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A stochastic approach to evaluating livestock marketing policy initiatives

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The problems of pastoralist livestock marketing systems in East Africa are well-documented in the literature. They include poor transport infrastructure, inadequate market access and frequent rejection of animals at certain markets. Thus far, few studies have analyzed the effects of eliminating these problems. This study was based on household and market survey data from the community of Il Ngwesi in the Laikipia district of Kenya. Our decision analysis framework for pastoralist livestock producers uses a stochastic simulation model to evaluate how policies that mitigate these marketing problems affect pastoralist incomes and marketing patterns. We find that three of the five hypothetical policy simulations yield statistically significant improvements on the baseline marketing scenario.

Keywords: pastoralism; livestock marketing; marketing systems; marketing patterns; decision analysis framework; stochastic simulation; sub-Saharan Africa

Les problèmes des systèmes de vente de l'élevage pastoral en Afrique de l'Est sont bien documentés dans la littérature. Ils incluent une infrastructure faible en matière de transport, un accès au marché inadéquat, et le rejet fréquent des animaux dans certains marchés. Jusqu'à présent, peu d'études ont analysé les effets que produirait l'élimination de ces problèmes. Cette étude s'est basée sur les données d'une enquête concernant les ménages et le marché dans la communauté de Il Ngwesi du district de Laikipia, au Kenya. Notre cadre d'analyse de la décision pour les éleveurs de bétail utilise un modèle de simulation stochastique pour évaluer la manière dont les politiques qui réduisent ces problèmes de vente affectent les revenus pastoraux et les modes de marketing. Nous nous apercevons que trois des cinq simulations de politiques hypothétiques améliorent de manière significative le scénario basique du marketing.

Mots-clés : *pastoralisme ; vente de bétail ; systèmes de vente ; modes de marketing ; cadre d'analyse de la décision ; simulation stochastique ; Afrique sub-saharienne*

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1. Introduction

For many pastoralist households in East Africa, selling household livestock is the primary method of monetary income generation. At the same time, households are reluctant to sell livestock because of their utility as food sources, stores of wealth, and status. When sales are conducted, maximizing income from the sale is essential to meeting household consumption smoothing needs. Many past development efforts aimed at pastoralist communities attempted to either circumvent or substitute for existing livestock marketing outlets in an attempt to increase household incomes. Though well-intentioned, such approaches were often costly and unsustainable and had little measurable impact on the targeted communities (Swift, 1991; Hodgson, 1999; Fratkin, 2001).

Pastoral communities are beset by many problems, including lack of access to transport, infrequency and unavailability of profitable markets, unavailability of established prices based on the market mechanisms of supply and demand, and the frequent rejection of animals by certain markets (McPeak & Little, 2006). While an extensive literature has documented these problems, little research has been done on the effects of eliminating them. A better understanding of how pastoral communities can improve marketing is essential if government and extension services are to develop effective livestock marketing improvement policies. Adequate data for evaluating the impact of policies are often lacking, but where data on current livestock marketing mechanisms are available, it is possible to analyze the effects of proposed policies for maximizing pastoralist livestock sale returns *ex ante* by incorporating uncertainty into stochastic profit maximization models.

This article evaluates the effect on pastoralist incomes and marketing patterns of policies that mitigate some of the marketing problems mentioned. In pastoral marketing systems, any policy that reduces transaction costs, increases market access or limits market risk can have positive effects for producers. To assess the effects, we develop a decision analysis framework for pastoralist livestock producers using a stochastic simulation model that relies on marketing data from pastoralists in the community of Il Ngwesi, Kenya.

We simulate three policies that address some of the main problems faced by pastoral communities: (1) improved access to transport, (2) increased access to more profitable markets and (3) decreased risk of not making a sale. Better transport to market would reduce opportunity costs for producers and make more distant markets with increased demand accessible, but the benefits might be offset by additional costs (such as vehicle operating costs). Increasing the frequency of more profitable markets, *ceteris paribus*, could also increase producer incomes by offering a larger variety of sale outlets each week, but the magnitude of the change in income may not make the policy change worthwhile. Reducing the likelihood of not selling once a producer has reached a market would probably increase a producer's expected return from a sale and could encourage producers to trek their animals to more distant, but higher-priced, markets. The introduction of market auctions would be one avenue that could reduce no-sale risk by ensuring that all producers and buyers have equal access to information, thus reducing the possibility of buyer collusion. Aside from these generic policies, we also test the effects of two community-specific scenarios for a community-run marketing program whose objective is to increase producer income. These are: (4) increasing the prices offered by this program and (5) changing the sale risk of this program. Our results show that most of the hypothetical policy simulations yield statistically significant improvements in the marketing mechanism from the baseline scenario that represents the existing problems in Il Ngwesi.

Our analysis uses data from Il Ngwesi, but our strategy could easily be extrapolated to many pastoralist communities in East Africa. Using stochastic analysis including risk components, policy impacts can be tested in a theoretical framework before money is spent on implementing programs. Development efforts can thus be directed toward those approaches most likely to generate significant income changes without changing the underlying dynamics of pastoralist marketing systems.

In the next section we present an overview of pastoral operations in Il Ngwesi, with an emphasis on some of the problems faced by community members. We then explain the approach used to model community livestock sales and we describe the data used in the model. This is followed by the results and interpretation of the policy simulations, and the paper concludes with policy recommendations.

2. Background

Like most pastoralist communities of Kenya's northern rangelands, most of the people of Il Ngwesi are impoverished, hold few non-livestock assets, have limited access to wage-earning employment and keep only a small number of livestock. In late 2007, half of them owned fewer than eight cattle and 68 smallstock (Baldwin, 2008). The primary method of income generation for most households is livestock sales. However, as Barrett et al. (2003) note, because a household's primary goal is to maximize the size of its livestock herds, most animals are sold for household consumption smoothing purposes and not in response to market prices. Income from livestock sales is most often used for food, school fees or healthcare. For these reasons, raising producer income from such sales should be a common goal of development projects in the region (McPeak & Little, 2006).

Currently, livestock marketing efficiency in Il Ngwesi is hampered by several obstacles. Principal among these is the poor condition of regional infrastructure. Producers almost universally trek their animals to market, walking for hours or even days. In the rainy season, many of the roads become impassable. Once producers arrive at the market, they are often subject to buyer-broker collusion, resulting in low sale prices. This collusion, combined with the unpredictable nature of supply and demand at area markets, often means that producers do not make a sale or are subject to hold-ups that lead to extremely low prices. At the markets around Il Ngwesi, producers reported that nearly 30% of their trips to market did not result in a sale. Nevertheless, some area markets are known for attracting more buyers and thus offering higher price distributions. Indeed, Bailey et al. (1999) concluded that much market price variability is linked to either variations in animal quality or individual market characteristics.

The producers of Il Ngwesi have the choice of participating in eight main marketing chains in the area. These offer a variety of potential returns but also involve a range of costs and no-sale risks. Extremely risk-averse producers can sell to their neighbors at a much reduced price, to a local butcher for a price based largely on the animal's approximate weight, or to an itinerant trader. By selling to traders who visit their homes, producers get a lower price than they would at the market but avoid the cost of trekking the animal to market and the risk of not selling it. The local livestock markets at Dol Dol, Isioli, Meru and Nanyuki offer higher prices than the others, but the transaction costs and no-sale risks may cancel out the advantage. At Dol Dol sales are held only once every two weeks. In the urban center of Isiolo they are held twice a week. There are several small markets outside of Meru town, the largest

being the Kianjai market northeast of the town, where sales are held twice a week. These markets are organized by county officials and sales take place via dyadic negotiations between producers and buyers or brokers. Nanyuki is a large urban center but it does not have an organized market because there are many smaller organized markets surrounding the town. However, sales do take place daily outside the town's slaughterhouse.

Pastoralists of Il Ngwesi also have access to a livestock marketing program sponsored by the Northern Rangeland Trust (NRT) 'Linking livestock markets to wildlife conservation' Ol Pejeta Ranch buy-and-fatten program. This initiative seeks to increase the community's livestock sale incomes by offering producers a fixed price per kilogram for their cattle, with no risk of not making a sale because all animals are accepted. Cattle are then fattened on the nearby Ol Pejeta Ranch, slaughtered, and sold at a premium to the local beef marketing chain.

While this program certainly reduces market sale risk, there may already be other ways of increasing producer income within the Il Ngwesi livestock marketing chain. During household interviews conducted in the community and with NRT and Ol Pejeta Ranch management, several research participants shared their ideas about ways to increase livestock sale income. At the same time, organizers of the NRT Ol Pejeta program were considering making alterations to the community program. Among the interviewees' concerns were the lack of access to a truck for livestock transport, the infrequency of profitable markets, the high level of no-sale risk, possible collusion between buyers, the optimal fixed per kilogram market price offered at the Ol Pejeta program, and the possibility that Ol Pejeta might reject some animals in order to make the program more profitable. More details about each of these concerns follow.

Poor local infrastructure and lack of transport make it difficult for producers to seek out distant markets offering higher cattle prices. While the opportunity cost of several days of trekking is small compared to the sale price of cattle, many producers are not willing to make the effort required for these long trips, given the risk of not selling their animals once they arrive. But if transport were made available to shorten the time, time costs would be reduced and the round trip transit time would decrease to less than one day for all markets. There would, however, be an added cost for operation and maintenance of a vehicle by any NGO or benevolent donor.

The infrequency of markets is a major concern. While Dol Dol market offers some of the highest prices seen in the markets available to Il Ngwesi producers, its no-sale risk, great distance, and the fact that it is held only every second week means that only producers living close by sell there. If the market occurred weekly, as do the other major markets, then producers might choose to use it more often and incomes could be improved.¹

At some markets around Kenya, livestock auctions have been implemented to reduce perceived market collusion by buyers and significantly reduce the risk of not selling. Indeed, Green et al. (2006) recommend the implementation of auction mechanisms as one way to increase marketing transparency and reduce the possibility of collusion.

At first Ol Pejeta planned to offer a higher price than the surrounding markets, but this was eventually changed in favor of offering an average but stable per kilogram price. This is still

¹ Households often need cash at short notice (e.g. for health emergencies) – they cannot plan two weeks in advance. If the market was offered weekly, then there is a greater probability that it would fall within their time constraints.

a big improvement on the typical market. It removes uncertainty because sales are guaranteed and the only factor that determines price is weight – not bargaining power, market characteristics or animal condition. Nevertheless, many interviewees felt strongly that the buy-and-fatten program should be offering higher prices to increase participation. A price premium would certainly improve producer incomes, but by how much is uncertain and the higher prices would harm the program's overall profitability.

The program's organizers have also considered restricting the type of animals they will accept, to increase the buy-and-fatten program's profitability. In such a case, they only purchase animals with a very high likelihood of being finished and sold for a profit. It is unclear how such a restriction would affect the volume of animals marketed into the program, or how this change would alter the stability of producer livestock sale incomes, because it introduces an unknown no-sale risk where previously none existed and of a type that cannot be extrapolated from observations in other markets.

We analyze a series of hypothetical policies that address the above concerns. While the effectiveness of some of these policies could be ascertained from field trials and experimentation, the detailed marketing data from Il Ngwesi provides a unique opportunity for ex ante simulation analysis.

3. Model

As previously explained, pastoralists face multiple dimensions of uncertainty when choosing to market animals. Several studies have used the capital asset pricing model (CAPM) developed by Sharpe (1964) to assess market equilibrium and portfolio performance when faced with multiple choices (Fama, 1972; Fama & Macbeth, 1973; Bollerslev et al., 1988; Fama & French, 2004). Portfolio theory assumes that a producer's choice is based on the expected returns and the uncertainty associated with each transaction during a given period. The producer's marketing objective is assumed to be to maximize his expected sales profit. Pastoral producers have the choice of marketing their animals at several different venues. We follow Tani (1978) and define the pastoral producer's decision problem by two variables, the decision variable d , which represents the alternative marketing venues, and an outcome variable v , which represents the consequences of their choice of market. We assess for each alternative market d the conditional probability distribution of outcome v given d .

The expected utility (u) of each sale's profits is determined by

$$u_d = \int \{v | d, \epsilon\} u(v) \quad (1)$$

where the optimal alternative d^* is determined by the choice with the highest utility and ϵ is the level of risk associated with the decision.

The sale profit is represented by a set of variables called the 'state variables', denoted by vector s where

$$\delta(v - g(d, s)) \approx \{v | d, s, \epsilon\} \quad (2)$$

It follows that the sale profit can be generated by the following expansion equation 3 as a deterministic function:

$$\{v | d, \varepsilon\}_k = \sum_s \delta(v - g(d, s)) p(s). \quad (3)$$

where the uncertainty about the future behavior of the state variables is expressed as a discrete probability function $p(s)$. However, Anderson (1972) argues that a deterministic approach to modeling this problem is not appropriate because of the uncertainty associated with some of the factors determining sales profit. We therefore employ a full model approach in equation 4:

$$\{v | d, \varepsilon\}_k = \int_s \{v | d, s, \varepsilon\} \{s | \varepsilon\} \quad (4)$$

where the discrete distribution is used to approximate the continuous distribution on the state variable s : $s | \varepsilon \approx p(s)$

Since our aim is to maximize the producer's expected sale profit, we determine that the potential profit at each market is a function of the following state variables (s): transaction costs associated with trekking to each market, the potential sale price at each market, and the expected price, incorporating the risk of not selling at each market. Transaction costs are determined by the distance to market, the trekking rate, and the opportunity cost of the time spent trekking. The model's goal of expected profit is the result of expected sale revenue (taking into account price distributions and the risk of not making a sale) minus the transaction costs involved in trekking to market.

We employ a stochastic Monte Carlo simulation approach as defined by Davis and McKeown (1984), using @Risk to model household marketing decisions under the expected profit maximizing behavioral assumption. As suggested by Kall and Mayer (2005), price and sale probability distributions for each market are drawn directly from interview data, described below.

4. Data

Data for this analysis come from both household and market surveys conducted in August–December of 2007 in and around the community of Il Ngwesi in the Laikipia district of Kenya. Potential marketing options were identified during interviews with more than 200 community households. Each market identified has specific characteristics that make it potentially more or less profitable based on distance, no-sale risk, frequency and expected sale price distributions.

Deterministic values were used to calculate approximate transport costs for each of the major markets (neighbors, Meru, butchers, Dol Dol, Isiolo, traders, Ol Pejeta and Nanyuki). An approximate distance from a central point of Il Ngwesi to each of these places was calculated using Google Maps. This distance was then multiplied by an estimated trekking rate of 4.8

km/hr to obtain an approximate number of hours for the duration of the trek to each market.² Using the number of hours, an estimated number of days for the round trip was calculated, taking into account the terrain that a trekker would face. We then multiplied the estimated number of days spent trekking by the average day laborer wage of 200 Ksh in order to obtain an opportunity cost of trekking to market.³

Prices for each of the markets used by Il Ngwesi members were simulated in @Risk using a triangular distribution (minimum, median and maximum price) of observed market sale prices. We chose a triangular distribution for several reasons. First, at some sale locations there were few observations, such that using a log-normal distribution would not accurately capture the probabilities over a range of prices. Second, the distribution could be easily understood by pastoralists and feasibly used by them to determine a likely sale price for their animal at each market. Indeed, our model assumes that producers do have approximate information about these distributions for each point of sale. We chose not to correlate these price draws because much previous work has concluded that prices in spatially different but temporally similar locations are not well-integrated (Fafchamps, 1998).

In addition, producers are aware that each market carries its own risk of not making a sale. We calculated this value by asking producers at each market how many of their trips to that market had not resulted in a sale. The average percentage of these answers was then recorded as the 'no-sale risk' for each market. The frequency of each market is also considered in this step by dividing the no-sale risk by the number of market occurrences per week. Thus, high-risk markets that occur often appear more attractive, in terms of expected profit, than high-risk markets that occur less often. Using all of this information, producers consider the risk, sale frequency and price distribution in order to calculate an expected sale price for each market. Some markets, such as selling to neighbors, traders and butchers, have no risk, so the producer is ensured of making a sale, although probably at a lower price.

The fixed transaction costs calculated earlier are then subtracted from the expected revenue and the model decides at which market a sale occurs based upon the maximum expected profit. Once this decision is made, the probability of selling or not selling at the market is calculated using a binomial distribution. If a sale is made, then the net profit is calculated using a separate draw from the triangular price distribution.

5. Simulation results and discussion

Before simulating the effect of policies that address some of the interviewees' concerns, a baseline scenario was first calculated from the model on the basis of the survey data (see Table 1). This baseline scenario contains both the percentage of total community sales destined for each marketing outlet and the expected individual producer sale profits from the simulation. Because of the lack of literature exploring the issue of no-sale risk once a producer arrives at a market, the predictive accuracy of the model is internally validated against the sale frequencies observed in our data. The model accurately predicts market use by +/- 10% for all destinations, with all deviations being explained by characteristics not captured in the model, such as animal condition, unobservable value in selling to certain

² This rate was calculated on the basis of interviews with community elders to discover how long it takes to trek a known distance.

³ At the time of our interviews, the approximate exchange rate was 68 Ksh per US dollar.

markets (such as the value of maintaining a close social network in the community by selling an animal to a neighbor at a low price), or a lack of awareness of the existence of some marketing outlets.⁴ As happens in reality, most sales are made close to the community at outlets that carry no risk of not making a sale (neighbors, butchers, traders and Ol Pejeta).

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Table 1: Baseline market usage

	Simulated market decisions							
	Neighbor	Meru	Butcher	Dol Dol	Isiolo	Trader	Ol Pejeta	Nanyuki
Simulated baseline	2%	3%	7%	0%	27%	30%	27%	4%
Observed	5%	3%	16%	5%	23%	23%	18%	5%

Note: Simulated sale profits (in Ksh) were:

Mean: 15,783.86

Std error: 176.42

Median: 16,845.24

Furthermore, while external validation was not possible, the conclusions of several similar studies substantiate our findings. For example, other studies have looked at the relationship between transport/transaction costs and market choice. Bekure and Chabari (1991) found that closer markets were generally preferred to distant ones. Despite knowing that a better price could be obtained by trekking an animal to market, 95% of producers in their study chose instead to sell their animals to a trader or other intermediary.

Some research has also been done on price differences between markets. Barrett and Luseno (2001) found that for cattle destined for slaughter (large males or older females), there was a big difference between the price offered at the primary market and that offered for the same type of animal at a terminal market.⁵ Furthermore, this difference was highly variable. This reinforces the behavior observed in our model – the highest prices are offered at terminal markets such as Isiolo and Meru, but these markets also exhibit the greatest price volatility. Overall, while the marketing choices observed in the baseline scenario may differ slightly from those made in reality, the baseline model is sufficiently robust for our analysis of changes in market usage and producer profits.

⁴ The discrepancy in Ol Pejeta sales between the simulation and the observed value can be attributed to community households' lack of information about the program. Our surveys were based on the 2006 sales year when this program was just beginning. Many households in isolated regions or in places lacking well-connected leaders were probably unaware of the opportunity to sell animals to Ol Pejeta at the time of the survey. Had they known about the opportunity, it is likely they would have sold more animals to the program. This hypothesis is reinforced by more recent anecdotes from the community suggesting that sales to the program have increased for all areas of Il Ngwesi.

⁵ This is the last market in the chain before the animal is slaughtered. Typically animals are sold several times, starting with local markets or traders, and then again at a second market and perhaps a third. Terminal markets are typically in large towns or cities.

Policy simulations

The direction of the change in producer profits from the baseline scenario are all as expected (Table 2), but the magnitude and significance of those changes vary. In addition, some scenarios motivate drastic changes in community cattle marketing patterns (Table 3). An evaluation of the results from each proposed policy scenario follows.

Table 2: Simulated producer sale profits

Scenario	Mean profit	Change from baseline	Standard error	Change from baseline	Median profit	Change from baseline
(1)*	15,876.60	92.74	176.04	(0.38)	16,922.59	77.35
(2)	15,716.50	(67.36)	186.01	9.59	17,071.65	226.41
(3)**	16,769.76	985.90	163.56	(12.86)	17,601.56	756.32
(4)**	16,497.20	713.34	182.06	5.64	17,338.18	492.94
(5)**	14,457.43	(1,326.43)	182.74	6.32	15,799.50	(1,045.74)

Notes: * and ** represent significance at the 5% and 1% thresholds, respectively.

Scenarios listed in the table are:

- (1) Improved access to transport,
- (2) Increased frequency of a highly profitable market,
- (3) Decreased no-sale risk at all markets in the area,
- (4) Increased fixed price per kilogram offered by Ol Pejeta, and
- (5) Not all animals accepted by Ol Pejeta.

Table 3: Simulated community marketing patterns

	Neighbor	Meru	Butcher	Dol Dol	Isiolo	Trader	Ol Pejeta	Nanyuki
Baseline	2.0%	2.9%	6.9%	0.2%	26.7%	29.5%	27.4%	4.4%
(1)	1.8%	3.9%	6.9%	0.5%	25.2%	27.9% ^b	27.4%	6.4% ^a
(2)	1.4%	2.2%	5.0%	11.2% ^a	24.2%	26.7% ^b	25.9%	3.4%
(3)	0.8%	4.2%	3.2%	9.1% ^a	31.9%	22.6% ^b	22.9%	5.3%
(4)	1.7%	2.3%	5.6%	0.2%	23.8%	25.7% ^b	36.9% ^a	3.8%
(5)	3.0%	4.3%	11.7%	0.7%	33.8%	39.1% ^a	0.5% ^b	6.9%

Notes:

^a signifies the market that gains the most sales under this scenario

^b signifies the market that loses the most sales under this scenario

Scenarios listed in the table are:

- (1) Improved access to transport,
- (2) Increased frequency of a highly profitable market,
- (3) Decreased no-sale risk at all markets in the area,
- (4) Increased fixed price per kilogram offered by Ol Pejeta, and
- (5) Not all animals accepted by Ol Pejeta.

Scenario 1: Improved access to transport

To address the issue of transport access, we assume that a truck is provided free of charge to the community and round trip transit times are adjusted accordingly. The transit time to neighbors and traders remains at zero, trips to butchers and the Ol Pejeta buy-and-fatten program at Lewa are reduced to half a day, and trips to Meru, Dol Dol, Isiolo and Nanyuki are reduced to one day. We assume that all costs are covered by a benevolent donor and are not the producers' responsibility.

The reduction in transport time cost results in a predictable increase in the usage of more distant, but more profitable, markets. Usage of Meru, Dol Dol and Nanyuki increase by 1%, 0.3% and 2%, respectively. Most of this volume comes from reduced marketing to traders and at Isiolo. While market choices are altered in this scenario, changes to producer profits are small. Mean profits increase by 93 Ksh per head, or about half of one day's wage. This positive change in mean profits is statistically significant, and median profits also increase in the time-cost scenario. From a distributional standpoint, the free use of a truck appears to generate a spread-preserving shift in the mean net return per animal sold, assuming a relatively symmetric distribution of net income.

Though our scenario assumes that the cost of operating and maintaining the truck would not be borne by producers, the costs of this policy to an NGO or benevolent donor may outweigh the sparse benefits gained by producers. The cost of a new truck for hauling approximately five cattle at the time of the study was estimated at 5 million Ksh, while fuel costs alone would be 26.25 Ksh per kilometer at 2008 diesel prices. In fuel alone, a trip to Meru, estimated at 65 km from a central point in Il Ngwesi, would cost 1,706.25 Ksh. The truck would have to haul 18 cattle to break even in fuel costs, but our hypothetical truck is only designed to hold five. The bottom line is that this scenario would be costly and provide only marginally higher producer returns.

Scenario 2: Increased frequency of a highly profitable market

To simulate the increased frequency of a highly profitable market, we adjust the market frequency of Dol Dol (the market where the highest sale prices were reported) from once every two weeks to once a week. This adjustment is made *ceteris paribus*, though holding the market weekly would possibly change market volumes and affect the sale price distribution.

As predicted, this change causes sales at the market in question (Dol Dol) to jump from less than 1% to over 11%. Most of the lost sales come from traders and Isiolo, though all markets lose part of their volume. Although sales are shifted toward a higher-paying market, the change has little effect on the bottom-line profits of producers. Mean profits per head in this scenario are not statistically significantly different from the baseline. Overall, the increase in frequency of the Dol Dol market shuffles around the market choices that producers make but has little overall effect on producer income.

Scenario 3: Decreased no-sale risk at all markets in the area

This scenario is simulated by reducing the no-sale risks of all markets by 50% compared to the baseline scenario. We take this 'all-or-nothing' approach because it is likely that if one market makes the change to an auction format, then the other local markets will soon follow because they would lose animal volumes to this 'fairer' market structure. As in the previous

scenario, this change in market risk is made *ceteris paribus* although a decrease in no-sale risk would probably affect the price distribution.

A decreased no-sale risk, such as could be brought about by the introduction of livestock auctions in place of dyadic negotiations, changes the dynamic between all markets involved in the model. Sales increase at all of the previously risky markets, with a dramatic shift toward sales at Dol Dol and lesser increases in marketing at Meru, Isiolo and Nanyuki. One of the reasons why producers use the trader or neighbor markets so frequently in reality appears to be that their expected profit maximizing behavior drives them to the more certain sales environment.

When the comparative uncertainty advantage is reduced, the door is opened to sales at actual markets. Traders suffer most heavily because their business is built on taking the uncertainty out of cattle marketing. The Ol Pejeta program also loses a large portion of its market share: it too was established with the purpose of reducing the riskiness of the sale process. If market risk is reduced by other means, then the market niche of these destinations disappears. The other 'safe' markets of neighbors and butchers also see reduced volumes.

The reduced uncertainty produces the largest mean and median profit increases seen so far in the simulated scenarios – 6% for mean profits and 4% for median profits. The standard deviation from the base scenario also decreases. This is an unsurprising result – if the risk of not selling decreases substantially, the spread of possible sale returns should fall. Producers in this scenario choose markets that offer the highest prices, and many more of them are able to sell at these higher prices because of the reduced risk of not selling. The mean difference in profit is highly significant, so there is little doubt that such a policy change would have a marked effect on producer profits if price distributions remained the same in the face of the decrease in no-sale risk.

While this scenario results in significantly higher producer profits, it is likely that any reduction in sale risk would be accompanied by a negative shift in the sale price distribution because of the market's tradeoff between risk and return. However, this simulation result is supported by Green et al.'s (2006) finding that auction systems brought higher prices than those obtained at purely dyadic negotiation markets.

Scenario 4: Increased fixed price per kilogram offered by Ol Pejeta

To simulate the effects of higher prices offered by the Ol Pejeta buy-and-fatten program, we increase the baseline minimum, median and maximum prices in the Ol Pejeta distribution by 10% to see how the originally intended price advantage would affect both the producers' profits and the distribution of community sales.

Sales at Ol Pejeta rise markedly in this scenario. Sales at its two main competitor markets of Isiolo and traders lose the most sales, but locations across the board lose volume in response to Ol Pejeta's price increase. The effects on producer profits are similar to the reduced market risk case. Mean profits increase by over 700 Ksh per head and median profits by almost 500 Ksh per head. These positive increases in both mean and median profits suggest that the change is good for all producers, and these changes are highly significant. This scenario has interesting implications for the future of the NRT-sponsored buy-and-fatten program. Producer incomes would certainly be improved by this increase in the program's prices. But even if the program offers a 10% increase in prices, the simulation suggests that most of Il

Ngwesi's producers would still choose other markets because of their potential to offer even higher returns.

Scenario 5: Not all animals accepted by Ol Pejeta

Finally, to simulate the policy of not accepting all animals at the Ol Pejeta program, we increase the no-sale risk parameter in this scenario from 0 to 0.1 (i.e. the program would accept only 90% of animals, compared with 100% in the baseline scenario).

While this policy scenario was thought to have the potential to make the buy-and-fatten program more profitable for the NRT, the simulation predicts it is not an advisable move for the program. At present, producers in Il Ngwesi seem willing to hold animals in anticipation of the Ol Pejeta sale day because of the absence of no-sale risk. But if a no-sale risk were introduced, then the low market frequency of once per month would drive producers to seek out another market that might give them a higher price in the meantime. The model suggests that if this risk were introduced, usage of the Ol Pejeta market would virtually end, reducing both the stability and the magnitude of producer profits. The changes in mean and median profit in this scenario are the largest seen in any of the simulations. Moreover, the increase in standard error shows that the profits in this scenario are not only lower but also more variable than in the baseline case.

6. Conclusions and policy implications

In this article we laid out a decision analysis framework for the pastoralist livestock producers of Il Ngwesi, tested the impact of various livestock marketing policy changes on their incomes, and examined how these changes would affect producer marketing choices. Of the scenarios presented, only two resulted in a positive significant change in producer sale profits. Decreased all-round market risk increased mean profits by nearly 1,000 Ksh over the baseline scenario. In addition, producers in this scenario were more likely to market their animals at markets in the area than sell to neighbors, butchers or traders. Mean producer profit increases were also significant when the prices offered through the Ol Pejeta buy-and-fatten program were increased by 10%. Profits under this scenario rose by less than they did in the reduced uncertainty scenario, but marketing to Ol Pejeta increased substantially, particularly at the expense of traders. It is important to note, however, that the observed marketing shifts in all the scenarios might not persist in the long run, as buyers at markets that lost sales might begin to offer higher prices to compensate for the reduced uncertainty or increased frequency of competing markets.

Although the income changes observed in our simulations were small, our results suggest that policies addressing transaction costs, market access and market risk can motivate significant changes in pastoralists' livestock sale income. The simulations suggest that the greatest benefits could be obtained by reducing no-sale risk, a finding that both policymakers and extension services can use to improve pastoralist livestock marketing systems. While implementing auction formats at livestock markets is one mechanism by which no-sale risk can be reduced, improved livestock health and animal condition would also help to increase producers' chances of marketing their animals successfully. Although our findings are specific to pastoralist livestock markets, policymakers and NGOs can use the methodology provided here to incorporate uncertainty into ex ante evaluations of policy changes for nearly any market where risk is a factor.

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