.

The "tight-tracking" scenario of the original model can be described as the embodiment of a "hard" version of the argument in favour of opportunism, in contrast to the "soft" version put forward by Sandford (1982). However, the claim that the "tight-tracking" scenario represents the tracking and buffering systems advocated by the new range science as voiced by Behnke and Kerven (1994) is unjustified. In the original model price is not a determinant of stocking level, and stocking levels follow the model's ecologically determined rules, whatever the price. Nothing, however, in the new rangeland science literature, to our knowledge at least, suggests that pastoralists should buy and sell livestock "whatever the price".

Other sources cited by Campbell et al. as advocating the tight-tracking scenario (e.g. Toulmin, 1995) are similarly misconstrued. In the case of Toulmin, the objective she discusses is not "economic efficiency" or "profit maximisation", as it is in the original model, but cost-effectiveness in terms of minimising the capital expenditure of re-establishing pastoral households in independent livelihoods post drought. Her main comparison is between restocking pastoralists' herds and their settlement on irrigation, and Toulmin's conclusions are very cautious in respect to restocking.

The "conservative" scenario as set out by Campbell et al. also presents a problem of plausibility. What is a "conservative" scenario? In their classic text, Box and Peterson (1978) write: "carrying capacity is limited by the harshest period during the climatic cycle. For instance the carrying capacity of the Sahelian desert areas would be limited to the number of animals able to sustain themselves during the driest year of the drought". That is a truly conservative scenario, and in some dry areas currently used by nomadic pastoralists it would, if followed, lead to no domestic livestock at all being kept. In other less harsh areas, however, a conservative scenario that kept cattle numbers constant at "carrying capacity" defined in that way (which is different from the "ecological carrying capacity" of Campbell et al.) might be able to keep yields, production parameters, and income levels positive, but not constant, from year to year.

Richardson (1986:11), adopting an approach also favoured by Sandford (1983:39), has talked of a "mildly conservative" stocking rate in which the ecological carrying capacity is met in 80 out of 100 years, and of a "moderately conservative" stocking rate in which it is met in 95 years out of 100. In areas such as Chivi, with a coefficient of variation in annual rainfall of 40% (and on the assumption of a reasonably normal distribution of annual rainfall and of a linear and positive relationship between annual rainfall and the amount of available livestock feed), this would imply stocking at a rate of 34% or 66% of average (rainfall/feed) for the moderately and mildly conservative stocking rates respectively. This "probabilistic" definition of carrying capacity accepts that "overstocking" will occur in some years (1 in 20 in the moderately conservative and 1 in 5 in the mildly conservative). For every progressively decreasing level of probability set there are "advantages" in terms of not understocking in good years and thereby avoiding the waste of feed unutilised in those years, and corresponding "disadvantages" in terms of the inevitable decrease in animal numbers or yields resulting from overstocking in drought years. The definition quantifies the frequency of disadvantage or advantage but does not quantify their magnitude.

Campbell et al.'s view of conservatism can be assessed with reference to this probabilistic approach. Their conservative scenario is one in which "animals are maintained at a constant stocking rate set at 67% of the average herd size at the ecological carrying capacity" (Campbell et al., 2000:419) which they maintain is the recommendation of the national extension service. This definition is somewhat ambiguous, but in practice (see Campbell et al., 2000:424, Fig. 1) under their conservative scenario cattle numbers are kept constant over the years. In Chivi in 4 out of the 15 years of simulation the actual stocking rate of the conservative scenario is above "the ecological carrying capacity" for that year, as shown by the number of livestock kept in the tight-tracking scenario. This is consistent with a normal distribution of rainfall, a coefficient of variation of 40%, and a stocking rate equal to 67% of average ecological carrying capacity. It is, therefore consistent with the mildly conservative stocking rate as defined by Sandford (1982) and Richardson (1986).

In good years, when all scenarios have stocking rates at or below ecological carrying capacity, one may reasonably expect that there will be little difference in productivity per head between different scenarios, but with possibly some advantage to those scenarios, i.e. the conservative ones, with lower multi-year stocking rates, as a consequence, for example, of better pasture composition (although the evidence presented in Fynn and O'Connor (2000) casts doubt on this multi-year effect). Where stocking rates are above the ecological carrying capacity, however, one expects the productivity (milk yield, growth-rate leading to live sales and meat, and manure yield) of different scenarios to reflect the single-year stocking rate as well as the multi-year average. If that were not the case it is difficult to explain the differences in inter-year calving rates on commercial ranches in Zimbabwe (CSO, 1983:7), or inter-stocking rate differences in per-animal gain elsewhere in southern Africa recorded by Fynn and O'Connor (2000). However, although Campbell et al. allow the absolute values of yields, some technical coefficients (but not calving rate), livestock sales/purchases, and prices to vary between years with annual rainfall, the relative yield advantage accorded by Campbell et al. to the "conservative" rather than "opportunistic" scenarios does not vary. In any year the level of outputs and inputs per head of cattle under the two conservative scenarios are higher than the level for the opportunistic scenario for that year.

In 4 out of the 15 years the stocking rate of the conservative scenario is also above the number kept in the opportunistic strategy. For example in 1993 (Year 13 of the simulation) in our simulation of the base case (medium price variability and high productivity), the conservative strategy has a cattle population 62% higher than the opportunistic strategy, but its yield of milk per animal in the herd instead of being less, due to a smaller amount of feed being generated per animal by that year's rainfall, is actually 82% higher. Campbell et al.'s "conservative" scenario surreptitiously grabs all the benefits associated with the title "conservative", while suffering little of the disadvantage in terms of fewer productive animals or of lower productivity where animal numbers are high.

A further criticism made by Campbell et al. of the economic claims of the new range science is that these are based on simple static (rather than "dynamic") economic comparisons. Their method of rectifying this is to use a multi-year simulation model whose economic results are integrated through the use of discounted cash flow techniques. We are not objecting to this as a general principle. However, Campbell et al. have used only two sets of years (1981–1995) and 1984–1995 (a subset of the previous set) to make judgements about the competing opportunistic (opportunistic and tight-tracking scenarios) and conservative (conservative and conservative-tracking) strategies. In systems where there is great variability over time in the benefits and costs, this can lead to serious error.

Forty years ago Dorfman (1962:129) wrote: "In design and operating decisions the results of which are influenced by chance or unknown factors such as the whims of weather this simplification [i.e. "it is frequently expedient to ignore uncertainty"] is clearly untenable". While exploring and recognising the danger of relying on "expected values" as a decision criterion (in simple form they ignore risk aversion), Dorfman recommended that the calculation of the expected value of net present value should be an essential step in the analysis. The expected value of a variable can be defined as the sum of all the possible values that the variable can take, with each value being multiplied by the probability of its occurrence. The sum of the probabilities is 1. Following Dorfman's advice (although his caveats are often ignored), the use of "expected values" is now fairly common in investment appraisal and is, for example, prescribed in the handbooks for economic analyses of projects in the developing world of both the World Bank and the Asian Development Bank, as well as in the analyses of share portfolios in the developed world's most sophisticated capital markets (Damodaran, 2001).

Particularly in evaluating general strategies for the future through the use of simulations, care is needed to ensure that different scenarios are not arbitrarily penalised or rewarded by the selection of particular input data. In Zimbabwe and elsewhere in semi-arid Africa repeated droughts occur, and account must be taken account of them in the calculations. The major input to Campbell et al.'s model is annual rainfall which is highly variable and may be, to some extent, cyclical with recurring patterns (Tyson, 1979:51; Tyson and Preston Whyte, 2000: 321–322).

What we need is the expected value of the net present value (NPV) of each of the different scenarios. Those net present values are themselves the products of physical inputs, physical outputs and prices. If the NPVs were simply the linear combination of a number of uncorrelated and not grossly abnormally distributed variables, we could use average annual figures for each of them and the result would be the expected value of NPV. But these conditions do not hold.

The textbooks and manuals on economic evaluation (e.g. see World Bank, 1996a; ADB, 2000) foresee the difficulty of discovering the probability distribution of large numbers of variables and recommend that there should be a focus only on the most variable and most important. Following this approach it seems that an appropriate compromise methodology would be to treat the 15 years of available rainfall data as representing a typical recurring weather cycle, thereby capturing some of the correlations involved in bunched runs of wet and dry years; and then to iterate the calculation of net present values, with each of the 15 iterations starting one year later in the cycle than the previous one and adding the previous iteration's "first year" to the end of its own cycle. Each iteration, in this way, involves entering the weather cycle at a different "first year" and results in its own NPV estimate. The mean value of all these years' iterations will then be an approximation to the true "expected" NPV of that scenario. This distinction between relying on the results of a single set of years and calculating "expected values" is not merely theoretical or trivial, as we shall see later in this paper.

3. Results: comparing different simulations

The following sections look at how, with different assumptions about parameters and causal structures, the original model and results presented by Campbell et al. can be questioned on a number of accounts on the basis of simulations run with a mimic model. This raises significant questions about the policy implications suggested in the original paper.

Without access to a working version of the original model, we have had to design our own model based on what Campbell et al. tell us about theirs. Doing so has been time-consuming and difficult. In our model, we maintain the overall causal structure of Campbell et al.'s model in order to be able to make comparison of the effects of changing only one or a limited range of assumptions (although see our reservations about this below). Although the general causal structure of the Campbell et al. model is clear, and the paper provides considerable detail about the chosen values of their technical coefficients (the age and sex structure of the herd is an exception to this), inadequate or ambiguous information is provided in respect of several relationships. In such cases we have had to make "best guesses" or to simplify to some degree (see Sandford and Scoones, 2002 for more details).

Despite this, however, we have sufficient confidence in our model as a reasonably robust mimic of the Campbell et al. version (see Sandford and Scoones, 2002 for a detailed evaluation of the models) to continue to test different scenarios under changed assumptions and parameters. We refer to Campbell et al.'s own model as the "original model" and to our attempt to imitate it as the “mimic model”. The results arising from the Campbell et al.’s model, using their “medium price variability” and maximum “productivity improvement” assumptions, we refer to as the “original model base-case results” and we refer to the mimic mode’s simulation of these results as the “A2 Case”.

Campbell et al. claim (2000:420, 428) that their base-case estimates are conservative and underestimate the true disadvantages of opportunistic scenarios. Our view, however, is that the original model has embedded within it a number of assumptions which lead to an overestimation both of the costs of more opportunistic scenarios and of the benefits of the more conservative ones (“conservative” and “conservative-tracking”, although the latter is not discussed in detail in the present paper[1]). The use of a simulation model to compare and rank strategies makes the correct estimation of the values of the parameters to be used essential. The evidence is strong that many of the values selected in the original model (and copied by our mimic model in the A2 Case), for important parameters in the calculations are inappropriate. We have, therefore substituted, in Cases A3, B3 and B4 (which will each be discussed below) values and assumptions which we believe are more realistic. Cases A3 and B4 are primarily concerned with the issue of diachronic (“through time”, e.g. inter-annual) variability in commodity prices. Case B3 deals with changes in other assumptions and technical coefficients.

3.1. Revisions in price variability

Campbell et al. give three alternative options for the degree of diachronic price fluctuation, with the actual price level of commodities produced in any year being a function of the quantity of output (in most cases) in the year in question and of the degree of price fluctuation. The degree of price fluctuation is expressed in the original model in terms of the range of the ratio between the maximum and minimum annual prices permitted for that commodity, and it has three options for variability, “high”, ”medium” and “no change”.

The degree of variability is of particular importance to range management strategies which, like the tight-tracking scenario analysed here, are heavily dependent on buying and selling animals at the same time as everyone else and where price elasticities of demand are likely to be important. Campbell et al. have chosen the “medium variability” as being their best guess of reality, but give very little space to justifying their choice, although this has a very substantial effect on the ranking of different alternatives.

Dissatisfied with the absence of evidence for price variability as high as that chosen by Campbell et al. as their best guess (their “medium price” variability option), we sought evidence elsewhere. A careful review of that evidence is available in Sandford and Scoones (2002). Our main sources were Scoones et al., 1996 and Zaal, 2000. On the basis of that evidence we substituted in Case A3 our own estimates of variability. Table 1 contrasts the three alternative price options (“high”, “medium” and “none”) of the original model with the mimic model’s A2 Case assumptions of price variability and with those of our own preferred estimate which is used in Case A3. The right hand column of Table 1 also shows our variability assumptions for Case B4 with which we will deal later. In Case A3 our maximum/minimum ratio in the case of live animals and meat is 2.5. We do not maintain that differences between maximum and minimum prices for livestock over short periods of time within a year, and in very isolated markets, never exceed a ratio of 2.5. But the original model uses a time frame of a complete year and it is differences between years in the average annual price which are relevant. Where price variations display higher ratios over shorter periods we believe that at the lowest “disaster” price level relatively few livestock are sold (the low price is a result of the quality of the animals, i.e. their low survivability rather than just of their numbers); and, similarly, high degrees of market isolation tends to be fairly short-lived (see Barrett et al., 2003).

The consequences of this change in assumptions about price variability on NPVs are set out in Table 2.

[1] The “conservative-tracking” scenario is not modelled by us in this paper partly for reasons of space, but also partly because, although Campbell et al. entitle it a “conservative-tracking” scenario, it could equally plausibly be entitled a “constrained opportunistic” scenario. It confuses rather than clarifies the distinction and choice between the two conservative and opportunistic strategies.

Table 1
Inter-year price variability of different commodities between the original model and various cases of the mimic model (the figures represent the ratio between the maximum and minimum annual values)

Commodity	Original model's price variability			Mimic model's price variability		
	High variability	Medium variability	None (variability)	Case A2 (mimics medium variability)	Case A3 option (best guess)	Case B4 option (see below)
Live animals and meat	15	10	1	10	2.5	1.5
Milk	5	3	1	3	2.0	2.0
Manure	5	3	1	3	2.0	2.0
Ploughing	1.5	1.5	1	1.5	1.5	1.5
Transport	1.5	1.5	1	1.5	1.5	1.5

Table 2 has two purposes. Firstly, it compares the results of the original model with case A2 of the mimic model which is supposed to simulate it most closely. As can be seen, in terms of the absolute values of the results the resemblance between them is not very close. The reasons for this are explored and discussed in Sandford and Scoones (2002). However, in terms of the ranking of different scenarios at different discount rates, the original and the mimic produce identical results for original model's base case (medium price fluctuation and maximum productivity improvement) in terms of NPV, capital cost, and proportion of the total value of output constituted by sales of live animals and slaughter.

Table 2
A comparison of the result of the original model[a] and Cases A2 and A3 of the mimic model (figures in Z$ million unless otherwise specified)

Variant/result	Scenario↓	Rate of discount								
		0%			8%			17%		
	Model/Case→	Original	A2[b]	A3[c]	Original	A2	A3	Original	A2	A3
No change: value of NPV[d]	Opportunistic		83	70		31	30	−18	5	10
	Conservative		80	64		34	29	18	13	12
	Tight-tracking		110	136		47	69	−3	35	35
MPI: value of NPV[e]	Opportunistic		28	51	20	−10	15	−7	−3	−3
	Conservative		77	80	47	28	35	58	13	13
	Tight-tracking		−51	31	−110	−60	2	−311	−11	−11
MPI: Capital Costs	Opportunistic		59	28		61	31	146	32	32
	Conservative		25	9		31	16	85	19	19
	Tight-tracking		147	74		117	60	513	51	51
MPI: Slaughter/sales as % of output[f]	Opportunistic	32	52	46						
	Conservative	42	50	42						
	Tight-tracking	38	57	59						

[a] In Table 2 "Original" indicates the published results of the Campbell et al. model. The original paper provided no information about the NPVs at the 0% discount rate and only limited information at the 8% rate.

[b] The A2 Case adopts Campbell et al.'s assumptions about potential productivity improvement and price variability (max. range = 10).

[c] The A3 Case adopts Campbell et al.'s assumptions about potential productivity improvement, but the best guess about price variability (maximum range for live and slaughtered stock = 2.5) is made by the authors of the present paper. The contrast between a maximum range of 10 and 2.5 refers specifically to the maximum range in respect of live and slaughtered animals. When the range for live and slaughtered livestock is reduced from 10.0 to 2.5 the corresponding reduced ratios for other commodities are: Milk and manure = 2. Ploughing and transport = 1.5.

[d] No change variant = both prices and productivity per animal remain constant under all scenarios and discount rates.

[e] The MPI set of results for Cases A2 and A3, run on the mimic model, adopts Campbell et al.'s assumption about maximum productivity improvement. However prices vary both because of different maximum/minimum price ratios between A2 and A3 and because of differences between different scenarios.

[f] In the case of the combined value of output of slaughter and live-sales as a % of all output, it is not quite clear in Campbell et al. (2000) whether the values quoted are undiscounted ones or discounted at 17%. Where value is estimated in % rather than in absolute terms, it makes little difference which discount rate is used.

Table 3
Changes in assumptions and estimates in B3 Case

Initial assumptions/estimates of Original (Case A2)	Revised assumptions/estimates (Case B3)	Comment
Slaughter rate (SR): (slaughter as % of total offtake)		
SR fluctuates inversely with rainfall, but in the conservative, conservative-tracking and tight-tracking scenarios is half the year's rate for the opportunistic scenario, due to "more intensive management".	SR fluctuates positively with grazing pressure (GP—"Threshold variant"). GP is defined as (number of livestock in Yeart)/(1 *ECC_{t-1})+(2*ECC_t)/3; where ECC is annual "ecological carrying capacity". "Threshold" GP has value of zero unless livestock numbers exceed ECC.	Campbell et al.'s formulation penalises dry years irrespective of herd size. This ignores GP. Our formula penalises overstocking in relation to ECC, and introduces lagging of GP in adjacent years. ECC is determined by rainfall, which is exactly tracked by the number of livestock in the tight-tracking scenario.
Milk price (MP)		
MP fluctuates inversely with livestock numbers.	MP fluctuates inversely with quantity of milk produced.	Campbell et al.'s method unfairly helps higher yielding cows of conservative scenario.
Quantity and price of transport work (TW)		
In conservative scenarios livestock are given 25% productivity (per head) advantage (expressed in terms of hours worked per day). This seems to indicate that there is demand for TW but too little supply. However in the opportunistic scenarios the number of days on which livestock take part in TW is tightly capped by Campbell et al., as though problem is lack of demand for TW.	The amount of TW to be done (demand) is positively related to rainfall while the amount done is limited by number both of animals available and of days they work (supply). Workdays are determined by grazing pressure (GP—"Continuous" variant). The higher the GP the more days cattle must spend searching for food rather than transporting. The gap between demand and supply of TW determines its price.	The logic of the original model is not transparent but has an inbuilt bias against opportunistic scenarios. Our revised assumptions assume that the amount of transporting work to be done ("demand") is determined by the amounts of crop biomass (grain and residues) and manure to be moved. All of these are substantially determined by rainfall. Transport of water is also important but its relation with rainfall may be + or −ve. There is no evidence for increased transport productivity per head at lower stocking rate, so we assume productivity is equal in all scenarios.
Quantity and price of manure (MN)		
MN output per head is inversely related to livestock numbers. MN price is also inversely related to livestock numbers. Conservative scenarios produce 20% more manure per head.	MN output per head fluctuates with ECC per head, i.e. the larger the number of livestock per unit of rainfall the lower the amount of MN produced per head. Price of MN is inversely related to ECC (rainfall).	We have found no significant evidence relating to inter-annual fluctuations in manure production. Many factors affect manure output per head, but most important is probably quantity of feed consumed, itself determined by the amount of feed produced and so by rainfall.
Livestock prices		
Livestock prices are inversely related to levels of net offtake (sales+slaughter minus purchases) in all years.	The original model rule applies except in Year 0 and Year 15 when the average price in Years 1–14 is used instead.	See text that follows this table.
Livestock in conservative scenarios have 20% higher price due to quality.	The original model's quality advantage in price in conservative scenarios is abandoned.	There is no evidence that in the communal areas price per kg is related to quality determined by stocking rates.
Milk yield		
There is a milk yield (per cow per lactation) advantage of 40% in conservative scenarios over opportunistic level.	Campbell et al.'s figure of 40% advantage of conservative scenarios is excessive and is reduced to 20%.	The number of livestock in the conservative scenarios is higher than the ECC in 4 out of 15 years, and less than 25% lower in a further 3 years.

Table 3 (*continued*)

Initial assumptions/estimates of Original (Case A2)	Revised assumptions/estimates (Case B3)	Comment
Calving rate		
The (inter-annual mean) calving rate in the conservative scenarios is 55%. The associated rate of growth of herd numbers is 14% per year.	The calving rate in the conservative scenarios is 50%. The associated rate of growth of herd numbers is 12.5% per year.	Both the original model and our mimic use a calving rate of 45% for the opportunistic scenarios. The previous comment relating to milk yield applies also to calving rates.
Slaughter rate		
In years of highest offtake emergency slaughter may account for a maximum of 90% of offtake. This rate of slaughter is twice as high in the opportunistic as in the conservative scenarios.	In years of highest offtake slaughter may account for a maximum of 60% of offtake. The slaughter rate is the same in the conservative and opportunistic scenarios.	The 90% figure is not supported by the study cited by Campbell et al. Stocking rates in conservative scenario are higher than in tight-tracking so the lower slaughter rate for the former can not be justified.

The second purpose of Table 2 is to compare the results stemming from the base-case assumptions about price variability, simulated by our mimic of it (A2), with those of the new assumptions by us (Case A3). The NPVs are calculated under alternative variants: (a) that there is no difference in per-animal productivity between the scenarios (the no change variant) or (b) that the improvements to productivity per head in the non-opportunistic scenarios are according to Campbell et al.'s best guess (the "maximum" improvement level = MPI). Other results, concerning capital costs and the importance of sales of live and slaughtered animals in total output, are also calculated under the MPI variant.

The first thing to note about the comparison of the results of Cases A2 and A3 in Table 2 is that, under the "no change" assumptions (that there are no inter-annual price changes brought about solely by the weather, and there are no inter-scenario differences in unit productivity) the tight-tracking scenario is preferable (i.e. has higher NPVs) to the other two scenarios under both the A2 (price variability range up to 10) and the A3 (range up to 2.5) Cases at all discount rates. This is confirmation of the "weak" argument put forward in favour of "opportunism" in Sandford, 1982. Under the "no change" assumptions the opportunistic scenario is also preferable to the conservative at the lower, but not at the higher, discount rates.

The second thing to note is that the effect of lowering price variability (the maximum/minimum range) in the model from 10 to 2.5 is far greater in the tight-tracking than in the other two scenarios. The difference, in the value of the NPVs, between Case A2 and Case A3, averaged over three discount rates, is Z$65 million in the case of the tight-tracking, Z$25 million in the case of the opportunistic and only Z$6 million in the case of the conservative scenario. Put another way, changing from Case A2 (maximum/minimum ratio of 10, the mimic of the original) to Case A3 (ratio of 2.5, our more realistic assumptions) reduces the value of the difference between the NPVs of tight-tracking and the opportunistic by about 80%, between the tight-tracking and conservative scenario by about 63%, and between the conservative and the opportunistic scenario by 50%. Nevertheless in both the A2 mimic and the A3 adapted mimic cases, when the productivity in the different scenarios are at the levels of Campbell et al.'s "best guesses", the conservative scenario is preferable to both the opportunistic and tight-tracking scenarios at all discount rates.

3.2. Further revisions in technical coefficients and price variability

Case A3 retains most of the assumptions made in the original model and used in the mimic, Case A2, but it reduces the degree of price variability. It leaves untouched Case A2's assumptions about the nature of the relationships between variables (e.g. the effect of changes in cattle numbers on the amount of transport work performed) and about the level of various technical coefficients (e.g. the relative milk yields obtained in the opportunistic and conservative scenarios). In this section we want to examine whether the original model makes assumptions and uses estimates of the values of technical coefficients which systematically discriminate against an opportunistic strategy. In our Case B3, therefore, we adopt Case A3's estimates of the degree of price variability and in addition change some of Case A2's assumptions about relationships and the values of other parameters and productivity in ways which, to us, seem better to reflect reality.

Case B3, then, represents our "best estimates" about relations and values of technical coefficients, based on an extensive review of the literature and our own knowledge of pastoral areas in sub-Saharan Africa. However, in it we mainly maintain the overall causal structure of the original model in order to be able to make comparison of the effects of changing only one or a limited range of assumptions. In Case B4 we also investigate the consequences of reducing price variability further, probably implying substantial government intervention in the market.

The changes that Case B3 makes are summarised in Table 3 which shows both the A2 assumptions and the B3 assumptions. Four of the more complex and significant changes, e.g. the choice of discount rate, the prices to be used in the analysis for livestock at the time of initial acquisition of the herd, the period (years of weather) over which the NPV is calculated, and further changes in price variability are discussed separately. Table 3 gives a very brief reason for each individual change. But collectively the results of these changes, in aggregate ouput terms, appear to be consistent (and more consistent than Campbell et al.'s results are), we would argue, with other evidence about the level of output that can be achieved at different stocking levels in east and southern Africa (see Sandford and Scoones, 2002 for a full justification).

3.3. Changing discount rates

Campbell et al. employ a range of discount rates between 8% and 25%. They select 17% as their best guess on the grounds that this approximates the rate of return from different types of investment within the opportunistic scenario and therefore represents the rate of time preference for rural households. The correct discount rate (see ADB, 2000) is the weighted average of the alternative rates of return that can be earned by different investors and of the supply price of different savers, with the weights being determined by the relative importance of the different sources of funds for the particular investment.

The error lies in assuming that all investment in livestock comes from rural savers and that the actual rate of return earned by them in specific investments is their marginal (rather than intra-marginal) rate. In practice most investment in communal areas' cattle is financed by off-farm employment (Scoones, 1990: 328; Campbell et al., 2002). Alternative real rates of return in others sectors which such resources might have earned in the period range from 0.8% in government stocks through 4% for investment in companies listed on the Zimbabwe Stock Exchange (Dailami and Walton, 1989:23, 31 and 33), through 5% payable to savers on their deposit accounts with banks (World Bank, 1996b: 14), to an undefined figure estimated for direct investment in the small scale enterprise sector which some evidence suggests is less than 12% (World Bank, 1996b:11,14; Kapoor et al., 1997:18). A certain amount of investment in communal areas in cattle does come from rural dwellers. However during the period under review, 30% of these were depositors in savings clubs (Chimedza, 1994) which lost money on their direct investments or earned 5% from deposits with commercial banks. It is difficult, therefore, to justify a time preference discount rate for rural people of 17%. The weight of the evidence favours a discount rate, either on grounds of time preference or of foregone rate of return, of less than 8%.

3.4. Price levels

Campbell et al. assume that the price of live animals, slaughtered animals and meat is negatively related to the net offtake (sales minus purchases) in a year. We have no objection to this rule when applied to the sale of surplus and the purchase of replacement livestock. However, Campbell et al. also apply this rule to the initial acquisition of the herd and its final disposal. That is inappropriate, since it assumes that all cattle herders act simultaneously with each other in buying their whole initial herd at the beginning and in selling their whole herd at the end of the same 15-year period. Such an assumption is simply one of convenience for the calculation of net present values, but has no relation to reality. A by-product of the assumption is that it produces large price swings that are adverse to one of the strategies under evaluation, i.e. to the opportunistic one, because of its high number of livestock purchased initially. To maintain the convenience of a finite 15-year period for calculation but to evade this purely arbitrary penalisation, we have in Case B3 (and B4—see below) used the 14-year average (Years 1–14) price both for the initial acquisition at the end of Year 0 and for final disposal in Year 15. This average price over the 14 intermediate years we take to be the best estimate available of the expected price faced by individual herders in the years of their initial acquisition and final disposal when herders are not forced to act simultaneously.

3.5. The results of simulating the B3 and B4 Cases

Table 4 sets out the principal results of the simulations of the B3 and B4 Cases. The B3 Case represents our mimic model, with its qualified acceptance of the original model's structure of causation, with our assumptions about the nature of the relationships between causes and effects and with our best guesses about the values of the technical coefficients. Case B4 is the same as B3, except that we have used an estimate of the value of the maximum/minimum price ratio for livestock and meat of 1.5, as compared to our best guess (a value of 2.5) of what this ratio would be in the absence of effective interventions by government to stabilise prices. B4 therefore represents the case where government intervenes effectively in the market.

Table 4 shows that, in terms of NPV, in the "no change" single-period variant of both cases (B3 and B4), both the opportunistic and the tight-tracking scenarios are superior to the conservative scenario at all discount rates. The tight-tracking scenario is also preferable to the opportunistic one at all discount rates.

Table 4
A comparison of the results of a revised model with different assumptions about price variability: cases B3 and B4[a]

Variant/Result	Scenario↓	Discount rate							
		0%		8%		12%		17%	
		Price variability option							
	Case→	B3[e]	B4[f]	B3	B4	B3	B4	B3	B4
Single period									
No change[b] NPVs[c] in Z$ millions	Opportunistic	90	82	41	39	28	27	16	17
	Conservative	66	61	30	28	21	20	*13	13
	Tight-tracking	91	84	42	#39	#*28	28	17	18
MPIREV[d] NPVs in Z$ millions	Opportunistic	80	78	*36	36	25	*25	15	16
	Conservative	75	70	34	33	24	23	*15	15
	Tight-tracking	68	84	29	40	19	28	10	18
Expected values									
MPIREV NPVs in Z$ millions	Opportunistic	87	81	#37	36	24	25	14	16
	Conservative	#83	73	37	33	25	23	#15	15
	Tight-tracking	83	91	34	41	22	29	12	18

# Indicates the slightly larger, after taking into account the effects of rounding, of two apparently equal values in comparable *rows* of the table.
* Indicates the slightly larger, after taking into account the effects of rounding, of two apparently equal values in adjacent columns of the table.
[a] In Table 4 all the calculations are done by the mimic model's software.
[b] No change = Prices and productivity remain constant under all scenarios and discount rates.
[c] NPV = Net present value.
[d] MPIREV = Assumes Campbell et al.'s maximum productivity improvement and medium prices variant subject to the described amendments made by us in A3, B3 and B4 Cases.
[e] B3 = Our best guess assumptions about potential productivity improvement and price variability (maximum range = 2.5).
[f] B4 = Our best guesses about potential productivity improvement. However, the B4 estimate about the maximum price variability range for live animals and meat assumes a degree of government intervention in the market which is, in our opinion, not successfully practised in Africa at present.

Table 4 then shows that, in the B3 case of the MPIREV "single set" of years variant for the period 1981–1995 selected by Campbell et al, the opportunistic scenario is superior to the conservative one at 0%, 8% and 12% discount rates, but the conservative scenario is superior to the opportunistic at the 17% discount rate. It also shows how both the opportunistic and conservative scenarios are preferable to the tight-tracking at all discount rates. Further, Table 4 shows that in the B4 case both the opportunistic and tight-tracking scenarios are superior to the conservative, and the tight-tracking one to the opportunistic scenario at all discount rates.

Fig. 1 illustrates, however, for three scenarios and one discount rate, how, under the single set of years variant, the value of the scenario's NPV varies depends on which year one enters the 15-year weather cycle. The "best" scenario (in terms of NPV) is highly unstable with different rounds in the iteration ranking, as "best" depends on the year which is regarded as Year 1 in the weather cycle iteration.

If one enters the 15-year weather cycle (Year 1) in 1981, 1988, 1990, 1993, 1994 or 1995 the opportunistic scenario is best. If one enters the 15-year cycle between 1982 and 1987 or in 1991 the advantage shifts to the conservative scenario; whereas if one enters in 1989 or 1992 the best is the tight-tracking scenario.

3.6. Expected values

As discussed above, we believe that more emphasis should be put on "expected values", and that a step in this direction is to do repeated iterations of a closed cycle of 15 years, using the 1981–1995 annual rainfall data, but with each of the fifteen iterations starting 1 year later in the cycle than the previous one and adding the previous iteration's "first year" to the end of its own cycle. The lowest part of Table 4 shows, in terms of the expected value of NPV calculated in this way, the relative inferiority of the tight tracking scenario in Case B3 and its superiority in Case B4 at all discount rates. In Case B3 the opportunistic scenario has a higher expected value than the conservative at the lower discount rates and a lower value at the higher.

Fig. 1, therefore also shows the "expected values" of the different scenarios calculated in this way. The expected value of each scenario is designated in the figure by an E, e.g. E(Conservative). The expected

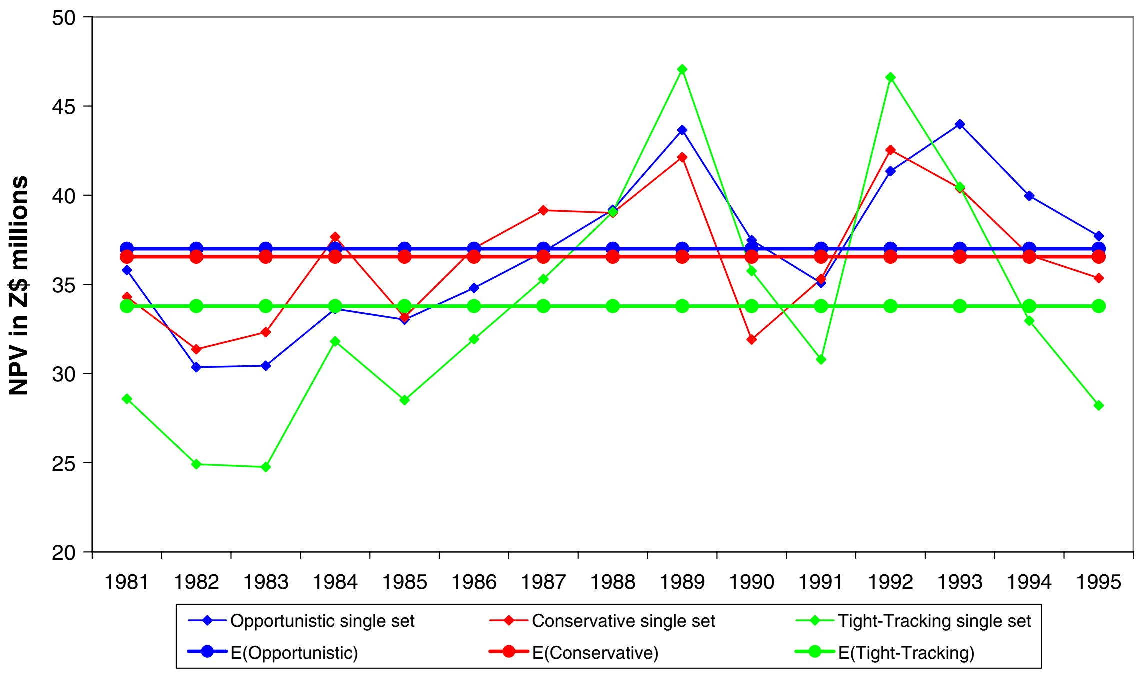

Fig. 1. Expected values of and variations in NPV by scenario and by year of entry to weather cycle (8% discount rate).

value of the opportunistic scenario in this instance is higher than that of the conservative scenario.

This exercise therefore well illustrates the importance of using expected values and how misleading it can be to rely on cost benefit calculations based on a single run of years with an arbitrarily chosen entry date, to evaluate general strategies. We pursue this issue in greater detail below.

3.7. The role of capital costs

Campbell et al. rightly point out that capital costs are by far the most important item in total cost. However, their choice of investment criterion (net present value), in contrast, for example, to criteria which incorporate capital costs into the calculations by averaging interest rates and depreciation/appreciation over a number of years, makes the time profile of the cash flows (i.e. whether they are higher or lower in early or late years) a critical issue. The same applies to the appropriate pricing of inputs and outputs in the early years. How much of the costs are incurred in the early years, and at what price, overshadows what happens later, particularly at the higher discount rates. Campbell et al.'s method of dealing with this issue, however, has severe drawbacks.

For the sake of simplicity Campbell et al. treated the decision situation as one in which the decision to invest was evaluated on the basis of present values at a particular "time zero", i.e. at the beginning of 1981 (to be precise the last day of 1980), or alternately in their other run, 1984. This may be correct for deciding, for example, whether a particular investment (e.g. to build a dam at a certain site) should be undertaken and where the timing of the outputs and inputs is certain. It is quite inappropriate in cases where we are trying to choose between alternate strategies undertaken by a myriad of small-scale livestock holders, when the timing of inputs and outputs is uncertain or where there is a possibility that not all of them invest at the same time, and where many of them have in fact already made the investment at some time in the past. In such cases the decision on strategy will almost certainly not be for all at once to invest in a new herd (implying an enormous inflation in prices as a consequence of the simultaneity). It might be to disinvest out of an old one (involving a downward movement in prices).

We have therefore corrected this oversimplification through the use of "expected values" in a recurring cycle of weather conditions, and by setting the prices of the capital goods (livestock) at the inception and termination of the investment, not at the prices which would obtain if everyone did invest/disinvest simultaneously, but at the average of the prices set by demand and supply conditions in individual years in a long cycle. We have also found that a more appropriate pricing of capital (setting the discount rate) makes a substantial difference to the result of the calculations (see Table 4).

We have accepted the other conditions about the use of capital implicit in the original model, but it is right to comment on some problematic aspects. First, the model assumes that every potential pastoralist investor has unlimited access to capital at a given discount rate. Second, the model assumes that at some price, albeit high, cattle are always available from outside the farm/village/production system being investigated, to replenish depleted herds. Such assumptions may be convenient for modelling purposes, but they present acute problems when one has to relate an abstract model to the field realities of African pastoral settings.

4. Discussion: challenges for ecological–economic modelling

Certain simplifications are, of course, unavoidable if one is to perform an economic evaluation of feasible complexity. However, less defensible is the causal structure of the original model which insulates the outputs of all scenarios, but especially of the conservative ones, from the influence of grazing pressure (the relationship between cattle numbers and the ecological carrying capacity/rainfall). This insulation has the weakness that the size of the sustainable herd in the conservative scenario, but not in other scenarios, is largely independent of the natural fluctuations in feed. This is despite the fact that, in 40% of the years of simulation, the amount of feed produced is less than the amount necessary in the conservative scenario to feed the number of livestock kept, as evinced by the ecological carrying capacity of that year and the fact that conservatively managed cattle are 20% heavier than opportunistic ones. This aspect of the original model puts an implicit, apparently unrecognised, heavy emphasis on the effectiveness of an inter-year "carry-over effect" of feed supplies from good years to bad, a carry-over effect which, regardless of the relative degree of grazing pressure, only applies to the conservative scenario and not to the opportunistic. This insulation, in the original model's causal structure, of feed supply from rainfall in the conservative scenario enables the scenario to maintain, throughout the reiterated simulations, a constant number of livestock, thus obviating the need for distress sales followed by repurchase at a high price.

Another weak aspect of this insulation is that the original model does not have an element in which the calving rate itself is endogenous to the model. In the original model different calving rates are assumed for different scenarios, and then remain constant and independent of the weather. Although the natural growth rate of the herd, which is dominated by the calving rate, remains constant, the proportion of the herd giving milk, however, fluctuates according to the weather, an anomaly not explained by Campbell et al. Yet it is well known that the calving rate is one of the most important determinants of overall herd performance, and that it varies, under all management systems, under the influence of the weather. For example, between 1977 and 1983 the calving rate in the large farm sector in Zimbabwe, which is generally assumed to be pursuing a conservative strategy, as far as this is possible, appeared to vary inter-annually by up to 20% (e.g. between 49% and 59%) by a variety of ways of calculating it (see CSO, 1983:7).

A parallel weakness of the original model is that the age and sex structure of the herd is also exogenous and constant, whereas one of the main adaptations that pastoralists, and also, but probably to a lesser extent, agro-pastoralists, make in time of drought is to vary the age and sex structure of the herd so as to increase the proportion of breeding cows and thus to make possible, when the drought ends, a very rapid rate of recovery in herd numbers from natural reproduction.

As a consequence of the independence of calving rate and herd structure from the weather and other elements in its causal structure, the original model does therefore not provide for the compensatory rise in natural reproduction that occurs when a string of bad years end and are replaced by good ones. Such a compensatory rise enables some of the purchases necessary to restock herd numbers to be displaced by natural herd growth and it favours the lightly stocked (at the time) tight-tracking scenario more than it helps the more heavily stocked (at that time) conservative one.

The result of these three weaknesses of the original model is that all scenarios, and especially the conservative scenario which displays a very high variability of grazing pressure (livestock numbers in relation to contemporary feed supply), have rather low inter-annual variability of output (see Sandford and Scoones, 2002 for further detail). The original model's causal structure, leading to preferential insulation of the conservative scenario, has also prevented us from showing that, as the variability of the environment increases, so the balance of profitability swings in favour of more opportunistic strategy.

In our mimic model, as explored above, we followed the basic causal structure of the original model with limited deviation from it when their assumptions and choice of parameters seemed to have gone seriously astray. We have been able, in respect of the manure output and slaughter rate (as a percentage of offtake), in Cases B3 and B4, to partially rectify the insulation of output from grazing pressure, but these partial rectifications are small in relation to the array of other problems we have identified.

5. Conclusion

The simulation models used by both Campbell et al. and ourselves have enabled the analysis of many of the consequences of adopting different strategies and of different estimates of technical coefficients. The original paper has, in our view, performed a useful service in reminding us of the importance of capital costs, and of the merits of using the related concept of net benefits, after allowing for these costs for evaluating investment opportunities. We agree with Campbell et al. that, in contrast, the use sometimes made of the concepts of gross output, or of net output (gross output less recurrent costs) can lead to the misleading results.

Our failure to reproduce exactly the results of Campbell et al.'s calculations, when we use the same assumptions and estimates as they do, is, however, disturbing. It shows either the extreme sensitivity of the original model to slight and unnoticed changes in assumptions or else its vulnerability to user errors. These can easily arise because its complexity, due to its size (but not its computational techniques) which makes errors very difficult to detect. What our exploration does suggest though is the need to exercise extreme caution in the use of simulation models where parameter sensitivities have not been rigorously tested and where assumptions are deployed for analytical ease rather than on the basis of ground realities.

If modelling is to have a role in policy-making, as it must in complex, highly variable settings such as the pastoral areas of Africa, it has to be based on a firm understanding of pastoral dynamics and a sound empirical base. Inevitably there have to be compromises between a highly sophisticated model, which accurately reflects the underlying ecological and economic relations, and a model which is simple enough for policy-analysts to operate and for policy-makers to understand well enough to trust the results. As we have shown, the Campbell et al. model is flawed, both in theoretical (structure of causation, use of single periods in calculation of NPVs) and practical terms (the logical incomparability of the opportunistic with other scenarios, the choice of technical coefficients).

We would argue, therefore, that the policy conclusions drawn in Campbell et al.'s paper with regard to the relative benefits of opportunistic and conservative strategies should be viewed with some caution and scepticism. Our use of a model with more realistic assumptions and technical coefficients comes to different conclusions, with major implications for what appropriate policy interventions might be.

However, neither the original model, nor our version of it, are sufficient to adequately explore the effect of changes in environmental variability on the merits of conservatism and opportunism. At this point, we do not know whether the conclusions of a similar economic simulations, but based on more sophisticated weather–plant–animal interactions (see, for example, Hahn et al., 1999) would lead to different conclusions about opportunism and conservatism. Before jumping to premature policy conclusions on the basis of inadequate or misleading models, we would argue strongly for more analysis of the ecological and economic interactions that shape the dynamics of Africa's communal rangelands.

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