
Kene Patrick Cyril Sinombe
A SHORT-RUN ECONOMIC ANALYSIS OF SOME
FACTORS INFLUENCING THE SUPPLY OF BEEF-CATTLE
AT AUCTIONS IN SOUTH-EASTERN BOTSWANA (1976-1980)

BY

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A SHORT-RUN ECONOMIC ANALYSIS OF SOME
FACTORS INFLUENCING THE SUPPLY OF BEEF-CATTLE
AT AUCTIONS IN SOUTH-EASTERN BOTSWANA (1976-1980)

This thesis is approved as a creditable and independent
investigation by a candidate for the degree, Master of Science, and is
acceptable for meeting the thesis requirements for this degree. Accept-
tance of this thesis does not imply that the conclusions reached by the
candidate are necessarily the conclusions of the major department.

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CHAPTER I

INTRODUCTION

STATEMENT OF THE PROBLEM

Auction sales provide a major cattle marketing outlet for farmers in Botswana.¹ There were 5,740 cattle auctioned in the South-eastern part of Botswana in 1976. This number represented 16% of the total export off-take from the area.² The main market outlet for slaughter beef is through direct marketing of cattle to the Botswana Meat Commission (BMC) abattoir.

The BMC, an export monopoly beef marketing board, sets prices and cattle buyers country-wide adjust them to derive producer prices, because they finally sell cattle to the BMC. The BMC price plays a major role in deriving producer prices at auction sales yards.

There have been fluctuations in the supply of slaughter cattle in South-eastern Botswana, but little is known about the relative impacts of various factors hypothesized to be important in affecting the supply of cattle auctioned.

In addition to BMC price changes, environmental and climatic factors are hypothesized to have some effects on the quality and quantity

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of cattle supplied at auction sales. In addition, the range condition, past and prevailing auction sales prices, subsistence cash needs and disease conditions, especially hoof and mouth disease, are postulated to affect the supply of beef animals auctioned. The nature of the impact of these factors on the supply of beef animals has only been casually addressed in other studies. An in-depth understanding of the effects of these factors on the supply of cattle at auction sales is required for the benefit of producers, buyers and the beef industry. Factors influencing the supply of beef animals at auctions need to be identified to serve as a basis for further research in beef marketing in South-eastern Botswana.

Knowledge gained from this research can be disseminated to researchers and producers to gain further insights about an industry which is an integral part of Botswana's economy.

OBJECTIVES

The general objective of this study is to analyze the supply of slaughter beef-cattle auctioned in South-eastern Botswana.

Specific objectives are:

1) To examine the impact of BMC price changes on the supply of cattle at auction sales.

2) To identify the relative importance of range conditions and hoof and mouth disease outbreaks on quantities of cattle auctioned.

3) To identify other factors impacting on the supply of slaughter beef animals and to investigate the importance of each factor identified.
SCOPe AND OUTLINE OF THE STUDY

The study begins with a description of the traditional and commercial beef-cattle management systems. This background information will be used in addressing the specific objectives.

In Chapter III, the review of the literature is presented, with a discussion of the wealth and income roles of cattle in traditional societies. The applicability of the "dual role of cattle hypothesis" to Botswana concludes the chapter.

Chapter IV addresses factors hypothesized to influence the supply of beef-cattle at auction sales in Botswana. The last part of this chapter discusses the model used in this study.

Chapter V explains the methods used in data collection, treatment of the data and a presentation of the results.

The summary, conclusions, limitations and suggestions for further research make up Chapter VI.
CHAPTER II

TRADITIONAL AND COMMERCIAL BEEF MANAGEMENT
SYSTEMS IN BOTSWANA

BACKGROUND

In Botswana, beef-cattle are produced under the traditional and commercial management systems. Botswana has a small human population (about 800,000) and a cattle population estimated at 3.0 million.1

The major differences between the traditional and commercial beef cattle management systems can be described under the following sub-headings:

Land Tenure

In 1980, traditional and commercial farmers owned 84.3% and 15.7% of the national herd respectively.2

Commercial beef production is practiced on freehold land which makes up 6% of the country's land surface area. The farmers own the land and can sell it. On the other hand, traditional beef cattle production is practiced on tribal land that makes up 71% of Botswana's land surface area.3 The farmers do not own the land and communal

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grazing is the general practice. There is no legal limit to the number of cattle that farmers can graze on the land.

**Beef Husbandry Practices**

The land tenure differences between the two beef-cattle management systems are associated with the following differences in general beef husbandry:

**Breeding:** Uncontrolled breeding is the common practice among traditional cattle owners. However, a small number of traditional farmers use the government artificial insemination service.

The commercial beef cattle management sector generally follows a breeding policy that includes a breeding season. This is possible because the farms are fenced in and sub-divided into paddocks.

**Weaning:** Unlike the commercial sector, traditional farmers have no set weaning policy, because of the problem of separating calves from cows without fenced ranches.

Table I illustrates how the differences between the traditional and commercial sectors result in beef-cattle productivity differences.

**Management**

Most traditional herds are left in the care of untrained herds-men, with the owner living a considerable distance from the cattle post. Commercial farmers usually reside on the ranch or employ a trained manager.

Traditional farmers own relatively small amounts of capital equipment, mainly consisting of a well, drinking trough and animal husbandry requisites. The main source of investment is represented by the
herd itself. Commercial farmers invest in land, buildings, fences and other forms of capital. "The objectives are to maximize cash income from the investment in land and capital". 4

**TABLE I**

**BEEF CATTLE PRODUCTIVITY UNDER TRADITIONAL AND COMMERCIAL MANAGEMENT SYSTEMS**

<table>
<thead>
<tr>
<th>TRAIT</th>
<th>TRADITIONAL MANAGEMENT</th>
<th>COMMERCIAL MANAGEMENT</th>
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<tbody>
<tr>
<td>Calving Percentage</td>
<td>47.3</td>
<td>74.8</td>
</tr>
<tr>
<td>Calf Mortality Percentage</td>
<td>10.2</td>
<td>8.5</td>
</tr>
<tr>
<td>Weaning Percentage</td>
<td>42.5</td>
<td>68.4</td>
</tr>
<tr>
<td>Weaning Mass (kg.)</td>
<td>123.5</td>
<td>180.4</td>
</tr>
<tr>
<td>Post Weaning Gain (7-8 months) kg.</td>
<td>89.7</td>
<td>105.9</td>
</tr>
<tr>
<td>Mass of Weaner calf/cow/year (kg.)</td>
<td>52.5</td>
<td>123.4</td>
</tr>
<tr>
<td>Mass of 18 month calf/cow/year (kg.)</td>
<td>90.6</td>
<td>195.8</td>
</tr>
</tbody>
</table>

*SOURCE: Adapted from, "Beef Production and Management in Botswana". Page 9.*

Hence the performance of the traditional herd compares unfavorably with the commercial herd for all productivity traits.

In the case of traditional farmers, "cattle are considered to be capital goods which are held by producers as long as their capital value in production exceeds their slaughter value. In essence, producers become portfolio managers seeking the optimal combination of different categories of animals to complement their non-cattle assets, given existing conditions and future expectations". Different animal categories have different uses, for example, oxen are used for draught power.

These attitudes towards cattle have contributed to a relatively larger share of slaughter animals coming from commercial farmers as compared to the lower off-take from the traditional sector. Average annual cattle off-take for the period 1978-1980 was 8.1% and 15.6% of cattle held by the traditional and commercial sectors respectively.6

Environment

Environmental conditions have different impacts on the productivity of beef-cattle under traditional and commercial systems. Losses due to drought and disease are higher in the traditional sector. A detailed account on environmental factors will be presented in Chapter IV.


This background about the beef-cattle industry in Botswana, serves as an introduction to a study of the supply of beef-cattle at Botswana's auction sales. The traditional sector supports the cattle auction markets more than the commercial sector.
CHAPTER III

REVIEW OF LITERATURE

A variety of theories has emerged from the studies undertaken in the area of slaughter beef-cattle supply. Emphasis will be limited here to those studies which have led to the theory of cattle serving as both capital and consumption goods, and those theories thought to be of particular relevance to the supply of slaughter cattle in Botswana.

Particular emphasis will be placed on the factors influencing the supply of slaughter beef-cattle, factors affecting producer response to prices and the impact of environmental factors. The findings and research procedures of these studies will be examined in order to select those that may be applicable to a study of slaughter beef supply at auction sales in Botswana.

CONCEPTS OF CATTLE KEEPING IN TRADITIONAL SOCIETIES

Two major concepts have been studied and advanced as possible theories to explain the supply of slaughter beef-cattle from producers.

The first study published in February, 1979 by Doran, Low and Kemp, addresses the concept of, "Cattle as a Store of Wealth in Swaziland : Implications for Livestock Development and Overgrazing in Eastern and Southern Africa".¹

In a non-disaggregated cattle supply/price response study, Doran et. al., found an inverse relationship between cattle sales and price. This was explained by employing the concept that cattle in Swaziland and in other traditional societies serve both wealth and income roles.

Wealth was defined as "The accumulation of assets which confer, among other things, security, prestige and status", while income was differentiated as, "The means of attaining wealth and supporting current consumption". 2

The study by Doran et. al., presents a number of factors that account for the hypothesis that cattle serve as a store of wealth and income, but for the purposes of this study, only those factors relating to reasons for cattle sales by producers and the impact of environmental factors on the supply of cattle for sale will be considered.

Doran et. al., argue that cattle provide satisfaction to owners, both in terms of numbers as well as in cash value. They postulate a dual role of cattle. The cash value is closely tied with current consumption needs of the cattle owners. They further state that, "In so far as cattle are regarded as an end in themselves, they cannot be likened to conventional disposable assets which are held as long as their capital value in production exceeds their current market value". 3

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2 Doran et. al, Opcit, p. 42.

3 Ibid., p. 42.
The dual role of cattle concept has the following implications on cattle sales:

1) When cattle have to be sold to meet specific cash needs, the minimum will be sold. Furthermore, those factors that increase the market value of animals will result in fewer animals being sold to maximize relative wealth.

2) Producers may seek high priced markets, precisely because they can sell fewer cattle and maximize relative wealth and meet subsistence needs.

3) Adverse environmental factors like drought or disease will increase the risk of holding cattle and cattle owners will be more willing to sell.

4) Low rainfall resulting in reduced harvest or crop failure will encourage cattle owners to sell more animals to meet increased subsistence needs.4

The study by Doran et. al., did not consider a basic principle of cattle keeping in traditional African societies, that the various components of the herd have different functions and that the age and sex of an animal are important factors in deciding which and how many animals are to be marketed. In Botswana, the following animal categories are used:

**Cow:** A full grown female (usually over three years old) that has calved.

**Heifer:** A young female that has not calved but is at least one year old and less than 3 years old.

**Tollie:** A young male that is at least one year old and less than three years old.

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4 Doran et. al., *Op cit*, p. 42.
Calf: A male or female which is under one year of age.

Bull: A full grown male that is used for breeding purposes (usually over three years of age).

Ox: A castrated male (usually over three years of age) used for draught power.

In their study, Doran et. al., grouped all cattle marketings and ended up with a negative response to price. This was interpreted to imply that traditional farmers may be keeping cattle for the sake of satisfying a wealth function. A disaggregated study for the various cattle categories may lead to other insights on factors that influence cattle marketings from the traditional sector.

A theoretical framework for studying cattle marketings in Botswana may be found in micro-economic models that treat cattle as capital goods and producers as portfolio managers. The study of, "Cattle as Capital Goods and Ranchers as Portfolio Managers", by Jarvis, is particularly relevant.

The theme of his study is, cattle are considered to be capital goods and are held by producers as long as their capital value in production exceeds their market value. Producers look for an optimal combination of different animal categories to complement non-cattle assets, given existing conditions and future expectations. Capital

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6Jarvis, S.L., Opcit, p. 489.
values of animals of different ages and sex are affected differently by price changes. Producer response to increased prices depends on the age and sex of animals held. Consequently, a disaggregation of equations explaining supply into animal categories is necessary to provide meaningful explanation of producers' responses in cattle marketings.

Jarvis noted that previous models were simple and some of their questionable results may have been due to the omission of variables and lack of reliable data. Jarvis further found that the supply of slaughter animals responds negatively to a price increase in the short-run. This contrasts with the supply of most agricultural goods whose output (in a Nerlovian sense) is expected to increase. The slow rate of biological reproduction may result in this negative supply response to price persisting for some time, especially under traditional cattle management systems. Sources of increasing cattle production are: increasing the size of the breeding herd and withholding animals for further fattening. Jarvis maintains that, "Producers must bid animals away from consumers to increase capital stock which is the source of higher beef production". This is similar to the hypothesized maximization of cattle numbers by traditional farmers for wealth purposes.

Jarvis cites as the principal distinguishing economic characteristic between oxen and cows, the fact that the latter have the ability to produce calves and that cows can produce beef either directly by being fattened for slaughter or indirectly by bearing calves. This

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7 Jarvis, S.L., Op cit., p. 491
takes into consideration the impact of the expected calf-stream on producers' decisions to sell. Jarvis found that heifer and cow slaughter respond negatively to a price increase in the short-run, because a higher price enables feeding to heavier weights and producers tend to retain animals for calf production. This situation may be reversed by persistent drought and disease conditions, when producers would rather sell than risk death losses.

Disaggregation of the cattle sector provides more information about the operation of the cattle sector with respect to producer behavior and a more accurate indication of the quantitative and qualitative changes in the supply of beef cattle. Good rainfall reduces the marketings of tollies, as the range is improved and they can be fed to heavier weights. The lifespan of slaughter cattle is short and interest rate has a negligible impact on the supply of slaughter animals. Important factors found to influence cattle marketings were, the price of beef, feed inputs and climatic effects.

Tryfos' study on "Canadian Supply Functions for Livestock and Meat", clarifies the inter-dependence between livestock supply and inventories. He used (3SLS) to estimate livestock supply and stock formation functions. The estimated functions succeeded in explaining a large percentage of the variations in inventories and slaughter.

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Tryfos recognizes the following uses for a quantity of livestock available in a given point in time:

- slaughter to meet current domestic demand;
- export to meet foreign demand; and,
- retention to replenish or increase inventories of livestock to meet future demand.  

In Botswana, the additional uses of keeping certain livestock classes for draught power, ceremonial purposes and a safeguard against total loss of one's herd in a drought have to be considered.

Tryfos observed that, "The aggregate available quantity in a period of time less than the production period for the particular class of livestock cannot vary in response to current prices and feed costs".  

This suggests a lagged response and future expectations. He assumed that the major determinants of desired inventories are the expected live animal price and expected feed costs. This relationship approximates a linear form. Higher price expectations lead producers to hold more cattle, other factors remaining constant. Assumptions on the formation of price expectations will be presented in the chapter on Data Analysis.

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10Ibid., p. 108.
In studying "Farmer Response to Price in a Subsistence Economy: The Case of West Pakistan", Falcon identified some of the problems associated with the controversy that producers respond negatively to price or that they appear to have zero or negative elasticities of supply.  

Major problems cited were: limited and unreliable data, neglect of the identification problem, inclusion of "abnormal" observations, disregard for problems of aggregation and failure to deflate prices. He noted the lack of the necessary data for computing supply elasticities. Nevertheless, it is possible to set forth some farmer reaction hypotheses to enable quantitative assessments of cattle supply response to price.

**APPLICABILITY TO BOTSWANA**

This brief exposition of several theories on the factors determining slaughter cattle supply has indicated that no single theory can be used to fully explain producer response to price and marketings of livestock. Consequently, certain elements applicable to this study must be extracted from various theories.

About 84% of Botswana's national herd is owned by traditional livestock producers. Hence this portion of the herd may be treated as that held for wealth and income roles. It must be noted that some traditional farmers market cattle regularly and thus may be regarded as

portfolio managers. The assumption that all traditional farmers are homogenous in their livestock marketing behavior may be inaccurate.

Another major difference between traditional and commercial farmers is that the former bear negligible to non-existent feed costs while the latter may have significant feed costs. However, traditional farmers bear energy costs of extracting underground water for their livestock, especially during the dry season.

It is in this regard that caution must be exercised in the treatment of some variables postulated to explain cattle marketings and producer response to price. This, however, does not call for the rejection of all slaughter cattle supply determinants. The impact of rainfall is of particular relevance to this study. The explanations on how producers form price expectations, though inconclusive, are important. The various postulates on producer response to price are essential in gaining further insights to the Botswana livestock supply situation.

The relevant results of the aforementioned studies will be compared later with the objectives and results of this study. A detailed discussion of factors hypothesized to influence numbers of cattle auctioned now follows.
CHAPTER IV

SOME FACTORS INFLUENCING THE SUPPLY OF BEEF CATTLE AT AUCTION SALES

In this study, cattle marketed at auction sales were disaggregated into the following categories: oxen, cows and tollies. This measure was taken because of the postulated various uses of different animal categories, especially under the traditional management system, where cattle are hypothesized to serve both wealth and income roles. The discussion which follows deals with factors that impact on the supply of beef-cattle of each category at auction sales in the short-run.

CLIMATIC FACTORS

Under the traditional management system, the effect of rainfall (amount, timeliness and duration) may be the most limiting factor to beef-cattle production. The grazing, forage and surface water supplies available depend on the amount of rainfall received. Temperature, humidity and other climatic factors are important in determining the quality and quantity of the range resources. The herd-size, condition of the cattle, and the number in the various cattle categories available for sale in turn are dependent on the past and current status of the range land.

The relationship between cattle marketed at auction sales and the amount of rainfall in the previous season may be discussed under the following conditions:
Below Average Rainfall in a season results in both qualitative and quantitative deterioration in range resources until the next rainy season. The consequences of which are:

- loss of condition, especially among oxen and cows;
- a reduced calving rate due to the deteriorating status of the range and scarce surface water supplies;
- an increased death rate among older cows and oxen because of under-nutrition and thirst.

Below average rainfall or drought conditions present a threat to cattle inventories which to some extent influences the selling behavior of producers. Producers are hypothesized to increase off-take by marketing more of their older cattle. This is a measure taken to reduce losses, as the duration and intensity of drought are uncertain events.

On the other hand, there is a strong tendency to retain heifers and tollies. It is hypothesized that these younger animals are kept in order to rebuild depleted herds after a drought and to satisfy the income role. Thus drought conditions may induce increased marketings, especially of older, more vulnerable animals, assuming other factors are held constant.

Above Average Rainfall conditions present ideal periods for producers to rebuild herds and sell mainly to satisfy their income needs. The marketing pattern may change to include younger oxen in good condition as these are known to command a higher price. Given the weather, future price and other market environment uncertainties,
total marketings may increase following an above average rainfall season. Other factors impacting on cattle marketings may reduce or ammeliorate the above-stated effects of rainfall on cattle marketings. Under the traditional management system, in semi-arid regions the season of the year may have far-reaching effects on producer marketing patterns.

The change from the rainy season through winter, autumn and spring is accompanied by fluctuations in range resource quality and quantity. These changes in the nutritive value of the range impose limits on the biological growth and performance of beef-cattle. The condition of herds fluctuates with season and this may induce producers to sell or retain animals, assuming other factors remain constant.

**DISEASE**

Hoof and mouth disease presents hardship to producers both in terms of animals held and sales. Veterinary regulations require an end to all sales and movement of cattle from infected areas. Outbreaks of hoof and mouth disease may last from several months to a few years. Depending on the duration and size of the area affected, producer marketing behavior may be altered. Producers in affected areas stop selling cattle and accumulate inventories if the disease is controlled and other production factors remain favorable.

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Hoof and mouth disease-free areas may experience increased sales because producers want to reduce income losses and hold cash in case the disease spreads to disease-free zones. Increased sales may also be a result of the relative increase in the quantities of animals demanded by buyers as part or parts of the producing areas are prohibited from selling and market demand for beef remains constant.

Under the Botswana Meat Commission's formula pricing policy, the wide fluctuations in prices that might be expected from such a situation are not experienced. This is because their prices are mainly determined by prices offered by beef-importing countries. Consequently, auction sales yards prices tend to closely follow the BMC's quarterly prices.

**BOTSWANA MEAT COMMISSION PRICES**

The BMC abattoir handled 74.6% of all slaughter beef animals sold in Botswana for the period 1976-1980. Given the situation where most cattle marketed at auction sales are in turn sold to the BMC abattoir, it is hypothesized that BMC prices play a role in the level and trend of auction sales prices country-wide.

The majority of animals sold to the BMC abattoir during the period of this study were grade 3 quality. Hence the grade 3 price was selected as a variable that might help explain price levels at

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auction sales and consequently, the quantities of cattle supplied. It is to be noted that the BMC prices are reviewed quarterly and, depending on external price levels, prices offered to producers are adjusted accordingly. The BMC prices may be reviewed and left unchanged, increased or decreased. Action taken at any particular review session depends on external market and other forces.

OTHER CONSIDERATIONS

Producer cash needs vary with season and their impact may accentuate the pressure to market animals. This may occur especially in the last quarter of the year when debts accumulated during the year have to be paid, school fees are due, money for the following year has to be secured and other annual commitments that must be met at the beginning of the year arise. The quarterly BMC price reviews may also enhance the seasonal pattern in cattle sales. However, the number and type of cattle auctioned also depend on the other factors discussed earlier. Given the possible interactions of these factors, a simple explanation of seasonal effects on cattle sales may be misleading.

Climatic and disease factors play an important role in determining calving and death rates. The calving and death rates of a herd partly determine the replacement rate and the level of inventories. Low calving and high death rates imply a reduced available supply of potentially marketable cattle, except when replacements are brought in. Thus, the age and sex of an animal are contributing factors in deciding to sell.
Government programs on road development, breeding and animal health improvements and range management contribute to rising cattle inventory levels. Some government programs reduce production costs thus encouraging increased production that may lead to an increase in potentially marketable animals.

**PRODUCER'S PLANNING HORIZON**

Producers are the primary source of all cattle auctioned. Therefore, the producer's planning horizon and formation of price expectations are integral parts of this study.

The producer's planning horizon may be conceptualized by selecting an appropriate number of years, say $T$, in which the net quarterly revenue is explicitly accounted for. The value of all future income from all animal categories in inventory is computed at the expiration of period $T$. The producer's objective is to maximize the present value of the income from all quarters in the planning period. It is assumed that the producer regards an animal's inventory value as the discounted expected future return. For animals that are auctioned, the return is the discounted profit on the animal's sales value. This return may be regarded as a measure of the hypothesized income role of cattle in the given period. The inventory values of other animal categories are similarly derived and the expected value of future off-spring is considered.

At any given point in time the valuation of stock can be obtained from the inventory value. This valuation of stock may be regarded as a measure of the wealth role of cattle.
Average quarterly auction sales prices are postulated to play a role in the formation of producer price expectations. However, it must be noted that, "A higher absolute price level may play the conflicting roles of encouraging producers to sell because of the greater assured profit versus encouraging expectations of higher prices and consequent withholding from the current slaughter supply..." This expectation complements the hypothesized withholding of cattle by producers in the event of a price increase, because at higher prices the postulated target income is satisfied by selling fewer animals. Secondly, a trend of rising prices implies an increase in the value of cattle inventories held and a satisfaction of the wealth role of cattle. Assuming this discussion partially explains producer marketing patterns, it can be postulated that in the case of a trend of falling prices, marketings will increase because with falling prices and a constant or increasing producer target income, more animals need to be sold. A trend of falling prices also signifies a wealth reduction as cattle held in inventory depreciate in value in the short-run.

Hayenga and Hacklander noted that "Farmers react to the direction of price change more than to the price level". Consequently, the difference in the average price per animal from one quarter to the next.

---


5Ibid., p. 542.
is hypothesized to capture the best aggregate response of producers. However, the impacts of hoof and mouth disease, drought and other market forces may alter this general producer response. Nevertheless, the change in cattle prices from the immediately preceding quarter to the current can be used to capture producers' short-run expectations.

**MODEL SPECIFICATION**

Assuming available forage resources to be the most limiting factor in native beef-cattle production, it is hypothesized that when accumulated inventories exceed the capacity of the available range resources, natural and producer adjustments are made. First, cattle lose weight, condition deteriorates, and death may result. Secondly, producers may willingly increase numbers of cattle marketed to avoid these losses. Conversely, it might be expected that when available range resources are abundant the following may occur:

- animals will gain weight and improve in condition;
- in the short-run, the number of potentially marketable animals will increase;
- death losses related to under-nutrition and thirst will be reduced.

The expected short-run effect of abundant forage resources is an increase in the number of potentially marketable animals. However, the impact of abundant forage resources is not clear-cut as this depends on other factors discussed earlier. An important factor in determining the impact of available surplus range resources on producer selling patterns is whether the income or the wealth role of cattle is paramount
in the given time period. If producers decide income is relatively more important, then sales may be expected to increase. Otherwise producers will retain cattle to maximize their wealth.

The magnitude of the effect of the previous quarter's inventory on the current inventory depends on the relationship between the calving and death rates. When the calving rate is greater than the death rate, then current inventories increase. The reverse situation contributes to a reduction in current inventories. When the calving rate equals the death rate, the calving and death rates have no effect on current inventories. The quantities of cattle auctioned would deplete current inventories to the extent of numbers sold.

It is hypothesized that the quantities of cattle potentially available for market is a function of current cattle inventories, available grazing resources and the occurrence of hoof and mouth disease.

The lag period in this study is equal to a quarter of a year. The choice of this period was dictated by the BMC's quarterly price review policy, the assumed seasonal effects on cattle marketings and seasonal fluctuations in the availability of grazing resources.

It was hypothesized that the quantities of cattle marketed from any category may be represented by:

\[ q_{mkt_{it}} = \alpha_1 + \beta_1 \text{Price}_{t-1} + \beta_2 \text{Rainfall}_{t-1} + \beta_3 q_{mkt_{it-1}} + \beta_4 \text{BMCPrice}_{t-1} + \beta_5 \text{HMD} + e_t \]
Where:

\[ Q_{\text{mkt}\_it} = \text{cattle marketings in period } t, \ i = 1 = \text{Tollies, } 2 = \text{Oxen, } 3 = \text{Cows} \]

\[ \text{Price}_t = \text{beef-cattle auction sale price per animal for a given category of cattle in the previous quarter} \]

\[ \text{Rainfall}_{t-1} = \text{amount of rainfall in millimeters in the previous year} \]

\[ Q_{\text{mkt}\_i\_t-1} = \text{quantities of cattle sold in a given category in the previous quarter} \]

\[ \text{BMCPrice}_t = \text{price for grade 3 animals per 100 kg. cold dressed mass at the BMC abattoir in the previous quarter} \]

\[ \text{HMD} = \text{a dummy variable for hoof and mouth disease in period } t \]

\[ e = \text{a disturbance term}. \]

The number of various types of cattle sold in the previous quarter may have an impact on the available current marketable supply. The magnitude of such an impact is assumed to depend on quantities sold in the previous quarter. The previous quarter's auction sales yards' prices and grade 3 BMC price are assumed pertinent in the formation of producer price expectations.

The missing values mentioned later on in this study refer to the time when no cattle auction sales were held. This may have been due to insufficient numbers of cattle offered for sale, outbreaks of hoof and mouth disease and the lack of buyers.
CHAPTER V

PROCEDURES

COLLECTION OF THE DATA

Cattle auction sales data were obtained from the Botswana Ministry of Agriculture's Livestock Marketing Section. The monthly data included the average prices per animal for oxen and cows auctioned at various locations in South-eastern Botswana. The monthly data was grouped into quarters of the year, by using a proc sort by quarter option on the SAS computer program. This procedure yielded the sums of cows and oxen marketed per quarter, the mean prices of oxen and cows per quarter and the ranges of oxen and cows sold. Locations were disregarded in the statistical analysis.

The number of cows marketed ranged from no sales in the third and fourth quarters of 1977 and 1978 to 446 cows in the first quarter of 1976. No oxen were auctioned in either the third or fourth quarters of 1977 and 1978, while oxen sales reached a maximum number of 1,457 head in the first quarter of 1976. The total number of cattle auctioned during the period of this study was 12,477 comprising 3,014 cows and 9,463 oxen.

The Botswana Meat Commission provided data on abattoir prices, carcass grades and quarterly price reviews. Abattoir prices were reported in Pula (One Pula = $0.89) per 100 kg, cold dressed mass by grade.
Price deflator data were obtained from "Statistical Bulletin", Volume 6, Number 3 of September, 1981, published by the Central Statistics Office, Ministry of Finance and Development Planning, Botswana.

The urban and semi-urban cost of living index for food, beverages and tobacco for the middle-income group was chosen to deflate cattle prices using August, 1980 as a base period.

Botswana's Department of Meteorology supplied average annual rainfall data adjusted for cattle areas and measured in millimeters. The Department of Animal Production provided data on cattle categories and prices and this raw data was used for analysis.

STATISTICAL ANALYSIS

The linear stepwise maximum $R^2$ method was used to run regressions using the means of oxen or cows auctioned per quarter in each year as dependent variables. The model used for the number of oxen sold per quarter is presented below:

$$
(1) \quad \text{Oxen} = \beta_{10} + \beta_{11}\text{DPR}_{t-1} + \beta_{12}\text{DBMP}_{t-1} + \beta_{13}\text{OXEN}_{t-1} + \\
\quad \quad \quad \quad \quad \quad \quad \beta_{14}\text{QUARTER} + \beta_{15}\text{RAINFALL} + \beta_{16}\text{HMD} + E_{1t}
$$

Where, \text{Oxen} = the number of oxen auctioned in the current quarter

$\beta_{10} = an \ intercept \ term$

$\beta_{1j} = partial \ regression \ coefficient \ measuring \ the \ change \ in$

the mean value of the dependent variable per unit change in the independent variable ($j = 1-6$)

$E_{1t} = disturbance \ term.$

The independent variables used for the oxen model were:
1) \( DPR2_{t-1} = \) Deflated price of oxen lagged one quarter

2) \( DBMP_{t-1} = \) Deflated abattoir grade 3 price in Pula per 100 kg, cold dressed mass lagged one quarter

3) \( OXEN_{t-1} = \) Number of oxen auctioned in the previous quarter

4) \( QUARTER = \) Periods derived by dividing the year into quarterly time periods, beginning from January 1st, and added to the model as dummy variables

5) \( RAINFALL = \) Annual rainfall (measured from July 1st of one year to June 30th of the following year) recorded in millimeters and adjusted for cattle areas

6) \( HMD = \) Hoof and Mouth Disease outbreak, a dummy variable

7) \( E_t = \) A disturbance term.

The model used for the number of cows sold per quarter is presented below:

\[
(2) \quad \text{Cows} = \beta_{20} + \beta_{21} DPR3_{t-1} + \beta_{22} DBMP_{t-1} + \beta_{23} COWS_{t-1} + \beta_{24} QUARTER + \beta_{25} RAINFALL + \beta_{26} HMD + E_{2t}
\]

Where, \( \text{Cows} = \) the number of cows auctioned in the current quarter

\( \beta_{20} = \) an intercept term

\( \beta_{2j} = \) partial regression coefficient measuring the change in the mean value of the dependent variable per unit change in the independent variable \( (j = 1-6) \)

\( E_{2t} = \) disturbance term

The cow model had the following independent variables:

1) \( DPR3_{t-1} = \) Deflated price of cows lagged one quarter
2) \[ DBMP_{t-1} = \text{Deflated abattoir grade 3 price in Pula per 100 kg. cold dressed mass lagged one quarter} \]

3) \[ COWS_{t-1} = \text{Number of cows auctioned in the previous quarter.} \]

QUARTER, RAINFALL, HMD and \( E_t \), defined as in oxen model above.

The results presented below have to be viewed and interpreted with caution, because of the high percentages of missing observations and the effects and limitations this problem may have imposed on the statistical analysis. The section on limitations of the study will address this problem further.

The best four variable model found for the dependent variable, oxen, is presented in Table II.

The explanatory variable, Hoof and Mouth Disease, was included in the regression design but failed to meet the specified default F value tolerance level of the stepwise regression program, therefore, this variable was excluded from the equation.

The lagged price of oxen, though included in the results, failed to meet the set selection criteria, because its F value is not significant at the 5% level of significance.

The lagged BMC price and the lagged number of oxen proved significant at the 5% level, which tends to suggest that the number of oxen auctioned in the current quarter is partially dependent on these two variables. The significance of \( DBMP_{t-1} \) may indicate the postulate that the Botswana Meat Commission price levels tend to positively influence the supply of oxen at auction sales in Botswana. The
significance of $OXEN_{t-1}$ seems to suggest that the number of oxen in a previous quarter tends to induce an increase in the number of oxen marketed in the current quarter and this may be due to a rising trend in cattle marketings between the current and previous quarters.

**TABLE II**

REGRESSION RESULT S WITH OXEN AS DEPENDENT VARIABLE

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>REGRESSION COEFFICIENT</th>
<th>F VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPR2$_{t-1}$</td>
<td>0.16728140 (0.11395241)</td>
<td>2.16</td>
</tr>
<tr>
<td>DBMP$_{t-1}$</td>
<td>0.42969871 (0.28267974)</td>
<td>2.31*</td>
</tr>
<tr>
<td>OXEN$_{t-1}$</td>
<td>0.10174146 (0.06231863)</td>
<td>2.67*</td>
</tr>
<tr>
<td>QUARTER</td>
<td>-13.92315540 (2.10569755)</td>
<td>43.72**</td>
</tr>
<tr>
<td>RAINFALL</td>
<td>-0.12680257 (0.02121040)</td>
<td>35.74**</td>
</tr>
</tbody>
</table>

Standard errors in parenthesis; 
F values for individual regression coefficients;

Critical $F^{5}_{258} = 0.05 = 2.29 = *$ = Significant at 5% level 

$0.01 = 3.17 = **$ = Significant at 1% level

Model $F = 25.63**$, $R$-square $= 0.33190283$
Considering that oxen are primarily kept for market, although they may serve a wealth function, this result seems consistent with general expectations. This may be so, because an increase in the numbers of oxen sold in addition to other factors, may indicate an income effect.

The variable, quarter, a proxy for season of the year, is significant at the 1% level of significance. The inverse relationship between the current quarter's oxen sales and change of season is as expected, based on theoretical considerations. This result may be due to the postulated seasonal effects on oxen available for market, due to other demands on oxen as seasons change, like draught power needs and the apparent seasonality in selling.

Rainfall, the proxy used for available forage resources, is significant at the 1% level of significance. The inverse relationship between the number of oxen auctioned and the rainfall seems consistent with expected oxen supply response under traditional management. Increasing rainfall may tend to reduce oxen marketings, because the abundance of forage resources is likely to ensure weight gains that may increase the wealth role to be tapped in the future. Secondly, increasing rainfall may tend to reduce the numbers of oxen auctioned because of the likelihood of adequate crop harvests to meet subsistence needs. Generally, when subsistence food requirements are met from producers' crop harvests, there tends to be a reduction in subsistence cash needs, which is one of the reasons for selling oxen.
The overall regression model explained only 33% of the variance in quarterly oxen sales. This $R^2$ value is low and may be due to the incidence of missing observations and some variables excluded from the model due to lack of data. This regression model was run with 45% of the observations deleted due to missing values. The same percentage of observations was missing in the cow data.

The best regression model for quarterly cow marketings is presented below:

**TABLE III**

REGRESSION RESULTS WITH COWS AS DEPENDENT VARIABLE

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>REGRESSION COEFFICIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPR3$_{t-1}$</td>
<td>0.01401775 (0.03526284)</td>
</tr>
<tr>
<td>DBMP$_{t-1}$</td>
<td>0.17980233 (0.07856641)</td>
</tr>
<tr>
<td>COWS$_{t-1}$</td>
<td>0.14811355 (0.06330404)</td>
</tr>
<tr>
<td>QUARTER</td>
<td>-3.43769874 (0.68110068)</td>
</tr>
<tr>
<td>RAINFALL</td>
<td>-0.03169497 (0.00686694)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F VALUE</th>
<th>F VALUE</th>
<th>F VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.16</td>
<td>5.24**</td>
<td>5.47**</td>
</tr>
<tr>
<td>25.47**</td>
<td>21.30**</td>
<td></td>
</tr>
</tbody>
</table>

Standard errors in parenthesis; 
F values for individual regression coefficients;

Critical $F_{258}^{5} = 0.05 = 2.29 = \ast = \text{Significant at 5\% level}$

$0.01 = 3.17 = \ast \ast = \text{Significant at 1\% level}$

Model $F = 15.44\ast \ast$, R-square = 0.23027040
The lagged price of cows, DPR3_{t-1}, was not significant at the 5% level of significance. Considering that the cow cycle in Botswana is three years and that the lag period used in this study is three months, this result is not surprising.

The lagged abattoir price, DBMP_{t-1}, was significant at the 1% level of significance. The positive sign of DBMP_{t-1}'s estimated regression coefficient suggests that an increase in the abattoir price in one quarter would tend to increase the number of cows marketed in the next quarter. This is the relationship that was expected, because DBMP_{t-1} was assumed to be a positive indicator for producers to increase cow sales.

The proxy for season of the year, quarter, turned out significant at the 1% level of significance. The negative regression coefficient is as expected because of reduced cow marketings that tend to be induced by changes from one season to the next, as discussed under "Climatic Factors" in Chapter IV.

The number of cows auctioned in period t-1 significantly influences cow marketings in the current quarter at the 1% level of significance. The positive sign of the variable COWS_{t-1} is puzzling, given the short-run nature of the study. However, it may be that an increase in cow sales in the previous quarter may induce increased cow sales in the subsequent quarter, because of a rising trend in supply set in the previous quarter.
The regression only explained 23% of the variance in the number of cows auctioned per quarter. This is indeed a low $R^2$ value and imposes limitations on the predictive power of the model. The problem of missing observations was also prevalent in the cow data. The low $R^2$ value may also indicate the absence of some important explanatory variables. The extent of missing observations in the different quarters analyzed in Tables IV-IX was as follows:

<table>
<thead>
<tr>
<th>QUARTER</th>
<th>% MISSING OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
</tr>
</tbody>
</table>

The percentages of missing observations for oxen and cows were identical in all quarters. In order to gain some insights about which explanatory variables have impacts on oxen and cow sales, separate step-wise/max$R^2$ regressions were run for each quarter through all the years in the study period. The independent variables specified in the results presented above were used.

The results for QUARTER 1, for the period 1976-1980 were as presented in Table IV.
TABLE IV

STEPWISE MAXR\textsuperscript{2} RESULTS WITH OXEN AS DEPENDENT VARIABLE
FOR QUARTER 1 IN THE PERIOD 1976-1980

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>REGRESSION COEFFICIENT</th>
<th>F VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPR\textsubscript{2} \text{t-1}</td>
<td>0.21906699 (0.36082673)</td>
<td>0.37</td>
</tr>
<tr>
<td>DBMP\textsubscript{t-1}</td>
<td>-0.17284900 (0.84263281)</td>
<td>0.04</td>
</tr>
<tr>
<td>OXEN\textsubscript{t-1}</td>
<td>-0.06988303 (0.12526693)</td>
<td>0.31</td>
</tr>
<tr>
<td>RAINFALL</td>
<td>-0.13255612 (0.04266624)</td>
<td>9.65**</td>
</tr>
</tbody>
</table>

Standard errors in parenthesis;
F values for individual regression coefficients;
Critical $F_{67}^{4} = 0.05 - 2.53 = \ast$ = Significant at 5% level
$0.01 = 3.65 = \ast\ast$ = Significant at 1% level

Model $F = 3.23\ast$, R-square = 0.16181891

The four independent variables included in the step-wise/maxR\textsuperscript{2} regression were DPR\textsubscript{2} \text{t-1}, DBMP\textsubscript{t-1}, OXEN\textsubscript{t-1} and RAINFALL, and only RAINFALL turned out to be significant at the 1% level of significance. The significance of rainfall tends to support the hypothesis that the increasing availability of forage resources tends to reduce marketings of oxen. There is no statistical backing to support any further comment on the non-significant variables.
TABLE V

STEPWISE MAX $R^2$ RESULTS WITH OXEN AS DEPENDENT VARIABLE
FOR QUARTER 2 IN THE PERIOD 1976–1980

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>REGRESSION COEFFICIENT</th>
<th>F VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPR$_2^{t-1}$</td>
<td>-0.05365427 (0.22670069)</td>
<td>0.06</td>
</tr>
<tr>
<td>DBMP$_{t-1}$</td>
<td>1.16041238 (0.45404447)</td>
<td>6.53**</td>
</tr>
<tr>
<td>OXEN$_{t-1}$</td>
<td>0.07109602 (0.10493592)</td>
<td>0.46</td>
</tr>
<tr>
<td>RAINFALL</td>
<td>-0.17456501 (0.03542640)</td>
<td>24.28**</td>
</tr>
</tbody>
</table>

Standard errors in parenthesis;
F values for individual regression coefficients;

$$4 \quad \frac{F_{91}}{0.05 - 2.53} = * = \text{Significant at 5% level}$$

$$0.01 = 3.65 = ** = \text{Significant at 1% level}$$

Model $F = 15.30**$, R-square = 0.40206167

In the second quarter, regression coefficients for DPR$_2^{t-1}$ and OXEN$_{t-1}$ were found not to be significantly different from zero at the 5% level of significance. However, regression coefficients for independent variables RAINFALL and DBMP$_{t-1}$ were significant at the 1% level of significance. The positive sign of the regression coefficient for the lagged abattoir price tends to support the postulate that increases in abattoir prices tend to induce an increase in numbers of oxen auctioned.
This may be expected because in the second quarter producers may be reacting to abattoir prices established in the first quarter and again, the second quarter signals the beginning of the dry season, a period when forage and water resources are becoming scanty.

Rainfall and oxen marketings are inversely related. This result seems consistent with theoretical expectations for the same reasons mentioned in earlier results.

The model explains 40% of the variance in oxen sold and this leaves the model with a low predictive power. The standard errors of the regression coefficients for lagged oxen, lagged BMC price and lagged cows in Tables IV-IX are larger than their regression coefficients. This may indicate that a high degree of multicollinearity exists and as a result, it may be impossible to isolate the individual effects of the explanatory variables. The large standard errors may tend to make the confidence intervals for the relevant population parameters larger and render sample data compatible with a diverse set of hypotheses.

It must be noted that whenever the standard error exceeds the regression coefficient, the concerned variable is not significant at the 5% level.
TABLE VI

STEPWISE MAXR² RESULTS WITH OXEN AS DEPENDENT VARIABLE
FOR QUARTER 3 IN THE PERIOD 1976-1980

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>REGRESSION COEFFICIENT</th>
<th>F VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPR₂ₜ₋₁</td>
<td>0.01020445 (0.30186733)</td>
<td>0.00</td>
</tr>
<tr>
<td>DBMPₜ₋₁</td>
<td>2.53669335 (7.57345876)</td>
<td>0.11</td>
</tr>
<tr>
<td>OXENₜ₋₁</td>
<td>-0.04683789 (0.17062887)</td>
<td>0.08</td>
</tr>
<tr>
<td>RAINFALL</td>
<td>-0.22588131 (0.31845767)</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Standard errors in parenthesis; F values for individual regression coefficients;

Critical $F_{43}^4 = 0.05 = 2.61 = *$ = Significant at 5% level

0.01 = 3.83 = ** = Significant at 1% level

Model $F = 3.70*$, R-square = 0.25600348

None of the independent variables specified are significant at the 5% level of significance for the third quarter. Any comment would be speculative and therefore, results for the fourth quarter follow.
TABLE VII

STEPWISE MAXR² RESULTS WITH OXEN AS DEPENDENT VARIABLE
FOR QUARTER 4 IN THE PERIOD 1976-1980

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>REGRESSION COEFFICIENT</th>
<th>F VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPR2_t-1</td>
<td>-0.05563672 (0.14357693)</td>
<td>0.15</td>
</tr>
<tr>
<td>DBMP_t-1</td>
<td>0.04510431 (3.70496417)</td>
<td>0.00</td>
</tr>
<tr>
<td>OXEN_t-1</td>
<td>0.01338724 (0.14070059)</td>
<td>0.01</td>
</tr>
<tr>
<td>RAINFALL</td>
<td>0.03110120 (0.22999547)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Standard errors in parenthesis;
F values for individual regression coefficients;

\[ F_{43}^{4} = 0.05 = 2.61 = * \text{ Significant at 5\% level} \]
\[ 0.01 = 3.83 = ** \text{ Significant at 1\% level} \]

Model F = 0.43, R-square = 0.0888225

None of the variables helps to explain the variance in oxen auctioned in this quarter at the 5\% level of significance. The third quarter had 60\% of the observations missing and the same proportion of observations was missing in the fourth quarter. When the model is run with only 40\% of the observations, results of this nature may be expected.
Missing values refer to times when no cattle auction sales were held. This may have been due to insufficient numbers of cattle offered for sale, outbreaks of hoof and mouth disease or the lack of buyers.

The results with cows as dependent variable now follow.

**TABLE VIII**

**STEPWISE MAXR$^2$ RESULTS WITH COWS AS DEPENDENT VARIABLE FOR QUARTER 1 IN THE PERIOD 1976-1980**

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>REGRESSION COEFFICIENT</th>
<th>F VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPR$^3_{t-1}$</td>
<td>-0.03704218 (0.08420934)</td>
<td>0.19</td>
</tr>
<tr>
<td>DBMP$_{t-1}$</td>
<td>0.11240635 (0.15943817)</td>
<td>0.50</td>
</tr>
<tr>
<td>COWS$_{t-1}$</td>
<td>-0.08770709 (0.12475767)</td>
<td>0.49</td>
</tr>
<tr>
<td>RAINFALL</td>
<td>-0.03002819 (0.01405552)</td>
<td>4.56**</td>
</tr>
</tbody>
</table>

Standard errors in parenthesis; F values for individual regression coefficients;

Critical $F^4_{67} = 0.05 = 2.53 = *$ Significant at 5% level

0.01 = 3.65 = ** Significant at 1% level

Model $F = 1.72$, $R$-square = 0.09312787

The whole regression model is not significant at the 5% level of significance. Only rainfall is significant at the 1% level of
significance with a negative sign for the regression coefficient. An
inverse relationship may be expected between increasingly abundant
forage resources and the number of cows marketed. This would be an
opportunity to increase herd size with the assured grazing and water
supplies. But, the $R^2$ value of 0.09 makes the model of questionable
explanatory value. It may also be noted that the first quarter is the
calving season in Botswana, so the reported 60% of missing observations
is not surprising.

TABLE IX

STEPWISE MAXR$^2$ RESULTS WITH COWS AS DEPENDENT VARIABLE
FOR QUARTER 2 IN THE PERIOD 1976-1980

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>REGRESSION COEFFICIENT</th>
<th>F VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPR$_t$-1</td>
<td>-0.00015543 (0.07286748)</td>
<td>0.00</td>
</tr>
<tr>
<td>DBMP$_t$-1</td>
<td>0.31872293 (0.11184453)</td>
<td>8.12**</td>
</tr>
<tr>
<td>COWS$_t$-1</td>
<td>0.17959529 (0.09863595)</td>
<td>3.32*</td>
</tr>
<tr>
<td>RAINFALL</td>
<td>-0.04488396 (0.01130487)</td>
<td>15.76**</td>
</tr>
</tbody>
</table>

Standard errors in parenthesis;
F values for individual regression coefficients;
Critical $F_{91}^{4} = 0.05 = 2.53 = * = \text{Significant at 5\% level}$

$0.01 = 3.65 = ** = \text{Significant at 1\% level}$

Model $F = 11.04**$, $R$-square = 0.32669883
In quarter 2, the whole regression model is significant at the 1% level of significance. The model, however, helps explain only 32.6% of the variance in the numbers of cows auctioned. The lagged price of cows is not significantly different from zero.

The lagged abattoir price, DBMP_{t-1}, is significant at the 1% level of significance. The positive sign of its regression coefficient suggests an increase in the numbers of cows marketed as DBMP_{t-1} increases.

The number of cows auctioned in quarter 2, COWS_{t-1}, is significant at the 5% level, suggesting increasing cow sales in the current quarter induced by sales in the previous quarter. This result may be explained by delayed response to market forces, because of poor information flow and other factors.

Rainfall, the proxy for forage resources, is significant at the 1% level of significance. The sign for its regression coefficient is negative. This inverse relationship between cow marketings and rainfall suggests that decreasing rainfall may tend to induce an increase in cow sales. This is consistent with the hypothesis that drought conditions may result in increased cow sales, when death losses reduce the relative importance of holding cattle for wealth purposes.

Quarters 3 and 4 had non-significant results and it may be noted that the two quarters both had 60% of their observations missing. Also, auction sales were suspended in the fourth quarter of 1977, because of an outbreak of hoof and mouth disease. There was a general reduction in
cattle sales in the third and fourth quarters in the five-year period studied.

DISCUSSION OF THE RESULTS

The results of the study by Doran et al., on, "Cattle As a Store of Wealth in Swaziland:...", are relevant for comparison with this study's results since Doran's study dealt with cattle sales from a traditional sector in a country faced with problems similar to Botswana.

Doran et al., found an inverse relationship between cattle supply and rainfall that was significant for their annual multiple regression model. This same relationship was found in this study, thus suggesting that rainfall and cattle marketings are inversely related and that the quantity of range resources is inversely related to cattle sales. Doran's model explained 65% of the variation in off-take, while this study's model with the least number of missing observations explained 40% of the variation in the number of oxen auctioned and 32% of the variation in cow sales.

Given the constraints in this study and the difference in the quality of the data, these results are consistent with a priori considerations.

The results indicated a positive relationship between the abattoir price per 100 kg. cold dressed mass and cattle marketings. This

\[1\text{Doran, M.H. et. al., Opcit., P. 43.}\]
is what theory would suggest, but then the low coefficients of determination found indicate that the results must be interpreted with caution.

Theoretical considerations suggest that the season of the year has an impact on both oxen and cow sales. The variable, quarter, a proxy for season, was significant at the 1% level in Tables II and III. The overall effect of seasonal change is negative and this is plausible when considering that there were no auction sales held in 25% of the seasons included in the study. The results for the separate quarterly regressions through all the years included in the study indicate the differences in the numbers of cattle supplied at auctions among seasons.

Lagged quantities of oxen and cows were found to be positively related to current cattle marketings. This may suggest a much delayed producer response to market forces.

The second quarter's results were the best for both oxen and cows. Several factors may have resulted in this outcome. The second quarter is the period when producers react to the abattoir prices set in the fourth and first quarters and a period when the rainy season has ended. The second quarter is the beginning of the winter, a time when forage resources are getting scarce and producers tend to sell cattle to safeguard themselves against possible drought losses.
THE PROBLEM OF MISSING OBSERVATIONS

Pindyck and Rubinfield stated that, "Our empirical work is often complicated by the fact that observations for one or more variables may be missing". This study was no exception and the missing observations were deleted in the SAS computer program used. Several estimation procedures for missing values in time-series data were outlined by Maddala, and none of them was found better than the others.

No definite relationship could be drawn between the percentages of missing values and the coefficients of determination. However, the random pattern between $R^2$ values and percentages of missing values in the data is presented below with oxen as the dependent variable.

<table>
<thead>
<tr>
<th>QUARTER</th>
<th>% MISSING OBSERVATIONS</th>
<th>$R^2$ VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
<td>3</td>
</tr>
</tbody>
</table>

Although it was due to the prevalence of missing observations that cautionary remarks were made throughout the presentation of the results, it must, however, be remembered that missing values may not be

2 Pindyck, R.S. and Rubinfield, D.L., Economic Models and Econometric Forecasts.

the only factor responsible for the low explanatory power of the models; multicollinearity may have been as indicated earlier.
SUMMARY

The study set out to examine and investigate some of the factors that impact on the supply of beef-cattle at auction sales in Botswana. The Botswana Meat Commission price per 100 kg. cold dressed mass was found to be positively related to the quantities of oxen and cows auctioned.

The availability of range resources proved to be an important factor in cattle supplies at auction sales. The inverse relationship found between range resource availability and numbers of cattle auctioned is consistent with the findings of other studies in Southern Africa. The effect of hoof and mouth disease could not be explained statistically, because this variable failed to meet specified entry levels into the step-wise maxR² regression method of analysis.

There was a negative variation of cattle marketings with change of season. The models for oxen and cow sales gave their maximum R² value for the second quarter and their minimum explanatory power in the fourth quarter.

The lagged quantities of oxen and cows were positively associated with the current quarter's marketings. But the lagged prices of cows and oxen had no significant explanatory power.
Primary data for analysis were obtained from various Ministries and organizations in Botswana. The study covered a five-year period in which there was a notable reduction in cattle auction sales in the third and fourth quarters of the year.

The SAS program was used to analyze the data employing the step-wise \( \text{maxR}^2 \) regression option. The variables that were found to significantly explain the variation in quantities of oxen and cows auctioned were, rainfall, quarter, \( \text{cows}_{t-1} \) and \( \text{oxen}_{t-1} \).

CONCLUSIONS

The supply of cattle at auction sales in Botswana may, at first glance, appear contrary to economic theory. But, when the peculiarities in cattle husbandry and management faced by Botswana producers are considered, some rational economic conclusions may be made.

There was a highly significant inverse relationship between cattle sales and rainfall, a proxy variable for range resource availability. This relationship tends to support the hypothesis that when forage resources are abundant, the building up of herds becomes the main objective among traditional farmers. Consequently, the range condition was found to be an important explanatory variable of the variation in cattle numbers at auctions.

The season of the year was significant, suggesting a strong seasonal pattern in marketing. The last two seasons of the year displayed reduced cattle sales. Contrary to expectations of increased cattle supply at auction markets in the fourth quarter, the empirical evidence did not support this. The results show a reduction in cattle
auction sales with the onset of the rainy season. This tends to suggest that producers may be reluctant to market cattle in the expectation of abundant grazing resources, and hence an opportunity to increase herd size and wealth. Under the extensive cattle management system such as Botswana's, owning large herds is a safeguard against drought and disease.

In the stepwise $\max R^2$ results presented in Tables II and III, the lagged numbers of oxen and cows were significant. This tends to suggest that producers respond to a trend of market and environmental forces in offering animals for sale.

LIMITATIONS OF THE STUDY

This study examined several factors hypothesized to have impacts on the supply of cattle at auction sales in Botswana. The duration of the study had to be limited to five years' data, because organized cattle auction sales were only started in 1975.

Cattle sales are reduced in the latter half of the year. Consequently, up to 60% of the observations had missing data for the third and fourth quarters. This deficiency in the data had negative effects on the statistical results of annual models. Quarterly models were run to alleviate the problem of missing data but even this did not eliminate the problem.

It must be remembered that auction markets are not the only selling outlets used by farmers. In addition, the practice of selling cattle without the use of weighing scales occurs and may impose limitations on the available data. Other cattle auction sales studies have
used live animal weight as an explanatory variable. Missing observations, however, remained the most limiting factor. Further data collection efforts and analysis of auction markets in Botswana should contain means to correct the missing observations problem.

The large standard errors of the regression coefficients suggest that multi-collinearity may be a problem in the model and this would make it impossible to isolate the individual effects of the independent variable. The main problem with ordinary least squares estimators under such circumstances is that they are inefficient.

If the model is used for predictive purposes only and the collinear relation that exists in the sample can be expected to exist in the future, then multi-collinearity is not a serious problem. However, when reliable estimation of parameters is part of the objective, then multi-collinearity becomes a problem due to the difficulties associated with high standard errors like the widening of the confidence interval.¹

The effect of the random variable, Hoof and Mouth Disease, could not be accounted for statistically. Also, the subsistence cash need of cattle producers could have been included as an explanatory variable, but due to the unavailability of data this variable was excluded.

The problems outlined above indicate that the models used in this study will require further statistical refinement before being used for explanatory or predictive purposes.

SUGGESTIONS FOR FURTHER RESEARCH

Further research needs to identify other pertinent variables that can help explain the short-run supply of cattle at auctions. Experimentation with model specifications not used in this study may also aid in quality of results in the future. The existence of multicollinearity in the explanatory variables should be investigated and, on detection, remedial measures should be taken.

This may be the time for introducing a live-cattle classification system. This may include the weight and age of the animals auctioned. Data on the contribution of subsistence cropping to total subsistence cash needs requires gathering, as this may lead to insights on cattle sales during different seasons. The effect of economic developments like road improvement, alternative marketing outlets, the increasing opportunities of satisfying subsistence cash needs from waged employment and improvements in animal health and husbandry need to be investigated.
BIBLIOGRAPHY


Pindyck, R.S. and Rubinfeld, D.L., Economic Models and Econometric Forecasts.