A TEMPORAL AND SPATIAL MODEL TO ASSIST IN EVALUATING INVESTMENTS IN THE NIGERIAN BEEF DISTRIBUTION SYSTEM

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

EARL DUANE KELLOGG

1971

This is to certify that the

thesis entitled

A TEMPORAL AND SPATIAL MODEL TO ASSIST IN
EVALUATING INVESTMENTS IN THE NIGERIAN BEEF
DISTRIBUTION SYSTEM

presented by

Earl Duane Kellogg

**has been accepted towards fulfillment
of the requirements for**

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Earl Duane Kellogg

AN ABSTRACT OF A THESIS

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ABSTRACT

A TEMPORAL AND SPATIAL MODEL TO ASSIST IN EVALUATING INVESTMENTS IN THE NIGERIAN BEEF DISTRIBUTION SYSTEM

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The purpose of this study was to develop and illustrate the use of a model that would help evaluate the consequences of alternative investments that might be made in the Nigerian beef distribution system. These investments are needed to reduce the large shrinkage, salvage, and death losses that are presently incurred in the distribution of beef from producers to consumers in Nigeria.

The model developed contains three basic components. The first component (TRNSCST) estimates the distribution costs per animal between each pair of 15 areas in Nigeria. These costs were calculated for rail, truck, and trek methods of moving live cattle and refrigerated rail and truck movement of frozen carcasses. The total distribution charge for each method was divided into important sub-categories so the impact of various policies on the distribution charge could be treated explicitly. The effects on distribution charges of programs to control trypanosomiasis and increase the speed of rail service were calculated.

The second component is a transhipment linear program which was utilized to calculate the least cost configuration of beef transportation facilities among the 15 areas in Nigeria using transportation costs estimated by the TRNSCST component in the objective function. The results given by this component are the quantity of both meat and

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cattle shipped between areas, method of shipment used for both meat and cattle, quantity slaughtered in each area at both modern and traditional facilities, and the number of rail cars to be allocated annually to each route. Several experiments were conducted with this component to analyze the effects on beef distribution activities of alternative model assumptions and policies. The first run on this component was made to find the optimum transportation configuration for conditions as they exist in Nigeria at the present time. The following experiments were conducted to estimate the effects on the optimum transportation configuration of: (1) expanding the number of rail cars available for live cattle shipment, (2) instituting a trypanosomiasis control program for cattle that are trekked, (3) assuming the proportion of "cold" meat demanded in southern Nigeria increased relative to "hot" meat demanded, (4) increasing the speed of turnaround time for rail cars, (5) furnishing an unlimited number of rail cars and increasing the speed of turnaround times, (6) assuming consumers make no differentiation between "hot" and "cold" meat in southern Nigeria, and (7) instituting a trypanosomiasis control program for trekking cattle and assuming consumers in the southern part of Nigeria do not differentiate between "hot" and "cold" meat.

The third component of the total model framework is a spatial equilibrium component which was run through 20 years of simulated time. Supply and demand functions were derived for each area and updated through time in accordance with assumptions regarding income and population growth. Using these functions and interarea transfer costs from t

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costs from the TRNSCST component, this model component calculates the equilibrium prices, quantities supplied and demanded in each area, and the interarea flows of beef through time. In these terms, the effects of various policies that change transfer charges or locations of beef demand and supply can be determined. Three policy options were explicitly considered. Option I would increase the number of rail cars at about 2 percent per year and continue investments in trek route feed and water supply. Option II would furnish as many rail cars for cattle shipment as are needed as well as continue investing in feed and water provisions along trek routes. The third investment option considered would establish a trypanosomiasis control program for trekking cattle and increase the speed of rail service. The consequences of these three policy examples are reported at 5 year intervals for 20 years of simulated time in terms of interarea flows of beef, equilibrium prices, and quantities supplied and demanded within each area.

The last step in the model process was to estimate the requirements that these interarea flows place on the beef transportation system through time. To do this, the three sets of interarea flows of beef through time (corresponding to the three policy options) were processed by the transhipment linear programming component. The results of this process were the number of rail cars required, allocation of these cars among the various routes, trek route utilization, and total distribution charges through time.

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Other possible uses of the model framework are discussed with reference to the kinds of problems that can be investigated and the adjustments in the model that would be required. The relationships between this beef distribution model and a simulation model of beef production in Nigeria are explored. Finally, a section discussing the needs for research related to the Nigerian beef distribution system is included.

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Gratitude is given to Professor Glenn Johnson for the creative guidance he gave throughout the author's entire graduate program at Michigan State University. Special thanks are due Dr. Marvin Hayenga for the time he took to discuss and constructively criticize this study. The author is also grateful for the academic atmosphere and financial assistance provided by Professors L. L. Boger and Dale Hathaway as successive Heads of the Department of Agricultural Economics.

Dr. Tom Manetsch and Dr. Robert Deans were very helpful and encouraging throughout this study and their assistance was greatly appreciated. Professors Al Halter, Lester Manderscheid, Robert Gustafson, and Carl Eicher all made special contributions that were appreciated. The author is also indebted to Alhaji Hamisu Kano of the Nigerian Livestock and Meat Authority for the multi-faceted assistance he gave. The U.S. Agency for International Development's Mission in Nigeria was also very helpful.

The author is grateful to Mrs. Lana Hilton for the careful typing of the manuscript.

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LIST OF SYMBOLS AND NAMES

1. Nigerian Monetary Units

   Ƚ = one Nigerian Pound

   s = one Nigerian Shilling

   d = one Nigerian Pence

   1Ƚ = 20s = 240d = $2.80

2. Lorry and truck are used as synonyms in this study.

3. Abattoir and slaughterhouse are used as synonyms in this study.

4. Trek, in this study, means to drive cattle to some destination.

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CHAPTER I

SCOPE AND PROCEDURE OF THE STUDY

Introduction

Agriculture, including livestock production, is the predominant industry in Nigeria, constituting about half of the value of exports and the gross domestic product (GDP) at factor cost {14,p.19}. While the livestock industry's share of the GDP is only five percent, the beef industry is quite important in the northern part of Nigeria {5,p.137}. The value of the capital stock in the northern beef industry is about Ⱡ120 million and the annual trade in beef products has been estimated conservatively at between Ⱡ20 and Ⱡ25 million {7,p.2}.

As a part of development, population increases, per capita incomes rise, producers become more specialized, and consumers more urbanized. During this process, the demand for agricultural marketing services increases. While the percentage contribution of agriculture to GNP usually falls as per capita incomes rise, the percentage contribution of agricultural marketing to the national product seems to be fairly constant over wide ranges of per capita incomes. Simantov {32} found that in most countries studied farm supply sectors comprised about three percent of the national product and the food-processing and marketing services about eight to nine percent, even though their income levels varied substantially. Therefore, agricultural marketing can be identified as a rapidly expanding part of the agricultural se

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agricultural sector in the development process. The same factors that tend to increase the demand for agricultural marketing services in general also apply to beef marketing services in particular. In addition, income expansion not only increases the demand for staples, but may also enable greater consumption of preferred foods such as vegetables, fruit, meat, fish, and poultry. Considering all these factors, one can assume that the demand for beef distribution services in Nigeria is likely to continue to expand rapidly in the future.

Need For This Study

The beef marketing system annually distributes between 800,000 - 1,000,000 cattle to the country's 56 million people. The system spans distances up to 1,000 miles between important producing and consuming regions. As the cattle are moved (either by walking or railing) from the producing to the distant consuming regions, large losses are incurred through death and live weight shrinkage. As will be shown in Chapter III, these losses constitute 40 - 60 percent of the total transportation charge between some regions. Until the beef distribution system's performance is improved to reduce these wastes, the success of policies to modernize beef production is likely to be limited. Because of its size, probable future demands for its services and the need for improved operation, the Nigerian beef distribution system's performance is and will be an important factor in the success of Nigeria's efforts to foster sound economic growth in agriculture that will support and contribute to the total development effort.

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Several studies have been done on various aspects of the Nigerian beef distribution system. However, policy makers are interested in the effects of various policies through time on the total system. Available information and "guesstimates" should be organized into a framework for evaluating specific policy decisions which may have significant impacts on producers and consumers. Of course, all the parameter values and relationships within the framework cannot be specified accurately. More research on these basic aspects will need to be done. However, planning goes on, decisions continue to be made and strategies for the beef distribution system's development are being implemented. This research is an attempt to integrate the available information into a model that will provide the policy maker with a more informed basis for planning development strategies for the Nigerian beef distribution system.

Any current policy research related to Nigeria must at least acknowledge their recent civil war. Some assumptions have been made here to account for changes the war may have caused. They are explicitly stated in the sections describing the components in which they were used.

This study is part of a larger research effort directed at assessing the usefulness of simulation as a tool for planning agricultural development in less developed countries. In order to do this, an interdisciplinary research team was organized at Michigan State University to build a simulation model of the Nigerian agricultural economy. Initially, this team constructed a model of the northern Nigerian beef production system {15}. The process of building the production model stimulated this research in beef distribution.

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Subsequently the research team has developed a simulation model of the total Nigerian agricultural economy {27,28}. This overall model will incorporate the beef production model and a simplified beef distribution model which will utilize many of the basic parameters and structural relationships estimated in this more comprehensive model.

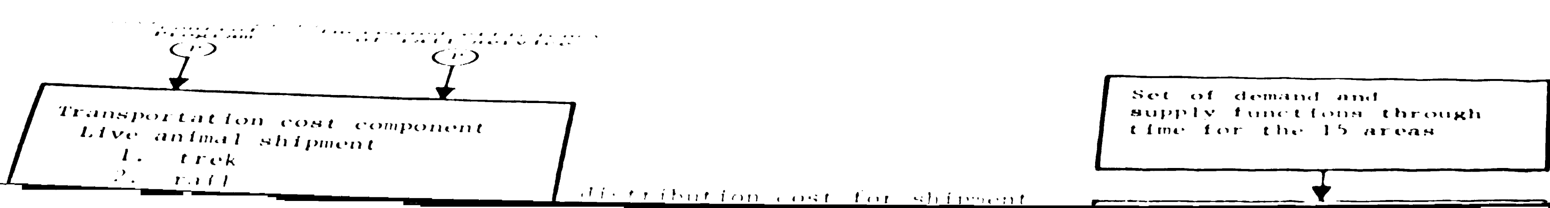
Purpose and Objectives

The purpose of this thesis is to develop a model to help evaluate policy decisions that might be made in improving the operation of the Nigerian beef distribution system through time. More specifically, the objectives are:

1. To estimate transportation costs among areas for rail, lorry and trek methods of cattle and beef shipment in Nigeria.
2. To estimate the distribution costs that result from implementing various policies that are directed at improving the beef distribution system.
3. To develop an optimum transportation plan through time related to these policies.
4. To indicate the equilibrium price, demand and supply quantities in each area that would likely result from these policies through time.

Procedure

To accomplish these objectives, a multi-component model was developed. Figure 1 illustrates the three components of the model and their interactions. For each of the components, Nigeria was divided into 15 areas all of which produce and consume beef. The transportation


Transportation cost component
Live animal shipment
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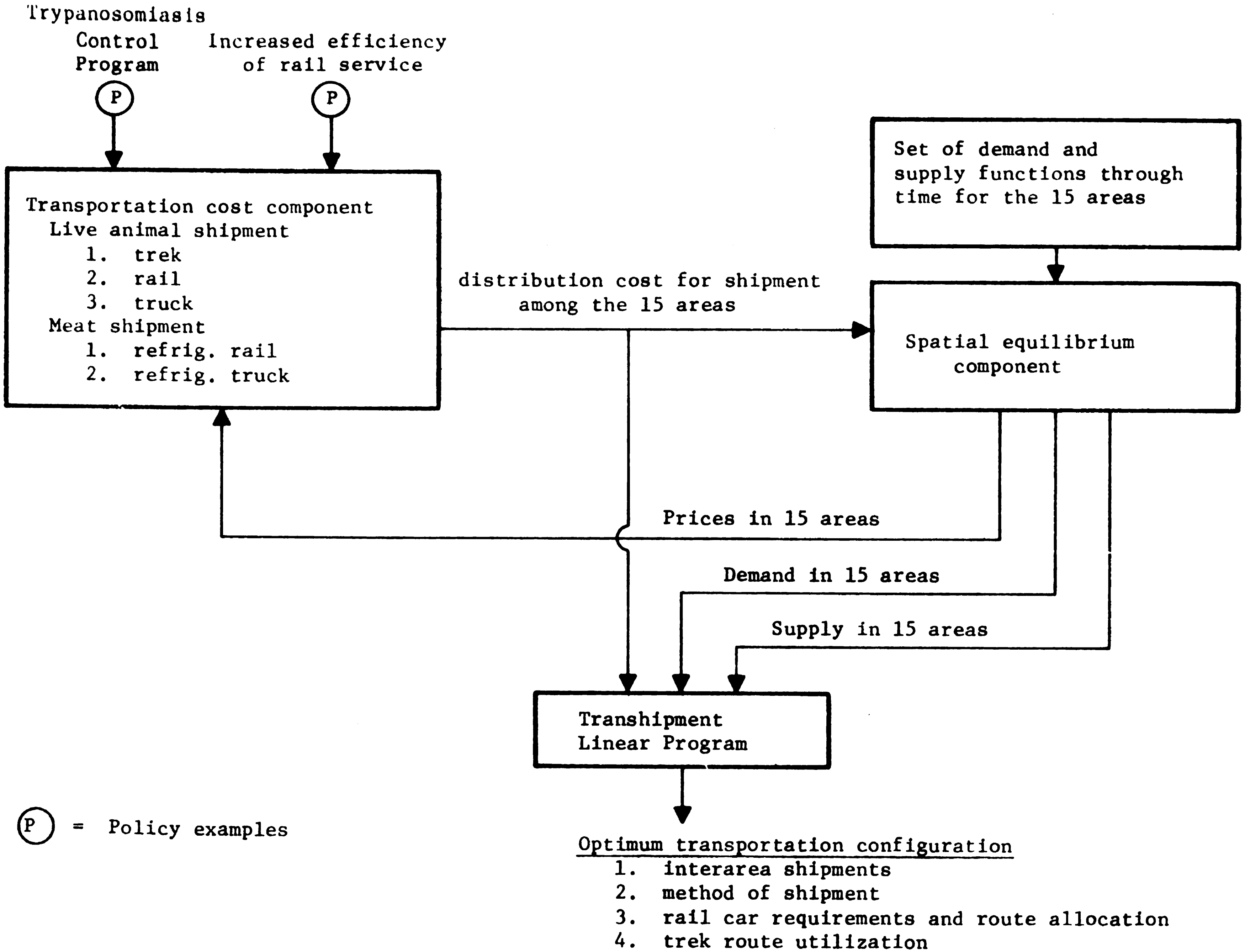
Set of demand and supply functions through time for the 15 areas



(P) = Policy examples

Figure 1: Beef Distribution Model Components

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cost component calculates the interarea shipping costs for the methods indicated and the changes in these costs as different policies are implemented to improve distribution methods. These interarea distribution costs become inputs to the spatial equilibrium component. Using these costs in conjunction with estimated supply and demand functions for the 15 areas, this component calculates the prices, quantities demanded and supplied and the corresponding interarea shipments (under the assumption that shipments will increase until the difference in prices between any two areas is less than or equal to the distribution charge between the two areas). These interarea transport costs depend in part on the prices of beef in the various areas as losses due to shrinkage and death are valued at destination market prices. Therefore, the equilibrium price array calculated by the spatial equilibrium component for year t becomes an input to the transportation cost component which calculates the interarea distribution costs for year t+1. Then, these distribution costs for year t+1 become inputs to the spatial equilibrium component that calculates the equilibrium price array for year t+1 and the cycle continues for each year through time. If prices increase through time, the transfer charges for year t+1 will be underestimated because the prices for year t were used to derive them. The extent of this downward bias is estimated in Chapter V.

The transhipment linear program uses the distribution costs calculated by the transportation cost component and the quantities demanded and supplied in the 15 areas furnished by the spatial equilibrium component to find the optimum transportation methods for beef.

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The model identifies the least cost method of shipment among areas, the required number of rail cars, the most efficient routes for rail and trek utilization, optimum location of slaughter plants, and total beef distribution costs.

This process was repeated at five year intervals for 20 years taking into account the growth of population and income on the demand functions for the 15 areas. Three policy examples are explored and their impacts on the demands, supplies, prices, and distribution requirements for the 15 areas of Nigeria are estimated. The three policies considered are:

1. Furnishing fewer rail cars than can be economically used along with little investment in trek route improvement--essentially the existing policy.
2. Furnishing all the rail cars demanded for live cattle distribution.
3. Instituting a large scale trypanosomiasis control program for cattle trekked to market and improving the speed of the rail service.

These policies illustrate what might be explored. The basic structure of the model is sufficiently flexible that other prospective policies designed to improve the beef distribution system's operation can be evaluated.

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Outline

This outline is provided to help the reader understand the total framework within which the thesis is developed and the procedures used to attain the stated objectives.

In Chapter II, a brief descriptive account of beef production, distribution, and consumption is given to clarify the problems of distribution. Also, the relationships of this model of the beef distribution system to the beef production model will be discussed.

Chapter III describes the model that estimates the costs of alternative methods of transportation and the effects of various policies on these costs. The methods of shipment analyzed are trekking, railing and lorry hauling of live cattle and refrigerated rail and lorry transport of meat. The costs of these methods are compared for all possible interarea shipments, and the effects of various policies designed to reduce live weight shrinkage and death losses are analyzed for important interarea routes.

In Chapter IV, the transhipment linear program model component is described. This component identifies the least cost method of shipment among areas, the required number of rail cars, the most efficient routes for rail and trek utilization, optimum location of slaughter plants, and total beef distribution costs. Eight static optimum transportation plans are compared and analyzed for alternative policies and model assumptions.

Chapter V presents the dynamic spatial equilibrium model which estimates the equilibrium structure of interarea prices and quantities demanded and supplied that result from the three policies previously described.

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described. The consequences of the policies are traced through a 20 year time period at five year intervals.

In Chapter VI, the results of the spatial equilibrium model component are processed by the transhipment linear program component to find the least cost transportation configuration through time for the three alternative policies. A summary of the conclusions of this study is also presented.

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CHAPTER II

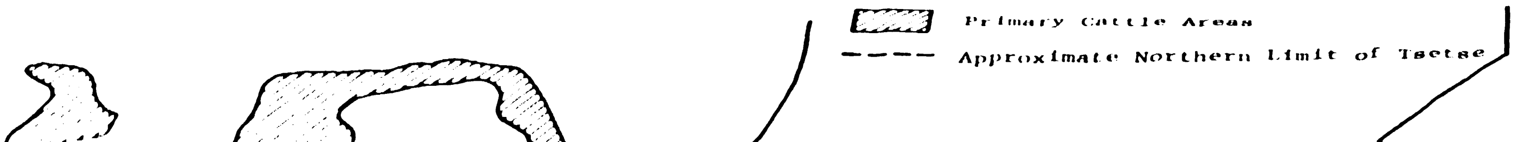
A BRIEF DESCRIPTION OF THE CURRENT NIGERIAN BEEF PRODUCTION, DISTRIBUTION, AND CONSUMPTION SYSTEM

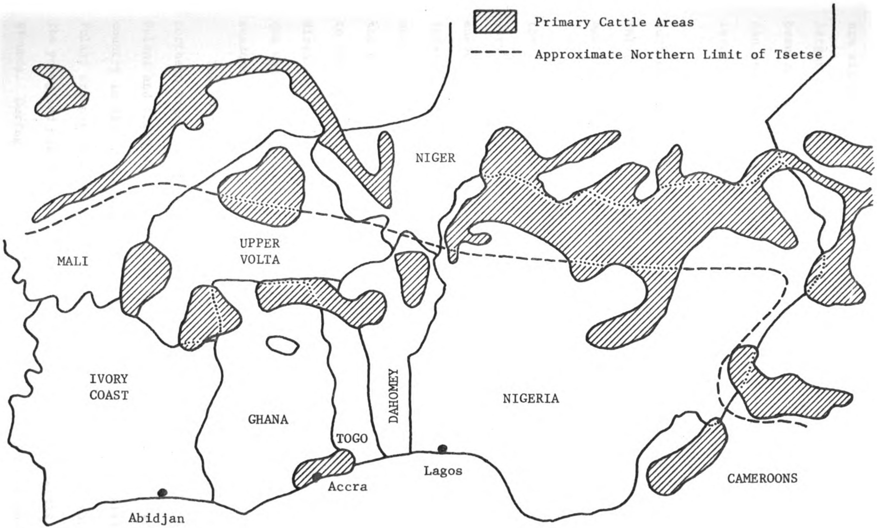
To better understand the context of Nigeria's beef distribution problems, descriptive knowledge of the production and consumption systems and institutions involved is crucial. This chapter provides that description.

Production System

The Nigerian beef industry is only a subset of the whole West African beef industry that stretches across about ten West African countries as shown in Figure 2. The fact that cattle are imported into Nigeria from four different West African countries is evidence of this intercountry dimension. These importations account for 1/4 to 1/3 of the total number of cattle slaughtered in Nigeria annually {7,p.97}.

One very important influence in beef production within Nigeria is the presence of the tsetse fly in the southern 2/3 of the country. Bites from infected tsetse flies cause trypanosomiasis, a disease that results in loss of weight and vigor and eventually causes death in cattle. Without modern management, including proper nutrition and health care, this disease is devastating to the large range Zebu type cattle that make up a large proportion of the cattle in Nigeria--and are the topic of this study. There are various breeds of tsetse-resistant cattle in Nigeria, but these are generally dwarf types that


Primary Cattle Areas
Approximate Northern Limit of Tsetse



Source: Ferguson, Donald. The Nigerian Beef Industry, unpublished M.S. Thesis, Cornell University, 1967, p. 26.

Figure 2: Primary Trade Cattle Production Areas in West Africa

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are significantly smaller and less efficient in other respects than the larger Zebu breeds in the northern parts of Nigeria. However, it has been and still is being demonstrated that these large Zebu type cattle can be raised in tsetse-infested areas if proper management, nutrition levels, and health care are present.

The presence of tsetse infestation not only influences beef production, but also limits the use of animal power in farming in Nigeria. This, in turn, influences farm size and input requirements for the agriculture of much of northern Nigeria.

Figure 3 shows the areas within Nigeria that are tsetse free all the time. Within the tsetse-infested northern areas, tsetse fly levels vary with the rainy season. As the rains subside and the dry season ensues, the fly levels recede in the north. Because of lessened fly infestation, some cattle migrate to southern areas to graze on the more productive grasslands. As the rains start to move north again, the tsetse level builds up. The Fulani herdsmen bring the cattle back to the far northern grazing lands to escape the trypanosomiasis disease. The estimated cattle populations in the various areas for the wet and dry seasons (shown in Figure 3) are evidence of this seasonal migration.

The overwhelming majority of the estimated 8 million cattle in northern Nigeria are owned by two semi-nomadic tribal groups: the Fulani and the Shuwa. The Fulani are found throughout the savanna country in Africa, from Senegal through to the Sudan. The cattle Fulani are not true nomads, but usually have permanent camps where the young and old live year-round near their wet season grazing grounds. During the dry season, the majority of the herd is moved to better grazing areas as far as conditions demand.


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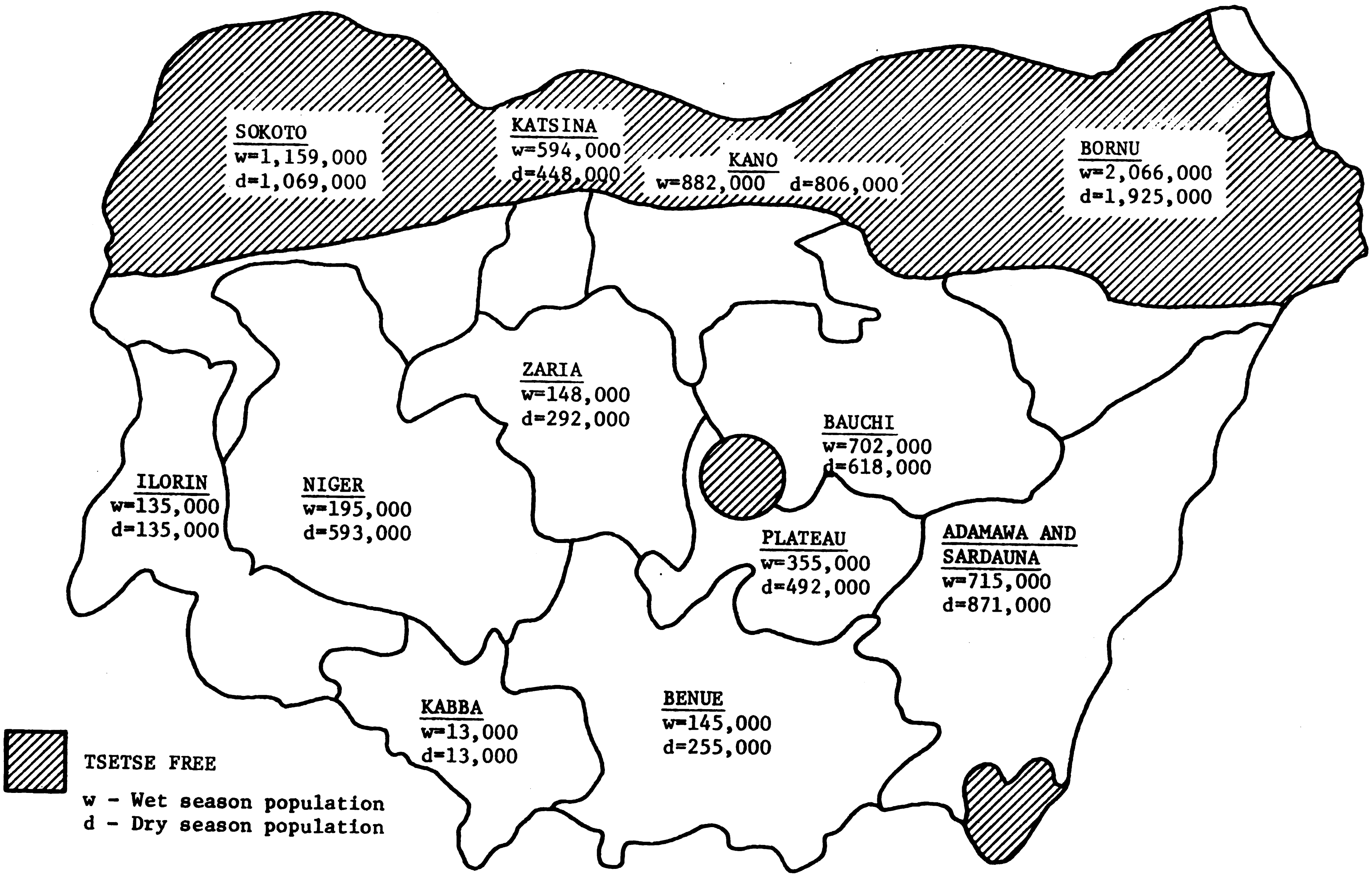

Figure 3: Tsetse Free Areas and Estimated Cattle Populations During Wet and Dry Seasons in Northern Nigeria, 1965

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The attitude of the Fulani toward his cattle and environment is a much debated topic. This debate will not be entered into in this study. However, the following excerpt from one analysis will be given to provide a background concerning the Fulani life-style.

"The cattle are the property of the men, and by ownership of cattle a man gains social status and prestige. Ownership of cattle confers on a Fulani man a social prestige which he can acquire in no other manner, and thus his desire is to have a large herd. Generally speaking, cattle are only sold to meet the major expenditures of the household, which usually involve support of the herd.

The reliance of the Fulani family on their cattle for much of their food and the importance of the sale of milk to their budget is often overlooked. It helps to explain why old cows are frequently kept until they have been barren for several years. In times of drought or disaster the less productive cattle can be sold or eaten to sustain life, and thus they also are a form of insurance. It is the presence of the many old cows in the herds which rightly gives the impression that the average age of the breeding herd is 8-9 years old. A close look at most herds will reveal that there are few males of mature size that are not needed for breeding purposes.

There is no social stigma against selling male stock, to which the thousands of cattle marketed each year from the Fulani herds bear witness. But to sell a female which is not barren is almost an admission of bankruptcy. Less than 20 percent of slaughter stock in Nigeria are females. But few can afford the luxury of selling cows as all are needed to simply maintain the herd size because the reproduction rate in the herds is low due to poor nutrition, disease, and the constant transhumance. In addition, many calves die before reaching maturity.

Historically the Fulani also have kept large numbers of cattle as a hedge against catastrophy in the form of severe drought or epidemic. The great Rinderpest epidemics of 1887-1891, 1913-1915, and 1919-1920, which decimated the herds, are still remembered, and total cattle numbers may just now be reaching former levels. Through hard experience the lesson was learned that older animals which had survived several dry seasons and acquired immunity in earlier epidemics were most likely to survive to form the nucleus of a new herd. A quick glance around any cattle market will confirm the impression that most surplus male stock are not marketed until 4-10 years of age. This is usually attributed to the lack of economic orientation on the part of the Fulani; they are assumed to be interested only in quantity and not in quality of stock. Quantity may come first due to the dependence on cattle for food and livelihood, but the many herds of matched pure red or pure white color of remarkably good condition and conformation under less than ideal conditions demonstrate the great value placed on what the Fulani consider quality.

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Much has been made on the Fulani's nomadic ways and his love for the nomadic life. The facts are that wherever conditions are such to allow permanent settlement, adequate grazing, water, and freedom from disease for his cattle, the Fulani have settled permanently.

Disease, seasonal rainfall, and seasonal grazing force the Fulani to be at least semi-nomadic. To an outsider the Fulani system of management may seem to be irrational, and he may not appear to be economically oriented. However, if it had not been the logical system, given the existing political, social, economic, and ecological conditions, the Fulani would long ago have disappeared from the face of Africa. The problem is not how to change the Fulani but how to change the condition on which the Fulani has based his management decisions. Although most Fulani are illiterate they are probably some of the world's best cattlemen" {7,p.23-24}.

The typical herd in northern Nigeria coutains 30-40 cattle. The age and sex distributions found in several studies is shown in Table II-1. From this table, it can be seen that approximately 50 percent of the entire herd are cows of calf bearing age. Male animals of the same age account for only 5-10 percent of the entire herd. This is consistent with the sex distribution of recorded sales shown in Table II-2. It is also interesting to note that 60 percent of the animals sold in these important markets were seven years and older. The age groups of 6, 7, and 8 accounted for approximately 58 percent of all cattle sold. This old age of market cattle illustrates the relatively low extraction ratio of the Nigerian herd. It is estimated that only 7 to 8 percent of the total herd is sold in a year. This compares with an extraction ratio of over 25 percent in the U. S. and other developed countries.

By developed country standards, the productivity of the Nigerian herds is low. Poor nutrition is one of the most important factors contributing to this situation. It is generally agreed that the tsetse-free grazing land in northern Nigeria is steadily deteriorating in quantity and quality. As the human population in the area grows,

Table II-1: Age and Sex Distribution of Nigerian Herds Reported In Various Studies

Author	Sharwood	St. Croix	Jangali reports	Tilani	?

Table II-1: Age and Sex Distribution of Nigerian Herds Reported In Various Studies

Author	Sharwood	St. Croix	Jangali reports		Tijani	?
Area of Study	Sokoto	Zaria	Kano	Kano	?	Mambila Plateau
Number of Cattle	130 herds	?	134	723	265 herds	160,991
Year	1934	1934	1932	1932	1952	1958
			(percent of total herd)			
Female						
Calves	15.7	10.0	6.0	5	13	10.5
1-3 years	20.3	12.1	30.6	31	12	13.25
3 years	43.6	58.0	38.8	36	47	55.0
Barren	4.4	3.6	?		1	
Total	84.0	83.7	75.4	72	73	78.75
			(percent of total herd)			
Males						
Calves	10.5	6.7	3.7	9	10	8.05
1-3 years	} 5.5	} 9.5	14.2	13	7	8.65
3 years >			6.7	6	10	4.55
Total	16.0	16.2	24.6	28	27	21.25

Source: Werhahan, Fricke, Hunger, Weltz, Gottschalk, Saager; The Cattle and Meat Industry In Northern Nigeria, Frankfurt, 1964, p. 67.

Table II-2:

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Source:

Table II-2: Number, Sex and Age Distribution of Cattle Marketed (Bukuru-Jos-Kaduna-Kano-Maidguri-Potiskum-Zaria-Ibadan-Lagos, 1963)

Age	Bulls		Age	Cows	
	(number)	(percentage)		(number)	(percentage)
2	508	.47	2	25	0.09
3	3,822	3.52	3	890	3.30
4	8,666	7.98	4	1,362	5.04
5	13,732	12.65	5	2,319	8.58
6	16,175	14.89	6	3,423	12.67
7	22,119	20.37	7	5,705	21.12
8	24,210	22.29	8	7,009	25.94
9	13,395	12.34	9	3,802	14.07
10	5,702	5.25	10	2,263	8.38
11	192	.18	11	216	.80
12	67	.06	12	2	.01
Total	108,588	100.00	Total	27,016	100.00
Percent of Total		80.1			19.9

Source: Werhahn, et al., The Cattle and Meat Industry in Northern Nigeria, p. 190.

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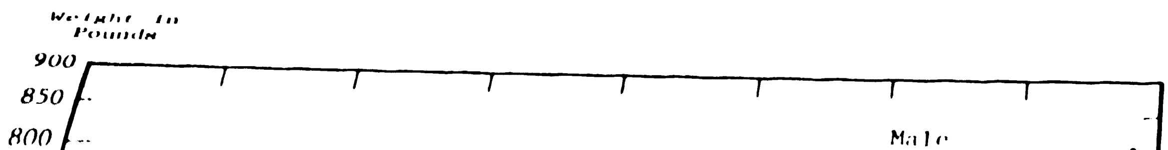
more grazing land is transferred to both food and cash crop land. Additionally, the total herd size in northern Nigeria is growing. These two factors have caused a serious problem in availability of perennial grass acreage. Some ecologists feel that the Sahara is slowly creeping southward in this area, meaning replacement of the perennial grasses with less productive annuals. It is an extremely serious matter, as 2/3 of the Nigerian cattle population use this area for grazing in the wet season to escape the tsetse fly in the southern areas.

As the dry season ensues, nutritional problems are compounded. Lack of bulk and protein become serious limiting factors on growth, reproductive ability, and lactation for the calves. In order to survive this period, the Fulani graze their cattle on crop residues left over from the harvests taken at the beginning of the dry season. Many times they are paid to do this as the farmers realize the value of the manure left behind.

In spite of the increased availability of crop residues, the Fulani cattle often suffer weight losses during the dry season, known as "dry season setback". Because of this setback, weight losses are incurred, mortality losses increase, live birth rates decrease, and calf mortality increases due to insufficient milk from lactating cows. The effect of this dry season setback is illustrated in Figure 4 which indicates the weight of an animal through time.

In addition to the serious nutrition problem, disease is an important contributing factor to low productivity. The major diseases of economic importance in Nigeria are trypanosomiasis, contagious bovius pleuropneumonia, rinderpest, streptothricosis, and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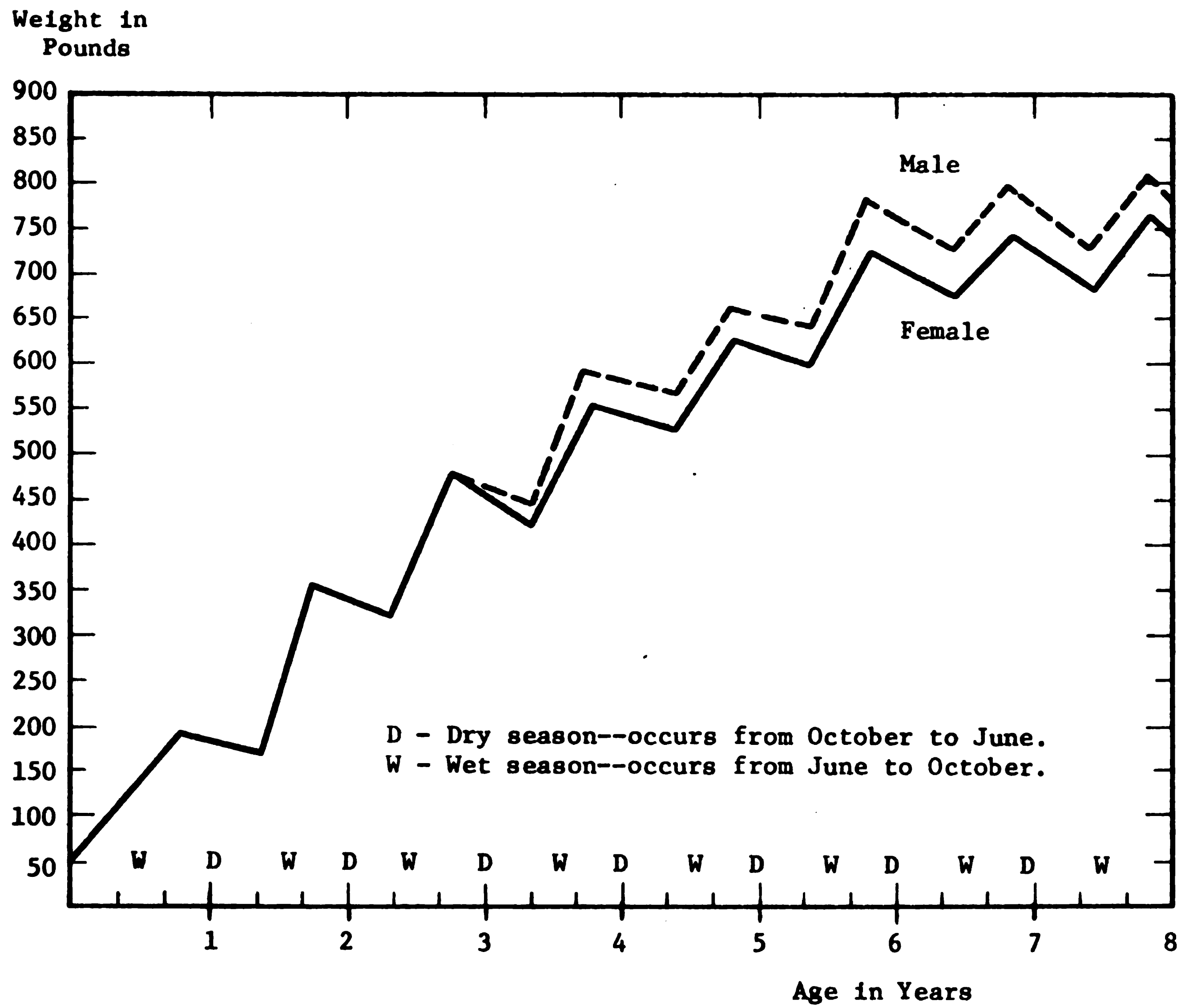

Source: This graph was constructed in consultation with Dr. Robert Deans, Department of Animal Science, Michigan State University and information contained in a forthcoming paper by Dr. John Wheat, "Seasonal Variations in Weights of Nigerian Cattle," to be published in a forthcoming issue of the Journal of Animal Science.

Figure 4: Average Weight Through Time of a Male and Female Range Animal in Northern Nigeria.

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parasitisons. Of trypanosomiasis, Dr. K. J. R. Maclennan says, "It is probably true to state that there is no other disease entity which limits to a greater extent the use which man in tropical Africa can make of fodder resources for the purpose of raising stock. It has been estimated that at a stocking rate of 12 head of cattle per square kilometer the tsetse infested area of Africa could hold over twice as many cattle as now exist" {25,p.1}.

Dr. Shebu Bida estimates that the loss through hide damage, death, and debility caused by the skin disease streptothricosis is over ₤100,000 each year {3,p.1}.

History has recorded the devastation of thousands of animals due to rinderpest epidemics. However, significant progress has been made in controlling this disease through mass vaccination campaigns carried out by the Nigerian government, the United Nations, and the U. S. Agency for International Development.

In general, the Fulani is faced with much adversity in raising his cattle. His management practices include the use of informal insurance in high risk situations. The cattle that do survive the droughts and disease may not be efficient converters of nutrients in comparison to breeds in much more favorable environments, but they are hearty and resistent to adverse conditions. These factors are important to the Fulani as they may mean the difference between existence and starvation.

Distribution System

The distribution system for moving cattle from producer to consumer is a fascinating study of an indigenous marketing system developed

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developed over the years with minimal foreign influence. Because of the nomadic nature of the producers, the great distances involved, and the risks of mortality losses due to disease and low nutrition, the distribution system is divided into small sections in terms of length of time the various participants own the cattle. The whole structure is held together by mutual indebtedness, which, in effect, links all trade levels and is run on mutual trust and fear of personal reprisals with little if any bookkeeping.

Distribution Channels

Three different channels of distribution will be described to illustrate how the system works. The first channel is from the producers in the northern parts of Nigeria to the consumers in the north. Petty traders, who buy one to three animals from the semi-nomadic cattle owners are the first link in this chain. They also very often supply the Fulani with household goods on account. This arrangement is made because the grazing areas are usually far removed from markets, making it very costly for the Fulani to acquire information regarding market values at first hand. After the petty trader has visited a few Fulani herds, he collects a small herd of 5 to 10 animals. This herd is taken to bush markets where independent intermediate cattle buyers and buying agents for large wholesale dealers come to purchase cattle. Some of the cattle collected by the petty traders are sold to local butchers who retail the meat in the small markets throughout the north. However, most of the cattle gathered by the petty itinerant traders are sold to the independent intermediaries and wholesale buying agents. The function of this group is to sort the beasts according to market value so that those suitable for the wholesale d

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wholesale dealers can be sold in the big provincial markets. The inferior ones are driven to the local cattle markets and sold to the resident butchers for sale to the consumer. The exchange made between the petty trader and the intermediaries and consequently the intermediaries and butchers is facilitated by middlemen. Their function is not restricted to the sale of the beasts on sellers' behalf only, but often they take over the interim financing by accepting the primary obligation to the cattle owner. Figure 5 indicates this organization as a flow diagram.

The second channel to be described is the flow from the producers in the north to the consumers in the southern urban centers such as Lagos, Ibadan, Umuahia, Port Harcourt and Enugu. This large flow of cattle is centered around large wholesale cattle dealers who have buying and selling organizations of their own. As mentioned previously, they may have buying agents gathering cattle in the bush markets to be sorted and consolidated for shipment to the south. The northern wholesale cattle dealers stand the risk of transporting the cattle from the northern provincial markets to the south involving distances of 500-1000 miles. They represent the largest and most powerful link in the distribution system. Usually they have selling agents in the large southern consuming areas who arrange the sale of the cattle in those markets. The distribution of the slaughter stock is usually settled through these local agent dealers residing in the cattle market using the services of the middlemen on the spot. The cattle destined to be consumed in the urban centers are usually purchased by butchers in the city from the wholesalers' agents through the middlemen. The butchers slaughter the cattle daily in the early morning and sell to consumers throughout the day.

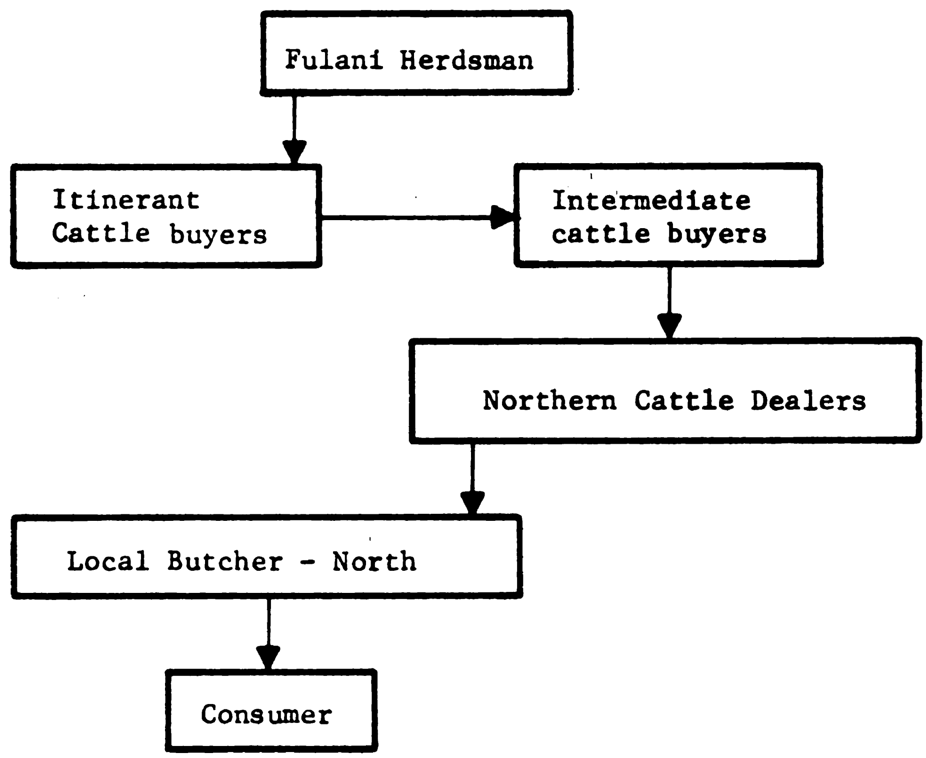

Figure 5: Distribution Channels for Marketing Cattle to Northern Nigerian Consumers

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The last channel to be discussed involves supplying cattle to consumers in the hinterland of the south. These cattle are purchased by local intermediaries in the south at the large markets from the agents of the wholesale cattle dealer through a middleman. These intermediaries take the cattle out to the local markets and sell in small lots to the local butchers who slaughter them and retail the meat to the final consumer. Figure 6 shows the last two channels discussed and Figure 7 is a summary of all three.

Transportation Methods

The transportation of live animals from producing areas to consuming areas is accomplished by three different methods. Listed in order of their importance by number of cattle transported, they are walking, rail hauling and truck hauling. The distances involved are considerable. For instance, the rail distance from Maiduguri to Abeokuta is approximately 1000 miles.

The trek method of transportation involves hired drovers who walk the cattle along pre-established trek routes. The drovers are fined if cattle are found off these routes. Besides the drovers' wages, the cattle owners must furnish them with money to purchase food. Along part of the trek routes during the dry season, maintenance feed and water must be purchased. The large costs incurred result from mortality, shrinkage, and salvage losses. In order to reach the large southern markets, the cattle must be walked through tsetse infested areas. The percentage of cattle infected with trypanosomiasis varies seasonally as seen in Figure 8. On the average, 1/2 of the animals reaching Ibadan by trek are infected by trypanosomiasis. In addition to disease stress, the animals are moved relatively rapidly causing

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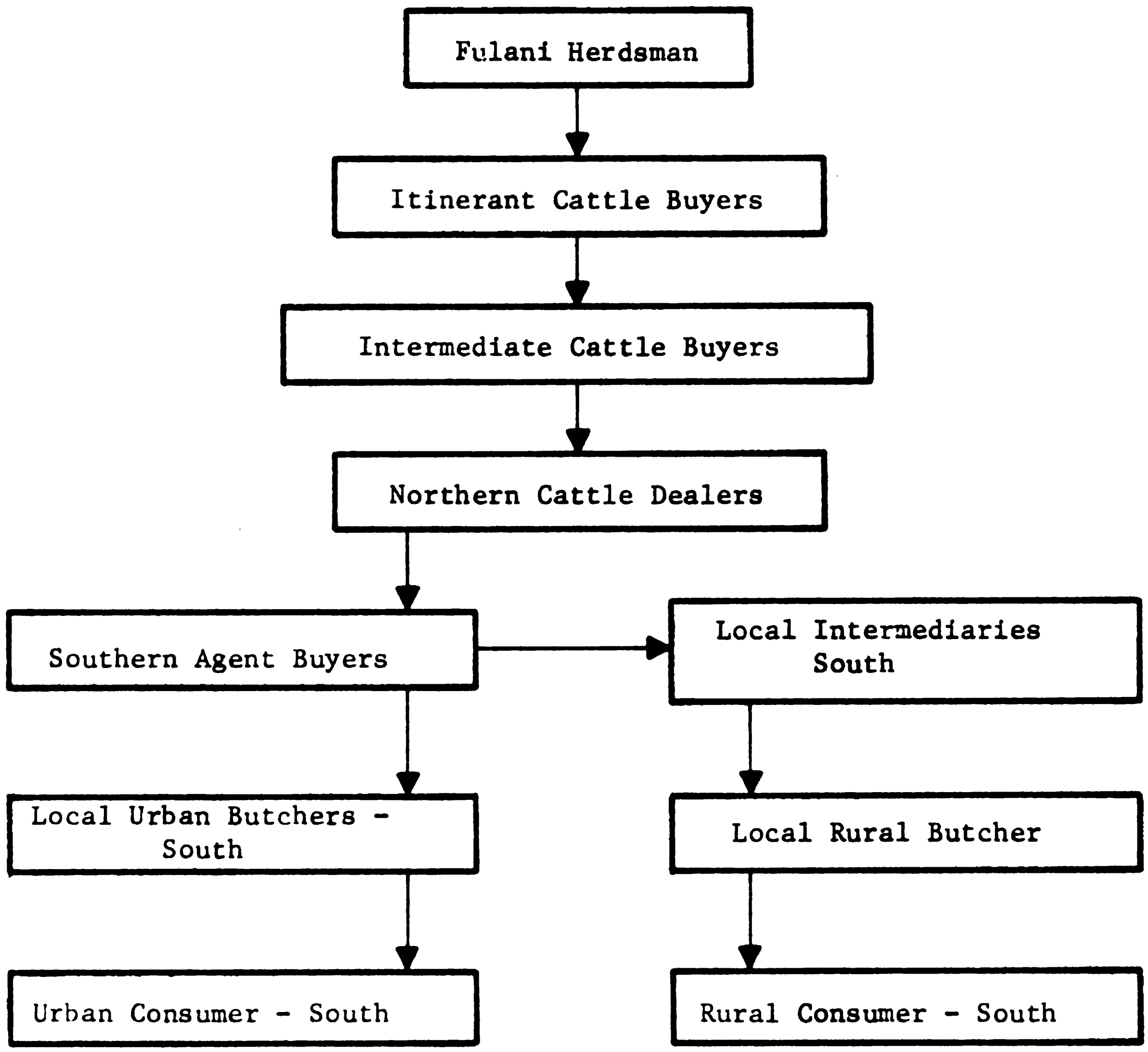

Figure 6: Distribution Channel for Marketing Cattle to Consumers in Southern Nigeria

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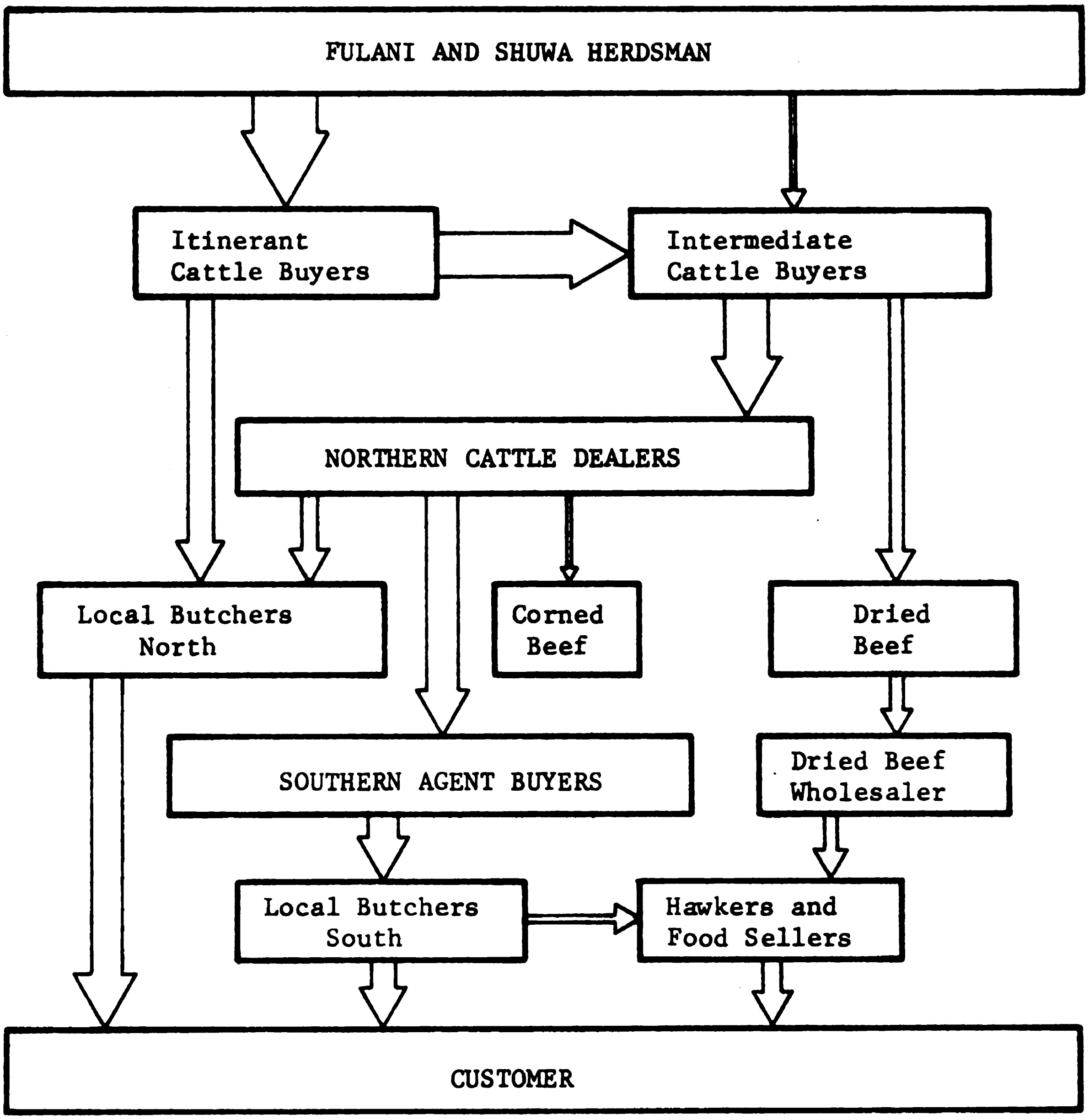
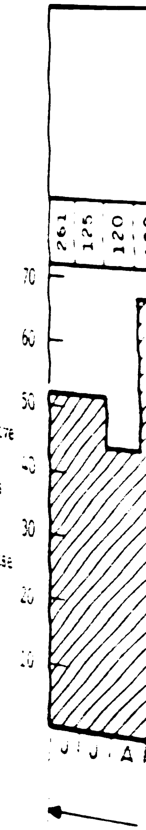


Source: Ferguson, Op. Cit., p. 29.

Figure 7: The Nigerian Marketing Pattern for Beef



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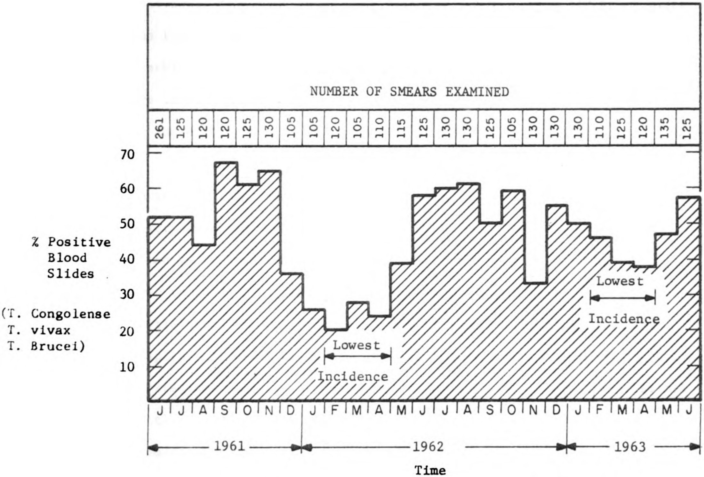

Source: Jones-Davies, W. J., "The Protection of a Small Group of Nigerian Trade Cattle From Trypanosomiasis Using Samorin" <u>Bulletin of Epizootic Disease in Africa</u> (1967), 25, p. 333.

Figure 8: Monthly Incidence of Trypanosomes in Thick Blood Smears Taken From Slaughtered Cattle at Ilorin

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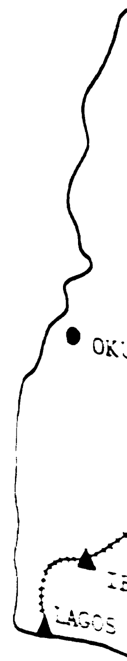
additional strain. The drovers will sell animals at a low price along the trek route if it is apparent that the animal will die before reaching the final destination. Other costs involved in trekking are the trade cattle tax, branding fee, and marketing charges. All of these charges will be quantified in the following chapter.

The second most important method of transporting cattle to the south is rail hauling. Figure 9 illustrates the rail system in Nigeria with major assembly points indicated. The rail service by advanced rail system standards is relatively slow. The trip from Kano to Lagos is approximately 700 miles, usually taking 3 days. Cattle often travel for several days without adequate food or water. Despite this, rail hauling is generally preferred to trekking because of its lower cost. The Nigerial Railway Corporation tries to dispatch cattle cars efficiently since they are in short supply. In 1961, a committee of cattle dealers was established to help regulate the numbers of cattle railed south in order to prevent past shortages and gluts.

Table II-3 shows the number of cattle transported by each method from the north to the south for the years 1952/53 and 1963/64. During the period from 1952/53 to 1961/62, the proportion of cattle shipped to the south by rail service generally increased. However, since 1961/62, the percentage hauled by rail has decreased. This may be due to failure of the railway to increase the number of rail cars in proportion to the increase in cattle being transported to the south. However, there are important production regions that are not served by the rail system. Therefore, until the rail system is expanded, a



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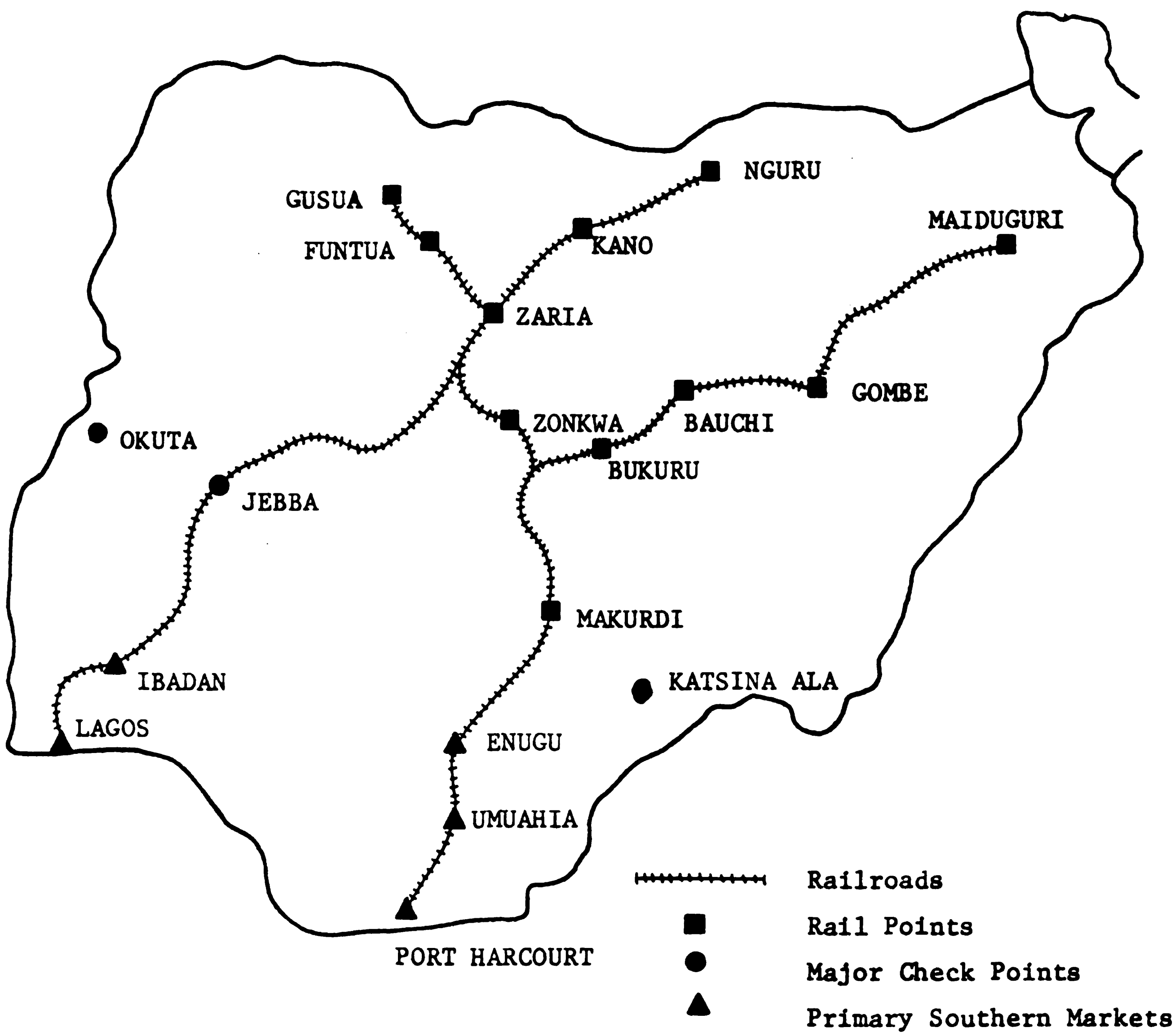

Source: Ferguson, op. cit., p. 94.

Figure 9: Nigeria--Rail Points, Major Interzonal Check Points and Primary Southern Markets for Trade Cattle

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Table II-3: Nigeria--Export of Cattle From the North to the South by Railway and on Hoof 1952/53 to 1963/64

Fiscal Year	Total	Rail	Hoof	% Hauled by Rail
	(thousands of cattle)			
1952-53	267	109	158	41
1953-54	282	111	171	39
1954-55	288	116	172	40
1955-56	276	120	156	43
1956-57	296	139	157	47
1957-58	293	156	138	53
1958-59	299	158	142	53
1959-60	323	167	155	52
1960-61	363	197	165	54
1961-62	368	204	164	55
1962-63	378	200	179	53
1963-64	397	201	196	51

Source: Northern Nigeria, Ministry of Animal and Forest Resources, Vet. Div. Annual Report, various years.

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large percentage of the cattle marketed in the south will continue to be trekked no matter how many rail cars are made available.

Truck hauling of cattle has become more important in recent years. Large lorries with capacities of 5 to 15 tons are used. The number of cattle hauled by this method is not known. They are usually loaded in the large markets in the north and driven nonstop to the south. Attendants are used to take care of the cattle during the trip. A typical trip from Kano to Lagos takes about 3 1/2 days. Because of less than desirable road conditions, driver stress from prolonged driving, and poor mechanical condition of the trucks, accidents are common. Individual accounts have been given of carcasses strewn along the main highways resulting from cattle truck mishaps. As will be quantified later, truck transport costs are relatively high compared to trekking or railing. However, it continues to be used as a means of reacting quickly to favorable short run price conditions that develop in the southern markets.

There is a relatively small amount of meat shipped to the south in refrigerated rail cars from large slaughter houses in the north. These large scale commercial slaughter houses are located in Sokoto, Kano, Maiduguri, Nguru, Kaduna, and Bauchi (see Figure 10) with capacities ranging from 200 to 400 head per day. Most of these abattoirs are operating at levels substantially below these capacities. The flow of frozen meat shipments amounted to about 12,000 cattle per year before the war in Nigeria. This figure may have decreased by over 1/3 with the loss of the eastern market. This represents meat sold to high income Nigerians and expatriates located in the large urban centers in the South.

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Beef Consumption

Meat is seldom used separately in the Nigerian's meal, but is added to the stew which is used to garnish the starch staple food. Nothing edible goes to waste. The edible offals are a valuable fifth quarter which may sell at only a slightly lower price than flesh.[1]

There is some indication that the "hot" meat available from local butchers who slaughter every day at the local slaughter stable is preferred by the average Nigerian to the "cold" meat shipped on refrigerated rail cars. There are three major reasons for this preference. First, a large number of the consumers do not have refrigeration to handle cold meat. Secondly, there is only slight, if any, differentiation made by the consumers as to the desirability of various cuts. However, the refrigerated meat is almost always sold by separate cuts. Thirdly, the "cold" meat is not usually available in the market areas where most of the Nigerians buy their food. Therefore, in order for the demand for "cold" meat to increase relative to "hot" meat, time must be allowed for tastes to change and market infrastructure to develop.

Ferguson has estimated the lean meat equivalent of a 700 pound market animal to be 198 pounds {7,p.130}. Using this calculation and estimated marketing numbers, the per capita consumption in Nigeria can be estimated. Table II-4 shows the estimated per capita beef availability by region in 1963/64. The total meat equivalent per

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[1]The fifth quarter is composed of material such as intestines, feet, horns, tail, blood, and bones. It is sold in the markets with the meat at only slightly reduced prices.

Table II-4: Estimated Per Capita Beef Availability by Region,

Table II-4: Estimated Per Capita Beef Availability by Region, 1963/64 Fiscal Year, Nigeria

Region	Population	Lean Meat Equivalent of				
		Lean Beef	Dried Meat and Edible Offals	Total Meat Equivalent	Lean Beef	Total Meat Equivalent
	(millions)[a]	Annual Availability (pounds)			Daily Availability (grams)	
North	23.0	4.32	3.02	7.34	5.37	9.13
East	10.2	2.02	1.18	3.20	2.51	3.98
West	6.5	5.89	6.08	11.97	7.33	14.89
Midwest	2.2	1.86	1.95	3.81	2.31	4.74
Lagos	.7	19.35	12.73	32.80	24.7	39.90
TOTAL/ AVERAGE	42.6	4.13	3.15	7.28	5.14	9.06

[a]Midyear 1963.

Source: Ferguson, op. cit., p. 135.

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capita for Nigeria is estimated at 7.28 pounds. This is indeed meager in relation to the U. S. per capita beef consumption of 105 pounds. As can be seen from Table II-4, the consumption of beef is much higher in the urban areas of the West and Lagos. Differences in income and prices probably account for most of this.

In general, the beef economy of Nigeria from production to consumption is characterized by activities that have been developed through time to meet the economic, physical, and social conditions that are present. Because many of the participants live close to the subsistence level, the system is noted for practices that insure against large losses. It could be termed a primitive system, but it would not be accurate to describe it as unable to react to economic changes.

Relationship to Beef Production Model

As indicated in this chapter, problems relating to the Nigerian beef industry are not confined solely to the distribution system. There are significant problems relating to disease, nutrition, breeding, and environment in the production sector. A closely related simulation model of the northern beef production sector has been used to investigate the interactions among the total herd size, number of cattle marketed, nutrition available from the range and crop residues, the growing human population and various policies that might be implemented to improve the production performance of the Nigerian beef industry {15}.

This thesis is primarily concerned with beef distribution sector problems and policies, with little emphasis on the possible production changes that might occur. However, it is recognized that the production a

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production and distribution sectors do not operate independently. For example, the relatively old age of market cattle in Nigeria (See Table II-2) is partly a result of the rigors of market treks that are devastating to young immature cattle. Therefore, if better transportation methods were available for moving the cattle to market, younger cattle might be marketed. This, in turn, would improve the beef yield produced from the herds. Another interaction would be the needed adaptation of the distribution system to serve the market animals taken from the modern grazing reserves. These cattle can not be economically trekked to southern markets. Other transportation methods would have to be used. While the integration of these two studies would provide a better framework for policy analysis than each taken seperately, this integration must be accomplished in future research.

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CHAPTER III

SPECIFICATION OF DISTRIBUTION COSTS - TRNSCST

Introduction

The three main methods of transporting cattle from producing areas to consuming regions are by trekking, railing, and truck hauling. These methods will probably continue to be important for many years. Therefore, information about the costs involved in these methods is important to policy makers involved in improving beef transportation. This is true for policies that may be instituted to either improve or replace these systems. Some studies on various aspects related to transport costs of trekking and railing cattle in Nigeria have been done {9,12,18,33,35,36}. Very little if any information is available on costs of truck hauling. The model described in this chapter organizes and integrates information from these studies, guessimates obtained from people with Nigerian experience, and data taken from a survey to estimate the costs of alternative transportation methods. In this framework, policy makers can identify major cost categories within each method, compare the same cost item among methods, and compare total cost differences among the various methods. The model gives the costs of these transportation alternatives on various routes enabling the user of the model component to identify differences in costs of transportation methods on different kinds of routes. For example, the comparative advantage of certain transportation alternatives

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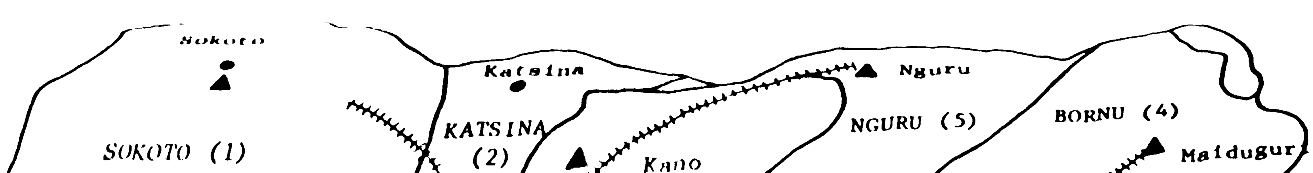
alternatives may be different for routes going through tsetse infested areas as compared to routes in fly free regions.

The results of this model component should not be considered highly accurate; more research on the various parameters and relationships must be done to attain higher levels of accuracy. However, the information used to estimate the parameters and relationships was the best available. Organizing this information into an integrated framework should help in the policy process that seeks to improve the performance of the Nigerian beef distribution system.

The Model Framework

The TRNSCST model is constructed so that the transport cost per animal (in ₦'s per animal) is calculated between each pair of the 15 areas for three different methods of shipment. The 15 areas chosen are shown in Figure 10. The 13 areas in the northern section of Nigeria correspond to the former provinces of the former northern region as follows. Areas 1, 2, 3, 6, 7, 8, 11, and 12 respectively have the same boundaries as the former provinces of Sokoto, Katsina, Kano, Niger, Zaria, Bauchi, Plateau, and Benue. Areas 4 and 5 divide the former province of Bornu. Area 9 combines the former province of Adamawa and the lower sector of the former Sardauna province, while the upper part of the former Sardauna province is designated as area 13 for this study. Area 10 is the combination of the former provinces of Ilorin and Kabba. Area 14 is the Western state plus 1/2 of the Mid-Western state. Area 15 is made up of 1/2 of the Mid-Western state plus all of the former Eastern region. Central locations within these



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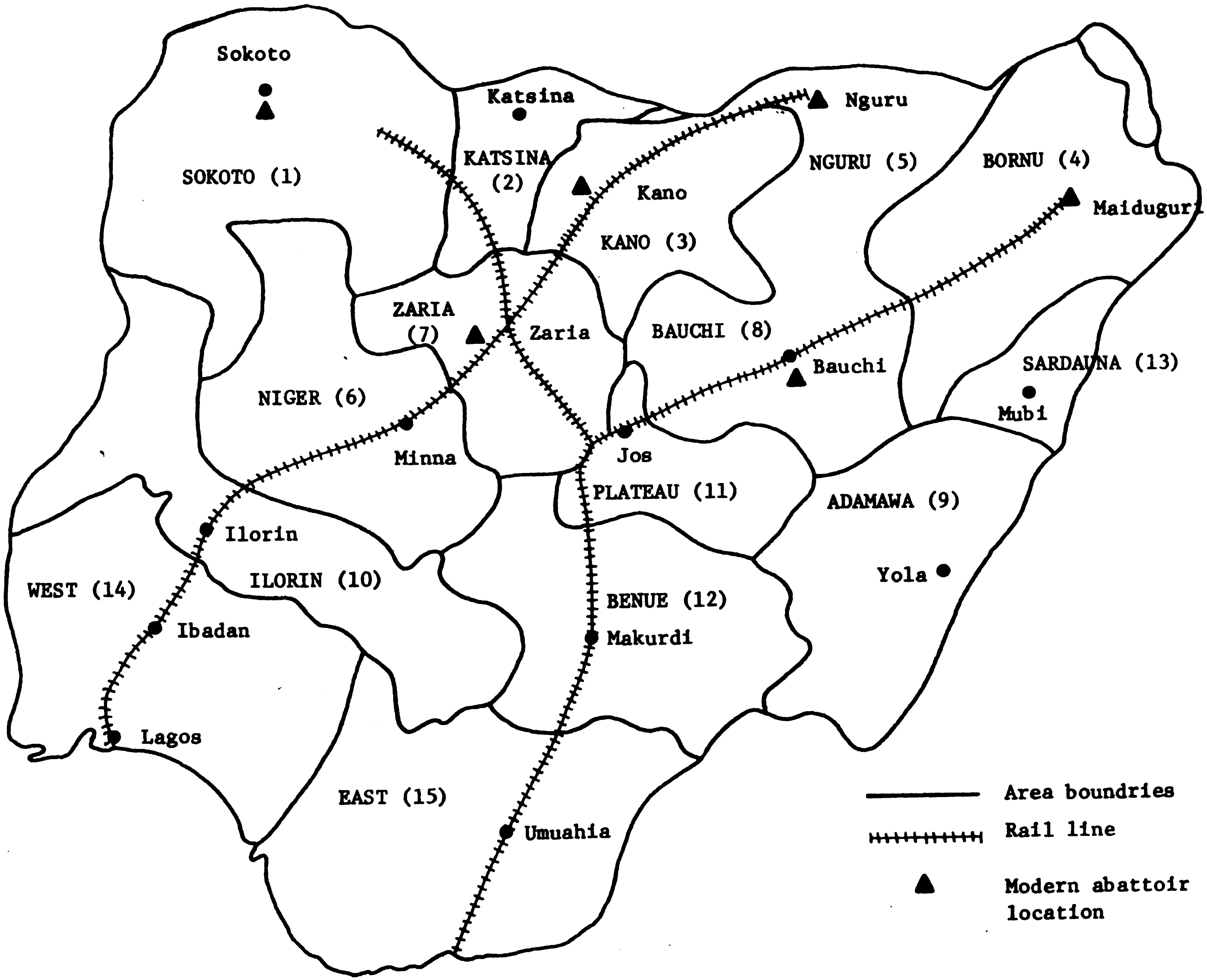

Figure 10: Designated Areas of Nigeria Used in This Study

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15 areas were designated for purposes of measuring average distances. The areas and central locations chosen are designated in Figure 10.

There are certain assumptions used in this model that need to be explicitly stated. The transportation costs derived are relevant for the Zebu type cattle raised in the north predominantly by Fulani nomadic herdsmen, not the dwarf partially tryspanosomiasis resistant type of cattle that are raised in the southern areas of the country. It is assumed that these cattle are not fed highly concentrated rations but are taken directly from the range to be transported for marketing. The average weight is assumed to be 700 lbs. live weight and 340 lbs. carcass weight.

The transportation alternatives considered in the TRNSCST model are truck hauling, rail hauling, and trekking. These were chosen because they are the most important methods of live cattle shipment and will continue to be for several years to come. Since all of these methods involve weight and mortality losses, the price of animals and meat is used to determine the costs related to these losses. Table III-1 shows these prices and the source from which they were calculated. The subsequent pages will be used to present the detailed costs specification of the model for these three shipment alternatives.

Cost Structure for Shipment of Live Animals by Truck

Survey for Truck Costs

Because information on cattle trucking costs was practically non-existent in Nigeria, a survey was made in conjunction with the Nigerian Institute of Social and Economic Research, the Department of

Table III-1

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Sources:

Note:

Table III-1: Prices of Beef and Cattle in the 15 Areas, Nigeria, 1963

Area	Price Per Pound of Meat	Price Per Head
	(d)	(Ꞓ)
1	12.2	17.8
2	14.3	20.8
3	14.3	20.8
4	11.0	16.0
5	12.0	17.5
6	18.8	27.4
7	15.5	22.6
8	12.0	17.5
9	11.0	16.0
10	15.2	22.2
11	12.0	17.5
12	16.8	24.5
13	11.0	16.0
14	21.6	31.5
15	21.3	31.0

Sources: Annual Abstract of Statistics - Nigeria, 1966. Federal Office of Statistics, Lagos, p. 120. Werhahn et. al., op. cit., p. 161 and p. 197. Ferguson, op. cit., p. 185.

Note: Hunger States that the price paid by the butcher for the animal is 80% of the price he sells it for on the retail market. The above prices are what the cattle sell for at the wholesale market, i.e., about 80% of the retail price (see 35,p.200). This procedure was verified by applying it to wholesale and retail prices in the A. D. Little report, "Ibadan Meat Slaughter and Market Requirements," p.20-25{1}.

The price of meat in d/lb and the price of cattle in Ꞓ/head are related by the following general relationship:

$$\text{Price of the Animal (Ꞓ/head)} = \frac{\frac{\text{Price of meat in d/lb}}{2} \times 700}{240}$$

or

Price of meat (in d/lb) = .686 x price of animal in Ꞓ/head.

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Appendix I

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Agricultural Economics at the University of Ibadan, and Michigan State University for the purpose of obtaining this information. The questionnaire and results appear in Appendix Table 1.

The equations of this model are presented in algebraic form. The actual computer program written in fortran and fordyn is given in Appendix II.

The following equations are used to calculate the transportation charges for truck hauling. Each equation is discussed in a corresponding following section which defines each term. The number on the left of each equation is simply a reference number.

21 TFC (I,J) = PTFC x TM (I,J)

22 TDL (I,J) = PDT x PA (J) x .34 x TM (I,J)

23 RTDL (I,J) = PDT x PA (I) x .34 x TM (I,J)

24 DT = TM (I,J)/700. x 3.5

25 LWS = TABEXE (VAL, SMALL, DIFF, KF, DT)

26 TSC (I,J) = LWS x CLC x PM (J) x CW + .5 x (LWS x WA - LWS x CLC x CW) x PPS x PM (J)

27 RTSC (I,J) = LWS x CLC x PM (I) x CW - .5 x (LWA x WA - LWS x CLC x CW) x PPS x PM (I)

28 TTDC (I,J) = (TFC (I,J) + TDL (I,J) + TSC (I,J) + TCT + FM)/240.

29 RTTDC (I,J) = (TFC (I,J) + RTDL (I,J) + RTSC (I,J) + TCT + FM)/240.

Freight Cost by Truck

21 TFC (I,J) = PTFC x TM (I,J)

where:

TFC (I,J) = Total freight charge for shipment by truck from area I to area J in pence per animal

PTFC = freight charge for shipment by truck in pence per animal per mile

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TM (I,J) = mileage from area I to area J for trucks

The freight cost per cow per mile (PTFC) was obtained by averaging the costs per animal per mile given by the survey. This amounted to approximately 3 pence per mile per animal hauled by truck. The mileage chart used for truck transportation is shown in Table III-2.

Mortality Cost for Truck Hauling

22 TDL (I,J) = PDT x PA (J) x .34 x TM (I,J)

where:

TDL (I,J) = Total death loss costs incurred by moving cattle from area I to area J in pence per animal

PDT = percentage of cattle that die on a 720 mile trip by truck

TM (I,J) = mileage from area I to area J for trucks

The mortality cost per animal is obtained by multiplying the percentage that die times the price of animals in the region of destination. The death percentage is calculated by multiplying the mortality percentage on a 720 mile trip times the ratio of mileage from I to J to 720. The PDT parameter (see equation 22), which is set at 2%, is essentially an educated guess made with advice from people experienced in transportation of cattle in Nigeria.

23 RTDL (I,J) = PDT x PA (I) x .34 x TM (I,J)

The equation estimates the mortality costs of moving cattle from area J to area I. Therefore, the only difference from it and the previous equation is that the relevant price is the price of animals in area I.

Table III-2: Road Mileage between Areas (TM (I,J))

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Table III-2: Road Mileage between Areas (TM (I,J))

(miles)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	---														
2	260	---													
3	340	110	---												
4	710	480	370	---											
5	515	285	175	235	---										
6	375	330	320	690	495	---									
7	245	205	95	465	270	225	---								
8	475	370	260	290	360	425	230	---							
9	720	525	415	475	510	670	475	245	---						
10	435	535	525	895	700	285	430	630	875	---					
11	395	355	245	370	440	345	150	80	325	550	---				
12	605	565	455	580	645	265	360	290	535	415	210	---			
13	720	525	415	275	510	700	475	250	100	875	340	550	---		
14	580	680	670	1045	845	430	575	750	1020	145	700	555	920	---	
15	835	800	700	820	890	630	600	530	770	350	450	240	790	480	---

Source: <u>Transportation - A Guide to Current Costs in Nigeria</u>, published by the Federal Ministry of Information for the Federal Ministry of Commerce and Industry, Lagos, Nigeria, 1965. Appendix B.

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Shrinkage Costs

24 DT = TM (I,J)/700. x 3.5

25 LWS = TABEXE (VAL, SMALL, DIFF, KF, DT)

26 TSC (I,J) = LWS x CLC x PM (J) x CW + .5 x (LWS x WA - LWS x CLC x CW) x PPS x PM (J)

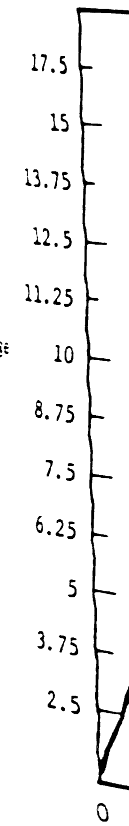
27 RTSC (I,J) = LWS x CLC x PM (I) x CW + .5 x (LWS x WA - LWS x CLC x CW) x PPS x PM (I)

This set of equations estimates the cost of tissue shrinkage per animal involved in moving from area I to area J (equation 26) and from area J to area I (equation 27).

DT = time in days to move between area I and area J. The survey indicated that a 700 mile trip (Kano to Lagos) took 3.5 days to complete by truck. Therefore, 3.5 multiplied by the ratio of mileage from I to J to 700 miles gives the time involved to move between I and J.

This time (DT) is taken as the independent variable in the functional relationship between time in transit and live weight shrinkage. This functional relationship is represented by equation 25. This TABEXE function is a simulation sub-program which approximates functional relationships by straight line segments. This sub-program is given in full by equations 101 through 107 in Appendix II. The actual functional relationship is illustrated in Figure 11. This sub-program returns the percentage of live weight shrinkage (LWS) that corresponds to the time in transit between areas I and J.

To estimate economic costs, live weight shrinkage is converted to tissue or meat shrinkage. Equations 26 and 27 do this by pricing the



Source:

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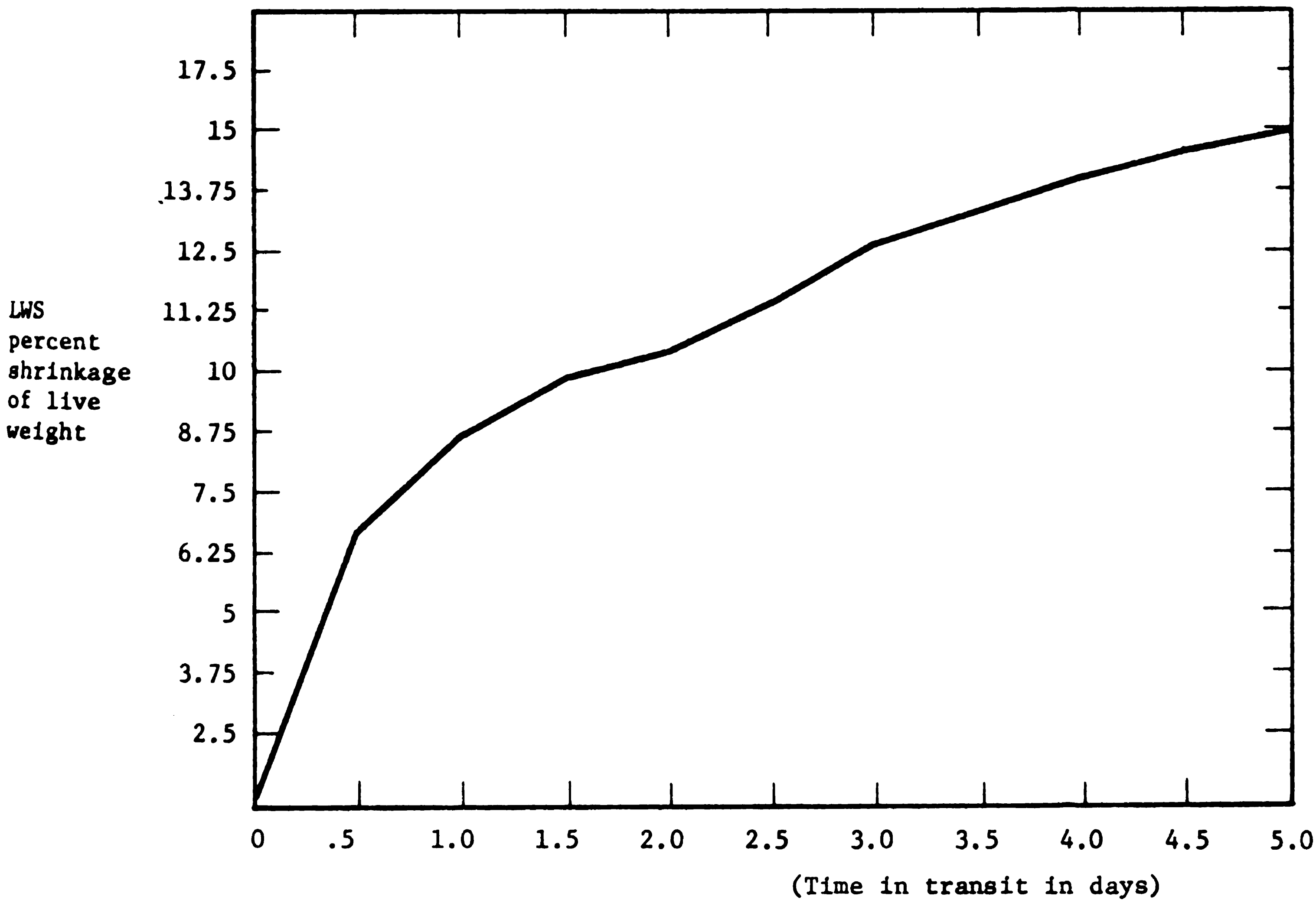

Source: Shorthose, W. R., "Weight Losses of Cattle Prior to Slaughter," CIS RO Fd. Prererv. Quarterly, Vol. 25, No. 4, (1965) p. 72.

Figure 11: Relationship of Live Weight Shrinkage to Time in Transit

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meat loss at prices of meat in the destination market. To understand this operation, the parameters in the two equations need to be explained in detail.

LWS = percentage of live weight shrinkage

CLC - factor used to convert percentage live weight shrinkage to percentage carcass weight shrinkage. This parameter is set at .77. This value was derived from data given in a report by L. Larson {22} that indicated the percentage of carcass shrinkage for railing cattle for two days was 7.7%. This time corresponds to a live weight shrinkage of 10% as reported in Table III-2. Therefore, the ratio of percentage of live weight shrinkage to percentage of carcass weight shrinkage is equal to .77.

PM (J), PM (I) = price of meat in area J and I respectively in pence per pound.

CW = carcass weight - assumed to be 340 pounds

WA = weight of the animal - assumed to be 700 pounds

PPS = proportion of the meat price at which other products (stomach, tongue, feet, etc.) from slaughter are sold. This parameter is set at .44. This was derived from information gathered on wholesale butchers' margins in Ibadan {1} . The total value of all products not included in the carcass was divided by their total weight yielding price in pence per pound. This price was then divided by the meat price which gave .44.

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The first part of equations 26 and 27 (LWS x CLC x PM (J) x CW) converts the live weight shrinkage to pounds of carcass lost and values these pounds at the price of meat in the destination market.

The second part of equation 26 and 27 (.5 x (LWS x WA - LWS x CLC x CW) x PPS x PM (J)) calculates the pounds of shrinkage lost by products other than carcass cuts and values them at a lower proportional price relative to the meat price in the destination market. As can be seen in equations 26 and 27, the difference between the total live weight pounds lost and the total carcass pounds lost is divided by two to estimate the total pounds lost on items not included in the carcass. This assumes that 1/2 of the loss difference between total live weight loss and carcass weight loss is attributable to items not consumed such as intestinal fill, etc.

<u>Total Cost of Shipment by Truck</u>

28 TTDC (I,J) = (TFC (I,J) + TDL (I,J) + TSC (I,J) + TCT + FM)/240.

29 RTTDC (I,J) = (TFC (I,J) + RTDL (I,J) + RTSC (I,J) + TCT + FM)/240.

where:

TTDC (I,J), RTTDC (I,J) = total cost of shipment by truck from area I to area J and from area J to area I respectively - in Ł's per animal.

TCT = Trade cattle tax. This is a tax imposed on all trade cattle which amounts to 72 pence per head.

FM = Marketing fee for cattle at destination markets which is about 24 pence per animal.

These equations simply add up the costs involved in shipment by truck.

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Cost Structure for Shipment of Live Animals by Walking

The costs involved in trekking live cattle fall into nine categories. These include drovers fee (DF), food money (CM), marketing fee (FM), salvage costs (SC), shrinkage costs (CS), mortality costs (MC), investment cost (CI), water and supplementary feed costs (WSF), and trade cattle tax (TCT). Each category is represented by one or more equations of the following set of equations which are used to calculate the cost of on hoof transport. Each equation is discussed in the following section which defines each term.

31 DF (I,J) = PDF x WM (I,J)

32 CM (I,J) = (PCM x WM (I,J) /MWD)/CPD

33 SC (I.J) = SF (I,J) x (PA (J) - .33 x PA (J)) x 240.

34 SCR (I,J) = SF (I,J) x (PA (I) - .33 x PA (I)) x 240.

35 MC (I.J) = .33 x SF (I,J) x PA (J) x 240.

36 RMC (I,J) = .33 x SF (I,J) x PA (I) x 240.

37 CS (I,J) = .025 x WM (I,J)/100. x CLC x PM (J) x CW - .5 x (.025 x WM (I,J)/100. x WA - .025 x WM (I,J)/ 100. x CLC x CW) x PPS x PM (J)

38 RCS (I,J) = .025 x WM (I,J)/100. x CLC x PM (I) x CW = .5 x (.025 x WM (I,J)/100. x WA - .025 x WM (I,J)/100. x CLC x CW) x PPS x PM (I)

39 CI (I,J) = ((PA (J) x RI x 240.)/365.) x ((WM (I,J)/MWD) + 4.)

40 RCI (I,J) = ((PA (I) x RI x 240.)/365.) x ((WM (I,J)/MWD) + 4.)

41 TWDC (I,J) = (DF (I,J) + CM (I,J) + FM + SC (I,J) + CS (I,J) + CI (I,J) + WSF (I,J) + TCT + MC (I,J))/240.

42 RTWDC (I,J) = (DF (I,J) + CM (I,J) + FM + SCR (I,J) + RCS (I,J) + RCI (I,J) + WSF (I,J) + TCT + RMC (I,J))/240

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31 DF (I,J) = PDF x WM (I,J)

where:

DF (I,J) = Drovers' fee between area I and area J in pence per animal

PDF = Drovers' fee per mile per animal in pence

WM (I,J) = trek mileage between area I and area J. See Table III-3.

The drovers' wages are calculated at 5 pence per mile and beast for distances up to 300 miles and at 6 pence per mile for more than 300 miles trek distances. It is assumed that one drover will look after 15 head of cattle. In addition to the wages, the cattle owners usually pay the return fare to the place of departure to the drovers (calculated at III class rail fare). An analysis of 25 different trek routes indicates this amounts to .54 pence per mile per animal {12}.

Food Money

32 CM (I,J) = (PCM x WM (I,J)/MWD)/CPD

where:

CM (I,J) = food money per animal in pence

PCM = food money per drover per day in pence

MWD - miles walked per day

CPD = number of cattle handled by one drover

The cattle owners pay 18 pence per day to each drover for food money. This amount must be multiplied by the number of days in the trek and subsequently divided by the number of cattle handled by a driver to find the cost of food money per animal.

Table III-3: Trek Mileage between Areas (WM (I,J))

Table III-3: Trek Mileage between Areas (WM (I,J))

(miles)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	---														
2	160	---													
3	250	100	---												
4	600	450	350	---											
5	350	200	140	200	---										
6	400	320	220	570	360	---									
7	350	200	100	450	240	130	---								
8	500	310	190	260	200	410	270	---							
9	710	550	450	200	350	710	580	200	---						
10	320	400	400	750	540	180	300	570	1250	---					
11	565	356	256	350	300	450	370	100	300	550	---				
12	620	510	410	510	460	590	530	260	320	720	170	---			
13	1000	900	850	200	700	1000	900	260	100	1000	320	350	---		
14	450	530	530	880	670	310	430	700	980	130	800	960	1200	---	
15	790	680	580	620	630	760	700	430	450	890	340	170	500	1160	---

Sources: Werhahn, Fricke, Hunger, Weltz, Gottschalk, Saager, The Cattle and Meat Industry in Northern Nigeria, Frankfort, Germany, 1964, Map 12.

Note: The trek route locations are reported in Werhahn, et al. Some mileages were reported in Hunger's unpublished paper {12} while the rest of the mileages were calculated from a detailed map of Nigeria.

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Salvage Costs

33 SC (I,J) = SF (I,J) x (PA (J) - .33 x PA (J)) x 240.

34 SCR (I,J) = SF (I,J) x (PA (I) - .33 x PA (I)) x 240.

SC (I,J), SCR (I,J) = Salvage costs per animal walking from area I to area J in pence.

SF (I,J) = percentage of cattle salvaged when trekked between areas I and J. See Table III-4 for these percentages and the method used to calculate them.

PA (I), PA (J) = price of animals in area I and area J respectively - in £'s per animal.

Because the trek times are sometimes very long and the cattle must pass through tsetse fly areas, stress and disease are important problems during the trek. To avoid total losses, cattle that are diseased or about to die for other reasons are sold at relatively lower prices along the trek routes. This is an important source of cheap meat to small villages along these routes. The price received for these salvaged animals is about one-third the price for healthy animals. Equations 33 and 34 are used to calculate the average attributable proportion of each beast in the total losses in market value due to emergency slaughter because of disease and overstrains.

Mortality Costs

35 MC (I,J) = .33 x SF (I,J) x PA (J) x 240.

36 RMC (I,J) = .33 x SF (I,J) x PA (I) x 240.

MC (I,J) RMC (I,J) = Mortality costs per animal trekked from area I to area J and area J to area I in pence.

Table III-4: Proportion of Cattle Salvaged Between Areas (SF (I,J))

Table III-4: Proportion of Cattle Salvaged Between Areas (SF (I,J))

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	---														
2	.008	---													
3	.012	.005	---												
4	.03	.022	.017	---											
5	.017	.01	.007	.01	---										
6	.032	.025	.017	.034	.024	---									
7	.017	.01	.005	.022	.012	.014	---								
8	.025	.02	.012	.018	.01	.045	.03	---							
9	.045	.036	.025	.01	.017	.078	.064	.01	---						
10	.027	.037	.039	.056	.047	.021	.034	.064	.13	---					
11	.051	.028	.022	.03	.024	.049	.04	.01	.033	.06	---				
12	.053	.046	.04	.049	.02	.065	.058	.029	.035	.079	.018	---			
13	.062	.051	.043	.01	.055	.11	.099	.03	.011	.11	.035	.038	---		
14	.04	.05	.052	.069	.06	.034	.047	.077	.1	.014	.088	.1	.13	---	
15	.075	.064	.058	.062	.06	.084	.077	.047	.049	.098	.037	.019	.055	.13	---

Source: Werhahn, et al., The Cattle and Meat Industry in Northern Nigeria, Frankfurt, Germany, 1964, p. 166.

Note: Salvage loss occurs most frequently after the cattle have traveled through tsetse infested areas for a few days. Werhahn et al. reported 5% of the animals on the trek from Kano to Ibadan (500 miles) were sold for salvage. I assumed that salvage sales would be 1% per 200 miles in tsetse free areas and 1.5% per 100 miles in tsetse infested areas.

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This mortality factor represents the average attributable proportion of each animal in losses due to mortality, thefts, and escapes along the trek routes.

In his analysis of 25 different trek routes, Hunger found that mortality percentage was about one-third as high as the salvage percentage {12}. To obtain the cost of these losses, the mortality percentage is multiplied by the price of animals in the market of destination.

Shrinkage Losses

37 CS (I,J) = .025 x WM (I,J)/100. x CLC x PM (J) x CW + .5 x (.025 X WM (I,J)/100. x WA - .025 x WM (I,J)/100 x CLC x CW) x PPS x PM (J)

38 RCS (I,J) = .025 x WM (I,J)/100. x CLC x PM (I) x CW + .5 x (.025 x WM (I,J)/100. x WA - .025 x WM (I,J) /100. x CLC x CW) x PPS x PM (I)

CS (I,J), RCS (I,J) = Shrinkage costs from trekking cattle from area I to area J and area J to area I respectively in pence per animal.

Information on live weight shrinkage of trade cattle during trekking time was taken from four different sources. Werhahn quotes live weight losses on trade cattle of 12.5% for treks from Kano to Ibadan and 10% for Kano to Ilorin {35,p.231}. Godrey, et al. report losses on 600 pound cattle of 13% from Jibiya to Ibadan {9,p.260}. Unsworth and Birkett report losses of 13 kg. on cattle trekked from Kano to Ilorin but amazingly never reported the initial live weights {33}. Jones-Davies reported 10% live weight loss of 450 pound young cattle for a trek from Jibiya to Ibadan {18}. Taking these observations and mileages between points, it appears that live weight shrinkage on treks is approximately 2.5% per 100 miles.

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The live weight shrinkage was converted to carcass and items other than carcass shrinkage in the same manner as outlined in the shrinkage equations for truck transportation.

Capital Costs

39 CI (I,J) = ((PA (J) x RI x 240.)/365.) x ((WM (I,J)/MWD) + 4.)

40 RCI (I,J) = (CPA (I) x RI x 240.)/365.) x ((WM (I,J)/MWD) + 4.)

CI (I,J), RCI (I,J) = cost of capital embodied in the cattle as they walk from area I to area J and J to I respectively.

where:

RI = rate of interest

The calculation of the capital costs is based upon the market value of the animal in the destination market and an interest rate of 10%. The daily interest charge (PA (J) x RI/365.) is multiplied by the trek time plus time in market before sale (four days) to arrive at the total cost of capital.

Total Transportation Charge for Trek

41 TWDC (I,J) = (DF (I,J) + CM (I,J) + FM + SC (I,J) + CS (I,J) + CI (I,J) + WSF (I,J) + TCT + MC (I,J))/240.

42 RTWDC (I,J) = (DF (I,J) + CM (I,J) + FM + SCR (I,J) + RCS (I,J) + RCI (I,J) + WSF (I,J) + TCT + RMC (I,J))/240.

TWDC (I,J), RTWDC (I,J) = Total cost for on hoof transportation in £'s per animal from area I to J and J to I respectively.

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WSF (I,J) = water and supplementary feeding expenses. Costs must be calculated for maintenance feeding and watering for a part of the trek routes during the dry season. The costs calculated and method used are shown in Table III-5.

FM - Marketing fee for cattle at the destination market which is about 24 pence per animal.

TCT - Trade cattle tax. This tax which amounts to 72 pence per animal is imposed on all trade cattle.

Equations 41 and 42 simply add the separate costs involved in trekking the cattle between all combinations of the 15 areas.

Cost Structure for Trekking Animals with a Trypanosomiasis Control Campaign Instituted

As discussed in the previous chapter, the tsetse induced disease of trypanosomiasis accounts for large mortality, salvage, and shrinkage losses in cattle that are walked through the tsetse infected areas. A vaccination campaign aimed at trade cattle moving through tsetse infested areas is being contemplated at the present time in Nigeria. Therefore, an attempt is made in this study to estimate the costs involved in trekking the cattle with the aid of prophylactic treatment against trypanosomiasis.

From the set of equations 31 - 42, only 33 - 38 are affected by a vaccination campaign. The set of equations listed below replace 33 - 38.

331 SC (I,J) = .5 x SF (I,J) x (PA (J) - .33 x PA (J)) x 240.

Table III-5: Water and Supplementary Feeding Costs in Pence Per Animal (WSF(I,J))

Table III-5: Water and Supplementary Feeding Costs in Pence Per Animal (WSF(I,J))

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	---														
2	110	---													
3	171	70	---												
4	415	306	243	---											
5	243	135	90	135	---										
6	270	225	153	394	243	---									
7	243	135	70	306	162	90	---								
8	346	207	131	180	135	283	180	---							
9	495	380	311	135	243	480	396	135	---						
10	225	277	270	513	369	117	207	396	864	---					
11	390	247	177	243	207	306	252	70	207	378	---				
12	429	352	283	351	315	408	360	180	225	498	117	---			
13	693	621	585	99	477	693	621	180	70	693	225	243	---		
14	225	277	270	513	369	117	207	396	864	0	378	498	693	---	
15	463	387	318	387	351	441	396	207	252	600	144	34	276	675	---

Source: Hunger, Friedrich, {12}, Survey of Trek Routes, unpublished manuscript.

Note: Hunger's analysis of 25 different trek routes indicated about 18 pence per animal per day was charged for feeding and watering for a part of the trek routes during the dry season. To average over the whole year, I assumed 9 pence per day per animal, for only that part of the trek route north of a line drawn from Ilorin to a point 50 miles south of Makurdi.

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341 SCR (I,J) = .5 x SF (I,J) x (PA (I) - .33 x PA (I)) x 240.

351 MC (I,J) = .5 x .33 x SF (I,J) x PA (J) x 240.

361 RMC (I,J) = .5 x .33 x SF (I,J) x PA (I) x 240.

371 CS (I,J) = VSF (I,J) x CLC x CW x PM (J) + .5 x (VSF (I,J) x WA - VSF (I,J) x CLC x CW x PPS x PM (J) + VF + VML x PM (J).

381 RCS (I,J) = VSF (I,J) x CLC x CW x PM (I) + .5 x (VSF (I,J) x WA - VSF (I,J) x CLC x CW) x PPS x PM (I) + VF + VML x PM (I).

The TRNSCST model is constructed so that these equations are substituted for equations 33 - 38 only if the route crosses tsetse infected areas.

Equations 331, 341, 351, and 361 estimate the salvage and mortality losses incurred if the cattle are vaccinated to be 1/2 of the losses of cattle that are not vaccinated. This is only a rough estimate. No good information based on large samples is available to estimate the improvement in death and salvage losses from a vaccination program.

Shrinkage loss is represented by equations 371 and 381. Some researchers have reported weight gains in cattle trekked southward that have been vaccinated. However, here again, only a few studies have been conducted so no consistent data is available. Essentially, the estimated percent shrinkage of cattle destined for tsetse infested areas was set equal to the shrinkage incurred before the tsetse infested area was reached.

The values estimated from equations 331, 341, 351, 361, 371, and 381 are used in equations 41 and 42 to estimate the total distribution costs for trekking cattle that have been treated against trypanosomiasis.

Cost Structure for Shipment of Live Animals by Rail

The costs involved in railing live animals fall into seven categories. They are freight costs, attendant charges, shrinkage, death loss, trade cattle tax, and marketing fee. The following set of equations are used to calculate these costs for all available rail routes between the 13 areas served by the Nigerian railroad.

51 AC (I,J) = .221 x RM (I,J)

52 DV = (TAT (I,J) - 2.)/2.

53 DR = AMAX 1 (1., DV)

54 LWS = TABEXE (VAL, SMALL, DIFF, KF, DR)

55 RSC (I,J) = LWS x CLC x PM (J) x CW + .5 x (LWS x WA - LWS x CLC x CW) x PPS x PM (J)

56 RRSC (I,J) = LWS x CLC x PM (I) x CW + .5 x (LWS x WA - LWS x CLC x CW) x PPS x PM (I)

57 DLR (I,J) = SDL x DR/2. x PA (J) x 240. + SSP x DR/2. x (PA (J) - .33 x PA (J)) x 240.

58 RDLR (I,J) - SDL x DR/2. x PA (I) x 240. + SSP x DR/2. x (PA (I) - .33 x PA (I)) x 240.

59 TRDC (I,J) = (RC (I,J) + AC (I,J) + RSC (I,J) + DLR (I,J) + TCT + FM)/240.

60 RTRDC (I,J) = (RC (I,J) + AC (I,J) + RRSC (I,J) + RDLR (I,J) + TCT + FM)/240.

Attendant Costs

51 AC (I,J) = .221 x RM (I,J)

where:

AC (I,J) = Attendant charges per animal in pence.

RM (I,J) = Rail mileage between area I and area J. See Table III-6 for these values.

Table III-6: Rail Mileage between Areas (RM (I,J))

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Table III-6: Rail Mileage between Areas (RM (I,J))

(miles)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	---														
2	99	---													
3	195	130	---												
4	700	630	660	---											
5	340	270	145	900	---										
6	260	255	240	620	380	---									
7	110	99	90	570	230	150	---								
8	435	370	400	250	555	360	300	---							
9															
10	480	475	460	840	600	220	370	580		---					
11	325	260	300	360	450	270	225	100		490	---				
12	440	375	420	580	560	380	330	320		600	230	---			
13															
14	660	660	640	1020	780	400	540	770		180	675	780		---	
15	660	660	640	800	780	600	550	540		820	450	220		1000	---

Source: _Transportation - A Guide to Current Costs in Nigeria_, Federal Ministry of Information for the Federal Ministry of Commerce and Industry, Lagos, Nigeria, Appendix C.

Note: Areas 9 and 13 are not served by the Nigerian railroad.

This equation estimates the costs of hiring attendants to accompany the cattle being transported by rail. The data reported in Werhahn, et al. indicates that this charge in pence is about .221 times the mileage between loading and destination {35,p.168}.

Shrinkage Costs

52 DV = (TAT (I,J) - 2.)/2.

53 DR = AMAXI (1., DV)

54 LWS = TABEXE (VAL, SMALL, DIFF, KR, DR)

55 RSC (I,J) = LWS x CLC x PM (J) x CW + .5 x (LWS x WA - LWS x CLC x CW) x PPS x PM (J)

56 RRSC (I,J) = LWS x CLC x PM (I) x CW + .5 x (LWS x WA - LWS x CLC x CW) x PPS x PM (I)

DV = time the cattle are on the rail cars in days

TAT (I,J) = turn around time for one rail car between points I and J

AMAXI (1,, DV) = a fortran function that choses the maximum value of its arguments (1 or DV) and sets DR equal to that value.

LWS = live weight shrinkage

TABEXE = a simulation sub-program which approximates functional relationships by straight line segments. In this instance, TABEXE approximates the percentage of live weight shrinkage that corresponds to the number of days in transit (DR).

RSC (I,J), RRSC (I,J) = shrinkage costs incurred by moving cattle by rail from area I to area J and area J to area I respectively.

Equations 52 and 53 estimate the number of days the cattle will be on the train when being shipped between two areas. The turn around time for one rail car between two areas (TAT (I,J)) was estimated by checking the schedule of trains established by the Nigerian Railway Corporation {13,Annex Table 6}. This turn around time is defined as the number of days it takes a rail wagon to go from area I to area J and back ready to depart again from area I. Table III-7 gives these values.

Equation 54 estimates the percent of live weight shrinkage that corresponds to the number of days the cattle are on the rail car. The particular functional relationship is shown in Figure 11.

Equations 55 and 56 transform the live weight shrinkage to carcass weight shrinkage and shrinkage of consumed items not in the carcass. This is done in the same manner as described in the truck shrinkage section.

Mortality and Salvage Costs

57 DLR (I,J) = SDL x DR/2. x PA (J) x 240. + SSP x DR/2. x (PA (J) - .33 x PA (J)) x 240.

58 RDLR (I,J) = SDL x DR/2. x PA (I) x 240. + SSP x DR/2. x (PA (I) - .33 x PA (I)) x 240.

DLR (I,J), RDLR (I,J) = Death and salvage costs incurred by railing cattle from area I to area J and area J to area I respectively.

SDL = Standard death loss expressed as percentage that die on the trip by rail from Kano to Lagos. Werhahn, et al. report that on this route .07 percent of the cattle died in transit from 1960 to 1962. An additional .4% had to be salvaged {35,p.172}.

SSP = Standard salvage percentage.

Table III-7: Turn Around Time for Rail Cars in Days (TAT (I,J))

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	---														
2	2	---													
3	4	2	---												
4	10	9	8	---											
5	6	4	2	10	---										
6	4	4	4	8	6	---									
7	2	2	2	7	4	3	---								
8	7	6	5	4.5	7	6	5	---							
9															
10	7	6	5	9.5	6	4	5	7.5		---					
11	6	4	4	6	6	5	4	2		6	---				
12	7	6	5	8	8	6	5	5		7	4	---			
13															
14	7.5	7	6	11	7	4	5.5	8		3	7.5	11		---	
15	9	8.5	8.5	9	10	8	8	6		11	5	3.5		13	---

Source: <u>Economic Growth of Nigeria: Problems and Prospects, Volume V Transport</u> - International Bank for Reconstruction and Development, 1965, Annex Table 6.

Equations 57 and 58 estimate the costs of death and salvage losses incurred by transporting cattle by rail. The percentage that die or are salvaged is estimated as a proportion of the death and salvage losses on the Kano to Lagos route for which some information was available. The mortality loss was valued at the price of the animal at the destination market while salvage losses were valued at 2/3 the price in the destination market. This assumes that the salvaged animals are sold at 1/3 the destination market price.

Total Transportation Costs for Moving Live Cattle by Rail

59 TRDC (I,J) = (RC (I,J) + AC (I,J) + RSC (I,J) + DLR (I,J) + TCT + FM)/240.

60 RTRDC (I,J) = (RC (I,J) + AC (I,J) + RRSC (I,J) + RDLR (I,J) + TCT + FM)/240.

TRDC (I,J), RTRDC (I,J) = Total transport costs for moving cattle by rail from area I to area J and J to I respectively in £'s per animal.

RC (I,J) = Rail freight cost in pence per animal. These rates were taken from Werhahn et al. {35} and materials prepared for me by Dr. Zook, adviser (at that time) to the Nigerian Federal Ministry of Commerce and Industry. See Table III-8 for these costs.

TCT = Trade cattle tax. This tax amounts to 72 pence per animal.

FM = Marketing fee payable to the destination market owners. It amounts to 24 pence per animal.

Equations 59 and 60 calculate the total cost of transporting cattle by rail between all 2 area combinations of the 13 areas served by the railroad.

Table III-8: Rail Frieght Costs in Pence Per Animal (RC(I,J))

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	---														
2	99	---													
3	224	150	---												
4	805	725	760	---											
5	391	311	167	1035	---										
6	299	293	276	713	437	---									
7	127	99	104	656	264	173	---								
8	500	426	460	288	639	414	345	---							
9															
10	552	546	530	966	690	253	426	667		---					
11	374	299	345	414	518	311	259	115		564	---				
12	506	432	483	667	644	437	380	368		690	265	---			
13															
14	768	759	732	1224	900	460	636	876		207	768	897		---	
15	768	754	732	920	900	690	636	636		943	518	204		1150	---

Source: Werhahn, op. cit., p. 185, personal communication with Dr. Zook, adviser in Federal Ministry of Commerce and Industry.

Note: Rates not given in the above references were calculated at 1.15 times mileage. The 1.15 was derived by taking known rates and dividing by the mileage.

Meat Shipment

The shipment of frozen meat from the north to southern urban areas is considered in this study for three reasons. First, it is being done on a small scale at the present time. Secondly, there are abattoirs in the north equipped to do this that are operating at capacities well below their designed output. (See Figure 10 for their locations.) Thirdly, this form of beef distribution is being considered as a viable policy alternative for improving the system's performance.

The two alternatives for distributing frozen meat considered in this study are by (1) refrigerated truck and (2) refrigerated rail cars. Both methods involve picking up frozen carcasses and offal at the abattoir cold store in the north and transporting them to the cold stores in the southern urban areas of Ibadan, Lagos, Umuahia and Port Harcourt. Obviously the total demand in the southern areas cannot be satisfied by frozen meat shipment alone as the presence of cold stores and retail refrigeration units are practically non-existent in areas outside the main urban centers.

Cost Structure for Shipment of Carcasses by Refrigerated Truck

The main cost categories for carcass transport by refrigerated truck are (1) freight costs, (2) marketing costs, (3) offal freight costs, and (4) shrinkage.

The freight costs are taken from a study by Werhahn on meat distribution in Nigeria {36}. They estimated these costs to be 3d/carcass lb on a 740 mile trip with .43d/carcass lb added for chilling and loading costs.

The marketing charge of 48 pence/carcass covers middleman fees and handling at destination points.

The offal shipment is assumed to weigh 12% of the carcass or 52 pounds. The cost of transporting this is the same per pound as for carcasses.

Werhahn estimated that frozen meat transport shrinkage amounted to about 3% of the carcass weight for a 740 mile trip. The pounds shrunk were valued at meat prices in the destination market.

The freight and shrinkage costs were assumed proportional to mileage for the twelve routes over which meat is allowed to travel. Table III-9 gives these routes and the calculated costs per carcass on each for transport by refrigerated truck.

Cost Structure for Shipment of Carcasses by Refrigerated Rail Cars

The cost categories for carcass shipment by refrigerated rail cars are the same as for truck shipment--freight costs, marketing charges, offal freight costs, and shrinkage loss.

Interviews with two commercial companies in Lagos that transport carcasses in refrigerated rail cars indicated that the freight charge was about 5 pence per ten miles for wagons that were loaded to 2/3 capacity. The offal weight was charged 5 pence per ten miles also.

The marketing charge was assumed to be 48 pence per carcass--the same as for refrigerated truck transportation.

Shrinkage was assumed to be 3% of the carcass weight for a 740 mile trip as reported in Werhahn {36}. The total pounds lost were multiplied by the price of meat in the destination market to arrive at the cost of shrinkage.

Table III-9: Cost of Shipping Frozen Carcasses

ROUTE	METHOD	
	Refrigerated Trucks	Refrigerated Rail Car
	(₦'s per Carcass)	
Sokoto to the West	7.63	----
Sokoto to the East	7.78	----
Kano to the West	6.40	3.86
Kano to the East	6.40	3.86
Maiduguri to the West	9.50	6.00
Maiduguri to the East	7.63	4.80
Nguru to the West	7.88	4.80
Nguru to the East	8.20	4.80
Bauchi to the West	7.00	4.80
Bauchi to the East	5.00	3.25
Kaduna to the West	5.70	3.10
Kaduna to the East	5.80	3.15

Table III-9 compares the cost of transporting carcasses by these two methods. It shows clearly that refrigerated rail shipment is less expensive than refrigerated truck hauling. This is primarily due to the cheaper freight costs for rail shipment.

Costs of Shipping Live Cattle in Nigeria - Results

Truck Shipment

By far the most important categories of truck shipment are shrinkage costs and freight charges (see Tables III-10 to III-17). A major cause of high freight charges is the frequent occurrence of accidents. Some of the major factors causing these accidents are: heavy traffic on relatively poor roads, poor mechanical condition of the lorries, overloading the trucks, and driver stress from driving too long without rest. As a result, the freight charge per animal for lorry transportation is over twice the charge for rail hauling.

The survey of truck transportation costs made for this study indicated that the hauling time for lorries was not significantly different than the time for rail hauling between areas served by the railway. For example, the drivers interviewed in the survey indicated that it took them 3.5 days to drive from Kano or Katsina to Lagos. This is approximately the same time it takes a rail car to travel the same distance. Compared to developed country standards this time seems unduly long for either method. Apparently, no feed or water was given the animals on the 3 to 4 day trips from Katsina and Kano to Lagos. This long transit time with no feed or water is largely responsible for the high weight losses incurred. Over 1/2 of the drivers surveyed

Table III-10: Costs of Transporting Cattle from Sokoto to the West

Truck			Rail			Walk		
Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total
Mortality costs	.54	4.3	Mortality cost	.15	1.8	Mortality cost	.44	5.5
						Salvage cost	.89	11.2
Shrinkage cost	4.25	34.2	Shrinkage cost	4.00	47.9	Shrinkage cost	3.76	47.2
Other expenses	.40	3.2	Other expenses	.40	4.8	Other expenses	.40	5.0
Freight costs	7.25	58.3	Freight costs	3.20	38.3	Drover's fee	1.00	12.6
			Attendant cost	.60	7.2	Food money	.17	2.1
						Interest cost	.37	4.6
						Water and Feed cost	.93	11.8
Total	Ƀ12.44	100.0	Total	Ƀ8.35	100.0	Total	Ƀ7.96	100.0

Table III-11: Costs of Transporting Cattle from Kano to the West

Truck			Rail			Walk		
Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total
Mortality costs	.63	4.54	Mortality costs	.12	1.6	Mortality costs	.57	6.1
						Salvage cost	1.14	12.0
Shrinkage costs	4.46	32.2	Shrinkage cost	3.34	44.5	Shrinkage cost	4.43	46.9
Other expenses	.40	2.9	Other expenses	.40	5.3	Other expenses	.40	4.2
Freight costs	8.37	60.36	Freight costs	3.05	40.7	Drover's fee	1.19	12.6
			Attendant cost	.59	7.9	Food money	.20	2.1
						Interest costs	.40	4.2
						Water and Feed cost	1.12	11.9
Total	Ƀ13.86	100.00	Total	Ƀ7.50	100.00	Total	Ƀ9.45	100.0

Table III-12: Costs of Transporting Cattle from Bornu to the West

Truck			Rail			Walk		
Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total
Mortality costs	.98	5.0	Mortality cost	.25	2.7	Mortality cost	.78	5.2
						Salvage cost	1.51	10.0
Shrinkage cost	5.09	26.1	Shrinkage cost	4.84	42.0	Shrinkage cost	7.35	48.5
Other expenses	.40	2.0	Other expenses	.40	3.5	Other expenses	.40	2.6
Freight costs	13.06	66.9	Freight costs	5.10	44.2	Drover's fee	1.98	13.1
			Attendant costs	.94	8.1	Food Money	.34	2.2
						Interest cost	.65	4.3
						Water & Feed Cost	2.14	14.1
Total	Ƀ19.53	100.0	Total	Ƀ11.53	100.0	Total	Ƀ15.14	100.0

Table III-13: Costs of Transporting Cattle from Bornu to the East

Truck			Rail			Walk		
Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total
Mortality costs	.81	4.9	Mortality costs	.21	2.1	Mortality costs	.72	6.1
						Salvage costs	1.45	12.2
Shrinkage costs	5.05	30.6	Shrinkage costs	4.83	48.2	Shrinkage costs	5.55	46.8
Other expenses	.40	2.4	Other expenses	.40	4.0	Other expenses	.40	3.4
Freight costs	10.25	62.1	Freight costs	3.83	38.3	Drover's fee	1.40	11.8
			Attendant costs	.74	7.4	Food money	.24	2.0
						Interest cost	.50	4.2
						Water & Feed cost	1.60	13.5
Total	Ƀ16.51	100.0	Total	Ƀ10.01	100.0	Total	Ƀ11.86	100.0

Table III-14: Costs of Transporting Cattle from Bauchi to the East

Truck			Rail			Walk		
Category	Cost ₦/cow	% of Total	Category	Cost ₦/cow	% of Total	Category	Cost ₦/cow	% of Total
Mortality costs	.53	4.5	Mortality costs	.12	1.7	Mortality costs	.55	6.7
						Salvage cost	1.10	13.3
Shrinkage costs	4.28	36.2	Shrinkage costs	3.58	49.4	Shrinkage costs	3.85	46.7
Other expenses	.40	3.4	Other expenses	.40	5.5	Other expenses	.40	4.8
Freight costs	6.62	55.9	Freight costs	2.65	36.6	Drover's fee	.97	11.6
			Attendant costs	.50	6.8	Food Money	.16	1.9
						Interest cost	.36	4.4
						Water & Feed cost	.86	10.6
Total	₦11.83	100.0	Total	₦7.25	100.0	Total	₦8.25	100.0

Table III-15: Cost of Transporting Cattle from Maiduguri to Kano

Truck			Rail			Walk		
Category	Cost ₦/cow	% of Total	Category	Cost ₦/cow	% of Total	Category	Cost ₦/cow	% of Total
Mortality costs	.21	2.9	Mortality costs	.10	1.4	Mortality costs	.11	2.4
						Salvage costs	.23	5.0
Shrinkage costs	1.99	27.5	Shrinkage costs	2.63	38.1	Shrinkage costs	1.78	38.5
Other expenses	.40	5.5	Other expenses	.40	5.8	Other expenses	.40	8.7
Freight costs	4.62	64.1	Freight costs	3.17	45.9	Drover's fee	.79	17.1
			Attendant costs	.61	8.8	Food money	.14	3.0
						Interest cost	.17	3.7
						Water & Feed cost	1.00	21.6
Total	₦7.23	100.0	Total	₦6.91	100.0	Total	₦4.62	100.0

Table III-16: Cost of Transporting Cattle from Nguru to Niger

Truck			Rail			Walk		
Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total
Mortality costs	.44	4.1	Mortality costs	.11	1.9	Mortality costs	.26	4.1
						Salvage costs	.51	8.1
Shrinkage costs	3.68	34.4	Shrinkage costs	3.22	54.5	Shrinkage costs	2.90	46.1
Other Expenses	.40	3.7	Other expenses	.40	6.8	Other expenses	.40	6.4
Freight costs	6.19	57.8	Freight costs	1.82	30.8	Drover's fee	.81	12.9
			Attendant costs	.35	6.0	Food money	.14	2.2
						Interest costs	.27	4.3
						Water & Feed cost	1.00	15.9
Total	Ƀ10.71	100.0	Total	Ƀ5.90	100.0	Total	Ƀ6.29	100.0

Table III-17: Cost of Transporting Cattle from Nguru to Zaria

Truck			Rail			Walk		
Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total
Mortality costs	.18	3.0	Mortality costs	.04	1.1	Mortality costs	.09	2.6
						Salvage cost	.17	4.9
Shrinkage cost	2.07	34.3	Shrinkage cost	2.00	53.3	Shrinkage cost	1.35	38.9
Other expenses	.40	6.6	Other expenses	.40	10.7	Other expenses	.40	11.5
Freight costs	3.38	56.1	Freight costs	1.10	29.3	Drover's fee	.54	15.6
			Attendant costs	.21	5.6	Food money	.09	2.6
						Interest cost	.13	3.7
						Water and Feed cost	.70	20.2
Total	Ƀ6.03	100.0	Total	Ƀ3.75	100.0	Total	Ƀ3.47	100.0

indicated that the cattle they were hauling showed severe road stress on the trips from Kano and Katsina to Ibadan or Lagos. The detailed results of this survey are given in Appendix I.

Rail Shipment

Eighty-five percent of the total cost of shipping cattle by rail is accounted for by shrinking and freight charges. (See Tables III-10 to III-17).

Again, the large shrinkage costs occur because cattle are often railed 3 to 4 days with no feed or water. Additionally, the excitement and unfamiliar surroundings of rail transport causes heavy losses in the loading and unloading phases. Due to the excess demand for rail cars, cattle may have to wait at rail points for several days prior to loading. These waiting areas are heavily grazed around the rail heads. Therefore, weight losses probably start even before the cattle are loaded on the rail cars. As shown in Figure 11, the shrinkage percent increases rapidly from assembly at the rail points through the second day of travel and levels off for subsequent days. This is part of the reason why rail service becomes more attractive relative to trekking as the distance of transit increases.

As beef production methods improve, market cattle will probably be younger and exhibit a higher degree of finish than the cattle now marketed. Walking these higher quality cattle 600 - 1000 miles to market seems unreasonable. Therefore, rail and truck hauling will probably become more important relative to trekking. However, mortality and shrinkage losses account for approximately 40 percent of the total transport costs for both rail and truck shipment on important market routes (see Tables III-10 to III-16). If these methods of transport are to be improved to provide some incentive to produce higher quality cattle, death and shrinkage losses must be reduced. This involves both a reduction of transit times and provision of food and water on long hauls. This entails building more and better roads for truck hauling and improving the efficiency of rail service. Both of these actions will require large investments but would provide benefits to other industries as well as beef.

Trekking

The important cost categories for trekking are shrinkage losses, drovers' fees, salvage losses and feed costs. The large shrinkage and salvage losses (which account for approximately 58 percent of the total transport cost) are apparently due to a great extent to the trypanosomiasis disease contacted as the cattle walk through the tsetse belt. Trials have been conducted with vaccinations for the tryps. disease in which the cattle lost no weight at all on treks to the southern areas {33}. Policies aimed at improving trek movement of cattle will logically involve a form of trypanosomiasis control and provision of feed and water along portions of the trek routes. Mortality losses are relatively low due in great part to experienced drovers that sell the diseased cattle before death.

Comparison Of The Livestock Transport Methods

One of the obvious results of this comparative study is that truck transportation is significantly more expensive than rail hauling or trekking. This is reflected in the present situation in which the number of cattle transported by lorry is significantly less than the number

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number hauled by rail or walked. However, due to the shortage of rail cars, truck hauling is the only method northern cattle dealers have of reaction quickly to favorable price conditions in the southern market. Additionally, lorry shipment is used for higher quality cattle that cannot economically withstand the rigors of trekking and for some reason are not able to get rail permits.

In general, the longer the transporting distance, the more advantageous rail hauling becomes, especially if transit is necessary through tsetse infested areas. However, for distances of 250 miles or less in tsetse free areas, trekking is cheaper than rail as shown in Figure 12. This is primarily because shrinkage, salvage, and death losses increase proportionately more with distance increases on treks, while they increase proportionately less for rail transport. Therefore, the most efficient method of shipment from northern producing regions to southern consumer regions is generally by rail. Two policy implications are apparent here. First, improvement in shrinkage losses on rail hauling would further reduce the costs of hauling by this most efficient method. If this was accomplished, the demand for rail shipment would increase. Since the number of rail cars are inadequate to fulfill the demand at the present time, the number of livestock cars furnished by the rail lines would have to be increased to take advantage of any policy that would reduce rail shrinkage losses. However, not all major production regions are well served by the rail network. Areas 1, 9, and 13 (see Figure 10) are relatively isolated from rail loading points. Therefore, the distance by rail to southern areas is greater than the distance on more direct trek

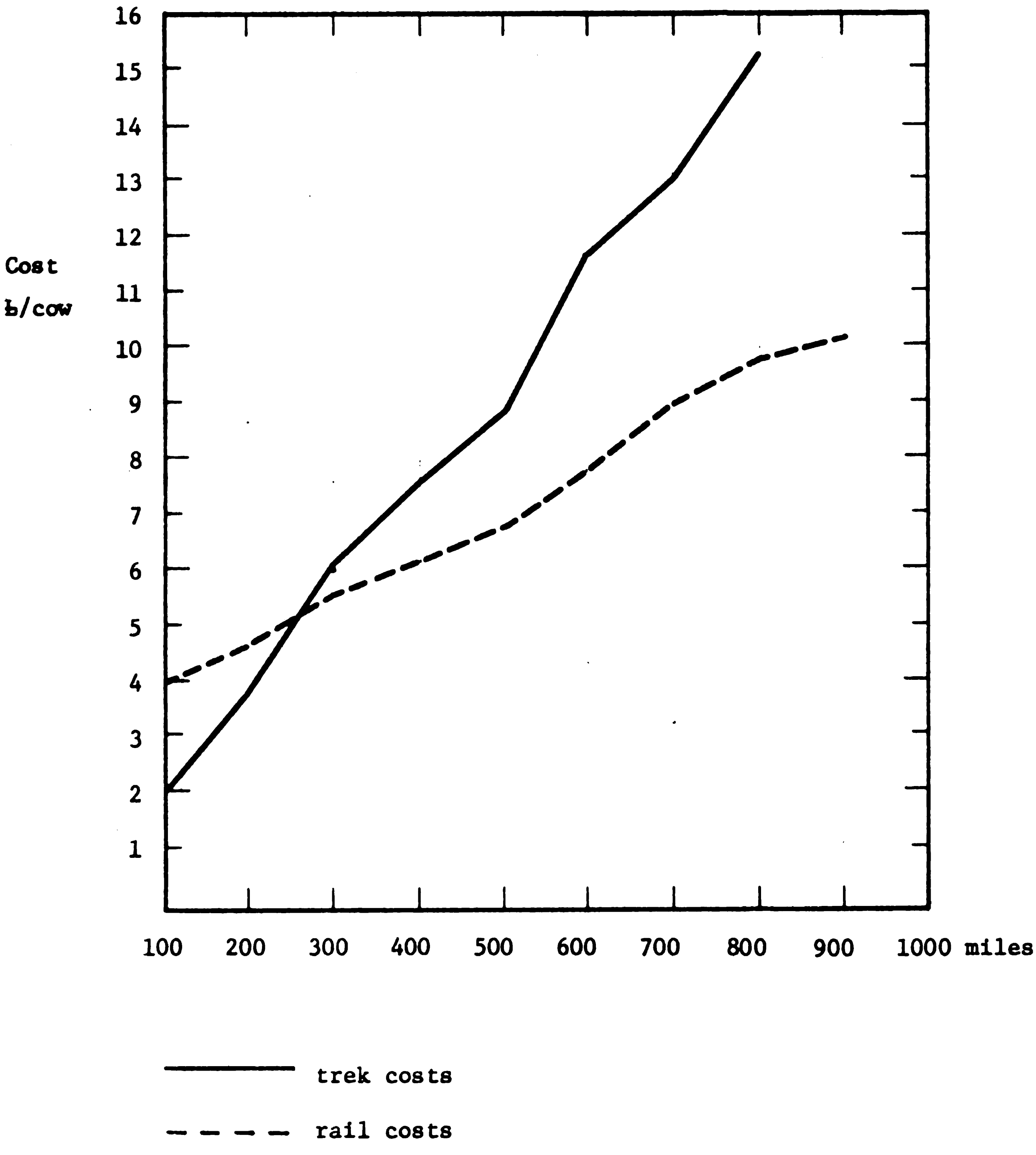

Figure 12: Costs of Transporting a Cow Over Varying Distances by Trek and Rail

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routes making trekking more attractive. This is the case for shipment from area 1 to area 14. (See Table III-10.) Trekking is less expensive than rail shipment because the distance traveled on the trek route is approximately 200 miles less than by rail hauling. (See Tables III-3 and III-6.)

In general, trekking cattle between areas in the northern tsetse free regions is less costly than railing (See Tables III-15 and III-17). This is true for two reasons. First, trek route distances between northern areas are usually much shorter than railing distances since the rail system in Nigeria is oriented to north-south travel. Secondly, in tsetse free areas, trek movement is cheaper than railing over distances of 250 miles or less.

Considering these results, a policy of furnishing adequate feed and water on trek routes to major northern rail heads along with adequate numbers of rail cars for hauling cattle to the south would seem reasonable.

Cost Reduction by Trypanosomiasis Control

A policy run was conducted on this model component assuming that a trypanosomiasis control program was instituted for all cattle being trekked through tsetse infested areas. Tables III-18 and III-19 give the results of this run. The savings amount to about 40% based on the experiments done by Unsworth and Birkett {33}; Godrey, Ferguson, and Kendrick {9}, and Jones-Davies {18}. This treatment reduced the large losses of shrinkage, salvage, and death by slightly over one-half. However, the results of these experiments should not be taken as final. More research trials should be conducted using several alternative

Table III-18: Trek Costs Resulting from Trypanosomiasis Vaccination Program

Sokoto to the West	Kano to the West	Maiduguri to the East

Table III-18: Trek Costs Resulting from Trypanosomiasis Vaccination Program

Sokoto to the West			Kano to the West			Maiduguri to the East		
Category	Cost ₺/cow	% of Total	Category	Cost ₺/cow	% of Total	Category	Cost ₺/cow	% of Total
Mortality cost	.21	4.2	Mortality cost	.29	5.4	Mortality cost	.36	5.2
Salvage cost	.44	8.8	Salvage cost	.59	11.1	Salvage cost	.73	10.5
Shrinkage cost	1.50	29.9	Shrinkage cost	1.14	21.4	Shrinkage cost	1.72	24.7
Other expenses	.40	8.0	Other expenses	.40	7.5	Other expenses	.40	5.7
Drover's fees	1.00	20.0	Drover's fee	1.19	22.3	Drover's fee	1.40	20.1
Food Money	.17	3.4	Food Money	.20	3.7	Food Money	.24	3.5
Interest cost	.37	7.4	Interest cost	.40	7.5	Interest cost	.50	7.2
Water & Feed cost	.93	18.3	Water & Feed cost	1.12	21.1	Water & Feed cost	1.60	23.1
Total	₺5.02	100.0	Total	₺5.33	100.0	Total	₺6.95	100.0

Table III-19: Trek Costs with no Vaccination Program

Sokoto to the West			Kano to the West			Maiduguri to the East		
Category	Cost ₺/cow	% of Total	Category	Cost ₺/cow	% of Total	Category	Cost ₺/cow	% of Total
Mortality costs	.44	5.5	Mortality costs	.57	6.0	Mortality costs	.72	6.1
Salvage cost	.89	11.2	Salvage cost	1.14	12.0	Salvage cost	1.45	12.2
Shrinkage cost	3.76	47.2	Shrinkage cost	4.43	46.9	Shrinkage cost	5.55	46.8
Other expenses	.40	5.0	Other expenses	.40	4.2	Other Expenses	.40	3.4
Drover's fee	1.00	12.6	Drover's fee	1.19	12.6	Drover's fee	1.40	11.8
Food money	.17	2.1	Food money	.20	2.1	Food Money	.24	2.0
Interest cost	.37	4.6	Interest cost	.40	4.2	Interest cost	.50	4.2
Water & Feed cost	.93	11.8	Water & Feed cost	1.12	11.9	Water & Feed cost	1.60	13.5
Total	₺7.96	100.0	Total	₺9.45	100.0	Total	₺11.86	100.0

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routes during different seasons. These trials should be done with mature trade cattle trekked at the usual speeds and weighed along the routes. To obtain statistically significant results, large numbers of cattle should be involved in both the treated and control groups. It is important that several trials be conducted as the use of drugs to relieve trypanosomiasis stress appears to have considerable promise.

Cost Reductions by Increasing the Speed of Rail Service

As previously indicated, shrinkage losses on rail transport are relatively high accounting for over 40 percent of the total transport charge on important market routes (see Table III-22). A policy run was conducted on the TRNSCST component to see what impact increased rail speed had on reducing shrinkage costs. Increasing the rail speed reduces turn around time between areas which in turn affects shrinkage in transit. The turn around times used in this experiment are 1/5 lower than the times thought to exist. Only turn around times to areas 14 and 15 were reduced in this trial. They are given in Table III-20. The results of this run are given in Table III-21.

The decrease in the rail hauling time of 1/5 reduced shrinkage losses by about 10 percent from Sokoto and Kano to the West and Maiduguri to the eastern area. The total cost of rail transport was reduced by about 6.5 percent on these routes. The main reason these costs were not reduced further is that most live weight shrinkage on rail hauling occurs in the first day (see Figure 11). It would be interesting to estimate the cost savings if adequate feed and water were furnished at the rail heads as well as on the rail cars during

Table III-20: Turn Around Time for Rail Cars in Days (TAT (I,J)) Increased Rail Speed

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Table III-20: Turn Around Time for Rail Cars in Days (TAT (I,J)) Increased Rail Speed

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	--														
2	2	--													
3	4	2	--												
4	10	9	8	--											
5	6	4	2	10	--										
6	4	4	4	8	6	--									
7	2	2	2	7	4	3	--								
8	7	6	5	4.5	7	6	5	--							
9															
10	7	6	5	9.5	6	4	5	7.5		--					
11	6	4	4	6	6	5	4	2		6	--				
12	7	6	5	8	8	6	5	5		7	4	--			
13															
14	6	5.5	4.5	9	5.5	3.5	4.5	6.5		3	6	11		--	
15	7	7	7	7.5	8	6.5	6.5	4.5		11	4	3		13	--

Source: Economic Growth of Nigeria: Problems and Prospects, Volume V Transport - International Bank for Reconstruction and Development, 1965, Annex Table 6.

Table III-21: Rail Costs Resulting From Increased Rail Speed

Sokoto to the West			Kano to the West			Maiduguri to the East		
Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total
Mortality cost	.10	.12	Mortality cost	.06	.8	Mortality cost	.15	1.6
Shrinkage cost	3.44	44.4	Shrinkage cost	3.08	42.8	Shrinkage cost	4.21	45.1
Other expenses	.40	5.2	Other expenses	.40	5.6	Other Expenses	.40	4.3
Freight cost	3.20	41.4	Freight cost	3.05	42.5	Freight cost	3.83	41.1
Attendant cost	.60	7.8	Attendant cost	.59	8.3	Attendant cost	.74	7.9
Total	Ƀ7.74	100.0	Total	Ƀ7.18	100.0	Total	Ƀ9.33	100.0

Table III-22: Rail Costs Resulting From Regular Rail Speed

Sokoto to the West			Kano to the West			Maiduguri to the East		
Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total	Category	Cost Ƀ/cow	% of Total
Mortality cost	.15	1.8	Mortality cost	.12	1.6	Mortality cost	.21	2.1
Shrinkage cost	4.00	47.9	Shrinkage cost	3.34	44.5	Shrinkage cost	4.83	48.2
Other expenses	.40	4.8	Other expenses	.40	5.3	Other expenses	.40	4.0
Freight cost	3.20	38.3	Freight cost	3.05	40.7	Freight cost	3.83	38.3
Attendant cost	.60	7.2	Attendant cost	.59	7.9	Attendant cost	.74	7.4
Total	Ƀ8.35	100.0	Total	Ƀ7.50	100.0	Total	Ƀ10.01	100.0

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transit. If decreased transit times could be established along with feed provision, further reductions in shrinkage would probably occur. However, information on the effects of this type of action is not available for Nigeria.

The cost savings realized from reduced rail transit times are not as large as those estimated to result from a trypanosomiasis protection program for cattle being trekked. (see Tables III-18 and III-21).

Estimate of Previous Marketing Losses

It is possible to estimate the shrinkage, death and salvage losses that have occurred in previous years with the information gathered for this model component. The assumption made in this calculation is that the average distance traveled by the cattle for both trekking and railing is from Kano to the western area. Using the estimated shrinkage and mortality factors for this route and the number of cattle moved to the south by rail and trek, (see Table II-2) the results given in Table III-23 are obtained.

The total estimated tons of live weight lost from shrinkage and death in the railing and trekking of cattle over the 1954 - 1963 decade was 144,835. Slightly less than 50 percent of the cattle were trekked to the south during the ten years. However, trekking accounted for over 57 percent of the total pounds lost. Assuming a market animal weighed 700 pounds, the total pounds lost in the ten years is equivalent to 423,138 cattle. This is an average of over 42,000 cattle equivalents being lost per year from shrinkage and death losses while being

Table III-23: Live Weight Pounds Lost From Mortality And Shrinkage From Transportation of Cattle In Nigeria, 1954-1963

Fiscal year	Cattle hauled by rail	Rail losses	Cattle trekked	Trek losses	Total rail and trek loss
	Number of cattle				
1954-55	116,000	4,355	172,000	8,763	13,107
1955-56	120,000	4,494	156,000	7,948	12,442
1956-57	139,00	5,205	157,000	7,999	13,204
1957-58	156,000	5,842	138,000	7,031	12,873
1958-59	158,000	5,917	142,000	7,234	13,151
1959-60	167,000	6,259	155,000	7,898	14,157
1960-61	197,000	7,377	165,000	8,413	15,790
1961-62	204,000	7,634	164,000	8,362	15,996
1962-63	200,000	7,490	179,000	9,113	16,603
1963-64	201,000	7,527	196,000	9,985	17,512
TOTAL	1,658,000	62,089	1,624,000	82,746	144,835

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transported to southern consuming areas. The total poundage lost is about 13 percent of the total pounds marketed. Stated another way, the total cattle equivalents lost in the 10 year period is greater than what was marketed in any one of the included years. All of these cattle equivalents were not lost to consumption as some cattle that died enroute were probably consumed by people in villages nearby.

Research Needs

The need for more information has been previously noted. Basically, the research needs can be divided into finding what the values of parameters and relationships are and what impacts various factors might have.

More information is needed on the shrinkage, mortality, and salvage percentages incurred by railing, trekking and truck hauling on various routes. The relationship between live weight shrinkage and tissue loss is crucial in discovering edible meat losses.

Data on the impact of furnishing adequate feed and water for the three transport methods is lacking. Losses may also be curtailed by feeding programs before and/or after transport. More evidence needs to be gathered on the effects of trypanosomiasis control programs for cattle that are trekked.

This kind of information is crucial to decision makers as they strive to improve the performance of the beef distribution system. This distribution system will be required to handle increasing numbers of cattle through time. It may also encourage increased production of higher quality cattle if it can be adapted to distributing them efficiently.

CHAPTER IV

TRANSHIPMENT TRANSPORTATION PROBLEM

Introduction

Public institutions are involved in many aspects of beef distribution in Nigeria. They help determine the number and allocation of rail cars to be used for cattle transport, specify trek routes, and help furnish feed and water along these routes. These institutions are also involved in locating and constructing relatively large scale abattoirs throughout Nigeria. Some are charged with the responsibility of implementing policies to improve the performance of the beef distribution system.

These institutions face several important policy questions concerning the organization of transportation and processing services in the beef distribution system that should be analyzed prior to implementing specific policy actions. These issues involve finding the most efficient location and organization of the transportation and processing activities under the present conditions. Trek routes must be furnished with feed and water and rail routes with cattle cars. Questions to be considered are: which rail and trek routes are likely to be utilized most heavily; how many cattle will use the various routes; how will the utilization change as the wet and dry seasons rotate; given the number of rail cars, how should they be allocated among the alternative rail routes; how many rail cars are needed on each ro

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each route. Shipping refrigerated meat to the southern areas presents further questions: what shipping methods should be used, and from which slaughter houses should the meat be shipped? Additional questions should be answered if alterations of the given system are planned: which investments are most effective in making the system operate more efficiently, and what effects will these changes have on the system?

The model component developed in this chapter is constructed to help answer some of these questions. Several model experiments are described that identify the likely consequences that alternative policies may have on the beef distribution system. It is hoped this will aid in making better policy decisions.

The basic question addressed by the model is: what spatial configuration and methods of transportation minimize the total costs of processing and transporting beef in Nigeria? Assuming a given level of raw product supply and demand in each area, a transhipment linear programming model was developed to help answer this question. The model utilizes the interarea shipping costs by alternative methods estimated by the TRNSCST component described in Chapter III. The results of this transhipment linear program include the least cost method of shipment among areas, number of cattle using each route and method, required number of rail cars on each route, most efficient routes for rail and trek utilization, optimum location of slaughter plants processing "cold" meat, and total beef distribution costs. The effects on these variables of various policies to improve the performance of the system are analyzed to assist in the policymaking process.

Model Structure

Mathematical Statement

This problem may be expressed in mathematical terms as follows:

minimize:

$$\sum_i \sum_j \sum_k T_{ijk} X_{ijk} + \sum_i A_i S_i + \sum_i \sum_j \sum_n t_{ijn} L_{ijn}$$

(total cost of meat shipment, slaughter, and cattle shipment)

subject to:

$$\sum_k \sum_j X_{ijk} = S_i$$

(meat shipments from area i equal the meat equivalent of cattle slaughtered)

$$S_i = Q_i - \sum_j \sum_n (L_{ijn} - L_{jin})$$

(number of cattle slaughtered in area i equals the supply in area i adjusted for shipments of cattle into and out of area i)

$$\sum_k \sum_j X_{jik} = H_i + C_i = D_i$$

(total shipments to area i equal the quantity of hot and cold meat consumed which is the total consumed)

$$X_{ijk}, L_{ijn}, S_i \geq 0$$

$$\sum_i D_i = \sum_i S_i = \sum_i \sum_j \sum_k X_{ijk}$$

(quantity consumed equals total slaughter equals total meat shipment)

$$\sum_i \sum_j L_{ij3} F \le R$$

(total livestock hauled in rail cars adjusted for number of cattle in one car yielding total rail cars used must be less than or equal to total number of rail cars available)

where

T_{ijk} = meat transfer cost from area i to j by method k.

X_{ijk} = meat shipment from area i to j by method k.

A_i = slaughter cost per head in area i.

S_i = slaughter of cattle in area i.

t_{ijn} = cattle transfer cost from area i to j by method n. (n = 1 for truck shipment; n = 2 for trek; n = 3 for rail shipment.)

L_{ijn} = live cattle shipment from area i to j by method n.

Q_i = supply of slaughter cattle in area i.

H_i = demand for "hot" meat slaughtered tranditionally in area i.

C_i = demand for "cold" meat slaughtered in modern slaughter houses in area i.

D_i = demand for meat in region i.

F = proportional part of a rail car taken by one animal.

R = total rail cars available for hauling live cattle.

Table IV-1 gives the linear programming format for an illustrative two-area case. For 15 areas, the model has 54 equations and 628 activities (210 for truck shipment, 210 for trekking, 156 for rail shipment, 15 for slaughter, 37 for meat shipment).

Table IV-1: A Two Region Example of the Transhipment Linear Program Model

Equation	Activity												Total
	Meat Shipment				Livestock Slaughter		Live Animal Shipment						
							Truck		Walk		Rail		
	X_{11}	X_{22}	X_{121}	X_{122}	S^1	S^2	L_{12}	L_{21}	W_{12}	W_{21}	R_{12}	R_{21}	
Objective Function	T_{11}	T_{22}	T_{121}	T_{122}	A_1	A_2	t_{121}	t_{211}	t_{122}	t_{212}	t_{123}	t_{213}	
1	1	--	1	--	-1	--	--	--	--	--	--	--	=0
2	--	1	--	1	--	-1	--	--	--	--	--	--	=0
3	--	--	--	--	1	--	1	-1	1	-1	1,000	-1,000	$=S_1$
4	--	--	--	--	--	1	-1	1	-1	1	-1,000	1,000	$=S_2$
5	1	--	--	--	--	--	--	--	--	--	--	--	$=D_1$
6	--	1	1	1	--	--	--	--	--	--	--	--	$=D_2$
7	--	--	--	--	--	--	--	--	--	--	1	1	=R

Activities

As stated in the previous chapter, three alternatives for shipping live cattle are considered: truck hauling, trekking, and rail hauling. The cattle transfer cost (t_{ijn} for all $i \neq j$ where $i,j = 1,2 \ldots . 15$ and $n = 1,2,3$) is taken from the TRNSCST model. Since areas 9 and 13 are not served by the Nigerian railway (see Figure 10), there are 54 fewer combinations possible for rail movement between areas.

Two alternative methods of cold meat shipment (refrigerated truck and refrigerated rail cars) are included. Areas 14 and 15 are assumed to be the two most important areas relative to the demand for frozen meat. Further, it is assumed initially that the demand for "cold" and "hot" meat in these two areas is not competitive but independent. Later this assumption is eliminated in some cases.

The modern slaughter houses that furnish the carcasses shipped to areas 14 and 15 are noted in Figure 10. The abattoirs in Kano, Maiduguri, Nguru, Zaria, and Bauchi are all served by the Nigerian railroad. Meat shipment from any of them to areas 14 and 15 may be by refrigerated rail car or refrigerated lorry. However, the abattoir at Sokoto is only allowed (in the model) to ship meat to areas 14 and 15 by refrigerated lorry since it is not a rail line.

Slaughter costs differ between the traditional open air slaughter slab and the relatively modern large scale abattoirs. The cost per head of traditional slaughter is estimated to be Ƚ1.40 {35,p.201 and 1,p.20} . Information on the cost of modern slaughter was obtained, from interviews with Mr. Fred Sicher of The Bauchi Meat Company and Mr. John Vines, Abattoir advisor for the Livestock and Meat Authority. An estimate of the costs of slaughter at various volumes of output was not obtained. Most of the abattoirs were operating at very low capacities and information on the costs at full capacity was not available. However, the estimates of Vines and Sicher ranged from ₺2.60 to ₺3.00 per cow. ₺2.80 per cow is used in this study as the slaughter cost in these relatively large modern abattoirs.

Equations

The first set of constraints (1-2 in Table IV-1) assures that the number of cattle produced and consumed locally, plus the number slaughtered and shipped to other regions is equal to the total slaughter of that region.

The second set of constraints or equations (3-4 in Table IV-1) are constructed so that no area can ship more cattle than are present in the area or are shipped into it. The entries in the matrix under the rail activities represent the number of cattle that may be hauled by one rail car between the two areas in one year. The number in the objective row is the product of the per cow cost of railing times the number that can be railed in one year. The TRNSCST model calculates this cost also. Two different sets of supplies in the 15 areas have been assumed for this model. As described in Chapter II, the cattle move to different locations as the tsetse fly and rains move. Therefore, the distribution of cattle among the fifteen areas changes, affecting the transportation pattern. The population distribution of cattle for the 15 areas is shown in Figure 10. The supply of slaughter stock for each area was calculated at 7.5% of the population in the area; the 7.5% figure is the extraction rate estimated by Ferguson for northern Nigeria {7,p.97}.

As previously noted, a substantial number of trade cattle enters Nigeria each year to be sold {7,p.91}. Table IV-2 shows the estimated number entering Nigeria during the last fourteen years. Importations are assumed to be 290,000 for this study. Using Figure 6 as an indication of the entry location of these trade cattle, the 290,000 were allocated to seven areas as shown in Table IV-3.

The wet and dry season supply distributions are simply the result of multiplying respective population distributions by the estimated extraction rate, plus imports into the respective areas. These two supply distributions are given in Table IV-3.

The demand constraints are represented by equations 5-6 in Table IV-1. The demand for areas 14 and 15 was taken from Ferguson's estimate of the total demand for 1963-64 {7,p.53}. Since it is inherent in the model construction that total demand must equal total supply, the demand for the other 13 areas was calculated by subtracting areas 14 and 15 demand from the total available and multiplying this residual by the percentage of population in each area. The result of this calculation is presented in Table IV-4.

Equation 7 in Table IV-1 illustrates the fact that only a certain number of rail cars are available for hauling livestock. In a report on Nigeria's transportation problems, the I.B.R.D. estimated that the Nigerian Railway Corporation had 281 livestock railcars {13,p.17}. However, at least 24% of the freight cars were estimated to be under or awaiting repairs. Therefore, for this study, a total of 212 livestock rail cars are estimated to be available for cattle hauling through one year.

Table IV-2: Nigeria: Trade Cattle Entering Northern Nigeria from Niger, Chad, and Northern Cameroons; 1950/51-1964/65

Fiscal Year	Total Entering	Source of Estimate
1950/51	160,381	Annual Report of Verterinary Dept. 1950/51
1951/52	(165,000)	Ferguson's personal estimate
1952/53	(168,705)	Annual Report of Veterinary Department
1953/54	(145,000)	Ferguson's personal estimate
1954/55	(145,000)	Ferguson's personal estimate
1955/56	142,000	Nigerian Economic Survey, 1959
1956/57	(160,000)	Ferguson's personal estimate
1957/58	(140,000)	Ferguson's personal estimate
1958/59	146,712	Annual Report of Veterinary Department
1959/60	156,496	Annual Report of Veterinary Department
1960/61	262,121	Annual Report of Veterinary Department
1961/62	202,249	Annual Report of Veterinary Department
1962/63	(260,000)	Ferguson's personal estimate
1963/64	291,351	Annual Report of Veterinary Department
1964/65	(260,000)	Ferguson's personal estimate

Table IV-3: Two Supply Distributions by Area of Cattle Available for Marketing, 1963

Area	Wet Season Distribution			Dry Season Distribution		
	Domestic	Imports	Total	Domestic	Imports	Total
	(number of cattle)					
1	98,500	72,500	171,000	80,175	72,500	152,675
2	46,500	29,000	75,500	34,000	29,000	63,000
3	69,600	46,400	116,000	60,600	46,400	107,000
4	109,000	29,000	138,000	96,500	29,000	125,500
5	53,500	58,000	111,500	48,500	58,000	106,500
6	15,000	--	15,000	44,475	--	44,475
7	11,775	--	11,775	21,700	--	21,700
8	55,300	--	55,300	46,350	--	46,350
9	20,400	40,600	61,000	35,325	40,600	75,925
10	10,700	14,500	25,200	10,125	14,500	24,625
11	28,000	--	28,000	36,900	--	36,900
12	11,000	--	11,000	19,125	--	19,125
13	34,500	--	34,500	30,000	--	30,000
14	2,500	--	2,500	2,500	--	2,500
15	12,500	--	12,500	12,500	--	12,500

Table IV-4: Quantity of Cattle Demanded by Area in Nigeria, 1963

Area	Quantity Demanded
1-Sokoto	77,942
2-Katsina	43,586
3-Kano	101,016
4-Bornu	28,715
5-Nguru	13,845
6-Niger	23,587
7-Zaria	26,152
8-Bauchi	44,100
9-Adamawa	21,023
10-Ilorin	31,992
11-Plateau	24,614
12-Benue	55,892
13-Sardauna	20,511
14-West	246,000
15-East	110,000

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Since the total number of rail cars needed and the allocation of the existing stock to the various supply areas are important questions in Nigeria, this model was constructed to give some information toward the possible solution of these problems. The turnaround time for a livestock car was estimated for all routes between the areas served by the railway system from a Nigerian Railway Corporation time table and reports of actual turnaround times {13,Annex Tables 6 and 7}. Using this estimate and an average rail car haul of 26 cattle, the total number of cattle hauled between any two areas in one year is calculated. With this data, the model allocates to each area the number of rail cars that minimizes the total distribution charge. Table IV-5 shows the estimated turnaround times and the resultant number of cattle that may be shipped yearly using one rail car between all areas served by the railway.

The last set of constraints concerns the capacities of the relatively large modern abattoirs in the north that are equipped to slaughter and process "cold" meat for shipment to areas 14 and 15. These abattoirs are located at Sokoto (area 1), Kano (area 3), Maiduguri (area 4), Nguru (area 5), Kaduna (area 7), and Bauchi (area 8), (see Figure 10). Mr. J. Vines, Abattoir adviser to the Livestock and Meat Authority, estimated that the capacities of all these except Kano was 200 head per day. The abattoir at Kano is able to slaughter 400 head per day. Not all this capacity will be allocated to slaughter for meat shipment to the south. Therefore, using an estimate of 300 operating days per year and with 2/3 of the capacity available to slaughter for meat shipment to the south, the slaughter constraints given in Table IV-6 result.

Table IV-5: Turnaround Time and Number of Cattle that may be Shipped by One Railcar Between Areas--Regular Rail Speed

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-	3900	1950	780	1300	1950	3900	1114		1114	1300	1114		1040	867
2	2	--	3900	867	1950	1950	3900	1300		1300	1950	1300		1114	918
3	4	2	--	975	3900	1950	3900	1560		1560	1950	1560		1418	918
4	10	9	8	--	780	975	1114	1733		821	1300	975		709	867
5	6	4	2	10	--	1300	1950	1114		1300	1300	975		1114	780
6	4	4	4	8	6	--	2600	1300		1950	1560	1300		1950	975
7	2	2	2	7	4	3	--	1560		1560	1950	1560		1418	975
8	7	6	5	4.5	7	6	5	--		1040	3900	1560		975	1300
9															
10	7	6	5	7.5	6	4	5	7.5		--	1300	1114		2600	709
11	6	4	4	6	6	5	4	2		6	--	1950		1040	1560
12	7	6	5	8	8	6	5	5		7	4	--		709	2229
13															
14	7.5	7	6	11	7	4	5.5	8		3	7.5	11		--	600
15	9	8.5	8.5	9	10	8	8	6		11	5	3.5		13	--

Source: See Table II-7.

Note: Numbers in lower left half of the square are the number of days required to go from the departure area to destination and back to the departure area, e.g. from area 4 to area 14 and back to area 4 takes 11 days.
The entries in the upper right half of the square are the number of cattle that can be hauled by one rail car in a year between two areas given the turnaround times, e.g. one rail car can haul 709 cattle between areas 4 and 14 in one year.

Table IV-6: Annual Capacity of Modern Abattoirs for Meat Shipment to the South

Location	Capacity
	(No. of cattle)
Sokoto	42,000
Kano	84,000
Maiduguri	42,000
Nguru	42,000
Zaria	42,000
Bauchi	42,000

With this structure, the model will show the quantity of both meat and cattle shipped between areas, the method of shipment used for both meat and cattle, quantity slaughtered in each area at both modern and traditional facilities, and the number of rail cars to be allocated annually to each route to minimize the total cost of distributing beef among the fifteen areas.

Model Experimentation

Several modifications of the basic model assumptions and constraints were employed to evaluate the changes in transportation costs and trade flows which would result if policies to similarly change the actual situation were implemented. The effects of changes in consumer tastes between "hot" and "cold" meat are also evaluated. This model is intended to serve as a "laboratory" in experimenting with various policies relating to beef distribution. Model experiments conducted in this study are:

(1) the optimum transportation pattern for the existing conditions of "hot" and "cold" meat demand, rail cars available, per unit transfer charges without vaccination programs or improved rail efficiency, and the two supply distributions (wet season and dry season).

(2) same as (1) except expanding the number of rail cars available.

(3) same as (1) except replacing the trek costs per animal with estimated trek costs resulting from a trypanosomiasis control program.

(4) same as (1) except increasing the proportion of "cold" meat demanded in areas 14 and 15 relative to "hot" meat demanded.

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(5) same as (1) except increasing the speed of turnaround time for rail cars.

(6) same as (5) except with unlimited rail car availability.

(7) same as (1) except making no differentiation between "hot" and "cold" meat demand in areas 14 and 15.

(8) same as (7) except using trek costs that result from a trypanosomiasis vaccination program.

The results for all the experiments conducted on the transhipment linear program component are given on an annual basis for the wet and dry season supply distributions. The wet season in the cattle producing areas lasts approximately 3 to 4 months from June to October. The dry season begins in October and usually continues until June. Therefore, the total number of cattle actually shipped in the wet season is about 1/3 of the number appearing in the tables. For the dry season, the number of cattle traveling over the various routes indicated is 2/3 of the annual totals appearing in the tables. The rail cars allocated to each route for the wet and dry season supply distributions are the number needed to transport the cattle during the respective seasons. Therefore, if 75 rail cars are allocated on the Kano to Ibadan route for the wet season and 50 are allocated in the dry season, 75 rail cars will be needed for four months and 50 will be required for the remaining eight months. Since the total rail cars needed for the wet season is higher than the number required for the dry season, some cars may be available for alternative uses during the dry season.

Results

(1) Current System

The first experiment of the model (specified as (1) in the preceding section) was run to find the optimum utilization of the transportation system as it existed in Nigeria in 1964. Table IV-7 gives the results of this run. The first obvious point is that no cattle are moved by truck nor meat by refrigerated truck in this solution. For longer distances, rail hauling is cheaper than trucks, and trekking is less expensive for shorter distances. There are many reasons for this. The road structure in the south is not adequate for the large traffic volume it carries. Accidents are frequent and costly. Overloading, poor mechanical condition, and driver stress are important factors causing accidents which result in high freight charges being levied by truck owners. To illustrate, the freight charge per cow from Kano to Lagos on rail cars is Ł3.35 {35,p.168}. For the same trip, the charge per cow hauled on a 15 ton lorry averages about Ł8.3, almost 2 1/2 times the rail charge.[2] The volume of cattle shipped by lorry is not known, but indications are that this method is used by cattle dealers in the north to react quickly to favorable price conditions in the southern markets.

For the wet season supply distribution, the number of rail cars was a constraining factor. Rail shipment was used for longer distances through tsetse-infested areas. However, for movement over shorter distances through tsetse-free areas, trekking seems to be less

[2] This cost estimate was the average charge per cow obtained from the truck hauling cost survey made for this study. (see Appendix I)

Table IV-7: Optimum Transportation Pattern for Beef in Nigeria Under Present Conditions

Table IV-7: Optimum Transportation Pattern for Beef in Nigeria Under Present Conditions

Activity	Wet Season Supply Distribution		Dry Season Supply Distribution	
	Rail cars	Cattle shipped	Rail cars	Cattle shipped
	Number			
X441-Frozen Meat Shipment by Rail-Bornu to West	----	13,860	----	13,860
X451-Frozen Meat Shipment by Rail-Bornu to East	----	8,140	----	8,140
S4 Modern Slaughter Level-Bornu	----	22,000	----	22,000
W110-Live Animal Trek-Sokoto to Ilorin	----	----	----	7,167
W114-Live Animal Trek-Sokoto to West	----	93,058	----	67,566
W210-Live Animal Trek-Katsina to Ilorin	----	6,592	----	----
W214-Live Animal Trek-Katsina to West	----	1,623	----	----
W36-Live Animal Trek-Kano to Niger	----	607	----	----
W37-Live Animal Trek-Kano to Zaria	----	14,377	----	4,452
W614-Live Animal Trek-Niger to West	----	----	----	----
W812-Live Animal Trek-Bauchi to Makurdi	----	11,200	----	----
W912-Live Animal Trek-Adamawa to Makurdi	----	16,317	----	14,992
W915-Live Animal Trek-Adamawa to East	----	23,660	----	39,910
D1112-Live Animal Trek-Benue to Makurdi	----	3,386	----	12,286
D1312-Live Animal Trek-Sardauna to Makurdi	----	13,989	----	9,489
R26-Live Animal Rail-Katsina to Niger	4.1	7,995	----	----
R214-Live Animal Rail-Katsina to West	14.1	15,707	17.4	19,384
R314-Live Animal Rail-Kano to West	----	----	1.2	1,560
R414-Live Animal Rail-Bornu to West	30.4	21,557	38.9	27,584
R415-Live Animal Rail-Bornu to East	75.7	65,609	54.4	47,148
R514-Live Animal Rail-Nguru to West	87.7	97,698	83.2	92,685
R614-Live Animal Rail-Niger to West	----	----	10.7	20,865
R815-Live Animal Rail-Bauchi to East	----	----	1.7	2,210
Total Rail Cars Used	212		208	
Total Cost of Transportation - Ƚ's		Ƚ4,640,000		Ƚ4,440,000
% Carried by Rail	53%		58%	
%trekked	47%		42%	

expensive. The TRNSCST model results show that, in general, distances of 250 miles or more are more efficiently traveled by rail, while distances of less than 250 are probably less expensive when trekked.

For the west area (14), approximately 65.3% of the arriving cattle were hauled by rail. For the eastern area (15), 52.3% arrived by rail. There are two primary reasons why these percentages were not higher. First, since all available rail cars were used, some cattle were trekked that would have been railed if more cars had been available. (In the next experiment, this rail car constraint will be removed). Secondly, for the west, the distance from area 1 (an important supply area) to area 14 is significantly shorter (about 200 miles) when the trek routes are used than by the rail lines. (See Figures 2 and 10.) A large number of cattle are walked to the eastern area (15) because major supply areas (9 and 13) are not served by the rail system and it is cheaper to walk straight to area 15 rather than trek to a rail head and rail the cattle to the eastern area.

In terms of rail car allocation, areas 4 and 5 (Maiduguri and Nguru) are major rail heads for cattle shipment. Approximately 100 rail cars a year are allocated to area 4 for shipment of cattle to the two large deficit areas (14 and 15). Area 5 is allotted 88 rail cars. The primary reasons for the large rail shipments from these areas are their large excess supply of cattle (due in part to the large imports from Niger and Chad and relatively small human populations) and the long distances to major deficit areas which make trekking costly.

The optimum rail car allocation changes as the location of the supply of cattle varies seasonally. For example, during the wet season,

cattle are railed to area 6 from area 2. However, in the dry season as the cattle move into area 6, it becomes an excess supply area from which cattle are railed to the west.

The results also show that the trek routes connecting area 1 with 14 and area 9 with 15 are heavily used. This indicates that investments for water and supplementary feed will be needed on these routes rather than the routes more efficiently served by the rail system. The trek routes connecting areas 8, 9, 11, and 13 with area 12 are also heavily utilized.

The use of trek routes also changes as the seasons vary. During the wet season, the trek routes connecting Kano and Katsina (areas 3 and 2 respectively) are utilized to walk cattle to areas 7, 10, and 14. However, in the dry season, the model shows that very few cattle would use these routes.

The cold meat demand in areas 14 and 15 was supplied by the abattoir in Maiduguri and shipped in refrigerated rail cars. Assuming the same turnaround time for these cars as for those hauling live cattle, four refrigerated rail cars would be needed on the Maiduguri to the west route, and two would be adequate for shipment from Maiduguri to the east.

The total cost of the live animal shipment slaughter and meat shipment among areas was Ƚ4,640,000 under the wet season supply assumption. As the wet season ensues and cattle move north, the distances from major supply areas to large deficit areas increases. Therefore, this charge drops to Ƚ4,440,000 on a per year basis assuming the dry season supply distribution when cattle migrate closer to the major excess demand areas.

(2) Expanded Number of Rail Cars

In the second experiment, the model was run with no effective constraint on the number of rail cars available for cattle shipment. During the wet season, 16 more rail cars were utilized to distribute the supply to deficit areas. The percentage of cattle railed to the west (area 14) increased insignificantly (from 65.3% to 66%). Area 15 received about 8% more cattle by rail than when the number of rail cars was small. The savings in distribution cost resulting from increasing the number of rail cars was insignificant. For the wet season supply distribution, they were small (Ƀ16,000 out of Ƀ4,640,000). These results are given in Table IV-8.

A note of caution should be injected here. The data used to estimate the costs of distribution and rail efficiency were fairly crude estimates. Since the model results were sometimes quite sensitive to cost changes, caution should be employed in interpreting the results. This precautionary word is especially appropriate for the shipments between area 1 and area 14. The cost of trekking a cow on this route is estimated to be Ƀ8.14. Alternatively, the rail cost was estimated at Ƀ8.61--a difference of only Ƀ.47--certainly well within any subjective confidence intervals placed around these estimates. Fortunately, most cost estimates are not this close. In later experiments this sensitivity is tested.

Irregardless of the previously noted data problems, it is apparent that many cattle will continue to be trekked to the two large southern excess demand areas because of the relatively shorter trek distances in relation to rail mileages. This is an expecially important point for areas 9 and 13 and the western parts of areas 1 and 10. It is also

Table IV-8: Optimum Transportation Pattern with Unlimited Rail Cars Available

Activity	Wet Season Supply Distribution		Dry Season Supply Distribution	
	Rail Cars	Cattle Shipped	Rail Cars	Cattle Shipped
	Number			
X441-Frozen Meat Shipment by Rail-Bornu-West	----	13,860	----	13,860
X451-Frozen Meat Shipment by Rail-Bornu-East	----	8,140	----	8,140
S4-Modern Slaughter Level-Bornu	----	22,000	----	22,000
W110-Live Cattle Trek-Sokoto to Ilorin	----	6,592	----	7,167
W114 Live Cattle Trek-Sokoto-West	----	86,466	----	67,566
W37-Live Cattle Trek-Kano-Zaria	----	14,377	----	4,452
W912-Live Cattle Trek-Adamawa-Benue	----	27,517	----	14,992
W915-Live Cattle Trek-Adamawa-East	----	12,460	----	39,910
D1112-Live Cattle Trek-Plateau-Benue	----	3,386	----	12,286
D1312-Live Cattle Trek-Sarduana-Benue	----	13,989	----	9,489
R26-Live Animal Rail-Katsina-Niger	4.4	8,580	----	----
R214-Live Animal Rail-Katsina-West	20.9	23,283	17.4	19,384
R314-Live Animal Rail-Kano-West	.47	611	1.2	1,560
R414-Live Animal Rail-Bornu-West	30.4	21,557	38.9	27,584
R415-Live Animal Rail-Bornu-East	75.7	65,609	54.4	47,148
R514-Live Animal Rail-Nguru-West	87.7	97,698	83.2	92,685
R614-Live Animal Rail-Niger- West	----	----	10.7	20,865
R815-Live Animal Rail-Bauchi-East	8.6	11,180	1.7	2,210
Total Rail Cars Used	228		208	
Total Cost of Transportation in Ⱡ's		Ⱡ4,620,000		Ⱡ4,380,000
% Carried by Rail	58%		58%	
% Trekked	42%		42%	

true, however, that the economic principles of supply and demand apply to the use of these trek routes. As the number of cattle using a particular route increases, the available grass and water becomes more scarce, increasing the cost of the transportation service which, in turn, influences the quantity of rail services demanded.

(3) Trek Costs Resulting from Trypanosomiasis Control Policy

An alternative run was made using the trek costs resulting from a trypanosomiasis vaccination program. A discussion of this program and the potential costs saving was presented in Chapter III. The results of this experiment are presented in Table IV-9.

As can be seen in Table IV-9, this program had a significant effect on the transportation configuration resulting from the model. No cattle were shipped by rail in the dry season and only six rail cars were used during the wet season. This, of course, means that the number of cattle moving on the trek routes would double, placing a heavy strain on the feed and water resources along the trek routes. As these resources became increasingly depleted, the shrinkage, salvage, and death losses on the treks would increase, raising the trekking costs. If a vaccination program did significantly lower trekking costs, additional investments in feed and water for the trade cattle would have to be made to keep the shrinkage and death from increasing to such a level as to eliminate the original cost savings.

The savings in the distribution costs due to the vaccination program were estimated in the model at about ₦975,000 on the average (a 20% decrease). However, this does not mean that the program is economically desirable. Estimates of the costs of administering the program along with the costs of furnishing additional feed and water

Table IV-9: Optimum Transportation Pattern with a Trypanosomiasis Vaccination Program

Activity	Wet Season Supply Distribution		Dry Season Supply Distribution	
	Rail Cars	Cattle Shipped	Rail Cars	Cattle Shipped
	Number			
X441-Frozen Meat Shipment by Rail-Bornu-West	----	13,860	----	13,860
X451-Frozen Meat Shipment by Rail-Bornu-East	----	8,140	----	8,140
S4-Modern Slaughter Level-Bornu	----	22,000	----	22,000
W114-Live Animal Trek-Sokoto-West	----	93,058	----	74,733
W210-Live Animal Trek-Katsina-Ilorin	----	6,592	----	----
W214-Live Animal Trek-Katsina-West	----	25,322	----	19,414
W36-Live Animal Trek-Kano-Niger	----	607	----	----
W37-Live Animal Trek-Kano-Zaria	----	14,377	----	4,452
W310-Live Animal Trek-Kano-Ilorin	----	----	----	1,532
W410-Live Animal Trek-Bornu-Ilorin	----	----	----	5,635
W412-Live Animal Trek-Bornu-Benue	----	1,529	----	----
W414-Live Animal Trek-Nguru-West	----	21,585	----	21,950
W415-Live Animal Trek-Bornu-East	----	64,171	----	47,200
W514-Live Animal Trek-Nguru-West	----	89,675	----	92,655
W614-Live Animal Trek-Niger—West	----	----	----	20,888
W815-Live Animal Trek-Bauchi-East	----	11,200	----	2,250
W912-Live Animal Trek-Adamawa-Benue	----	39,977	----	24,481
W915-Live Animal Trek-Adamawa-West	----	----	----	30,421
D1112-Live Animal Trek-Plateau-Benue	----	3,386	----	12,286
D1315-Live Animal Trek-Sarduana-East	----	13,989	----	9,489
R5-6-Live Animal Rail-Nguru-Niger	6.1	7,930	----	----
Total Rail Cars Used	6.1		0	
Total Cost of Transportation		₦3,640,738		₦3,477,003

must be made. Unfortunately, not even "ball park" estimates are available on what these costs might be.

A vaccination program against trypanosomiasis is being considered at the present time in Nigeria.[3] If, as is being considered, the cattle traders are charged only two shillings per animal treated, the private net benefit will be large. (The savings in trek costs are estimated to be over £2 per cow from Sokoto to the west.) However, for the institutions involved in the program, the benefits and costs must be viewed with a wider perspective, including opportunity costs of investing the capital in other programs. The relevant opportunity costs that should be considered by an institution depend on the array of investment opportunities available to that institution. For example, an agency involved only with the beef industry should consider the returns that might be achieved in other beef improvement programs such as grazing reserves and tsetse eradication. However, if the particular institution is involved in formulating policy for the whole agricultural economy, a much wider array of policies would need to be considered and compared with a trypanosomiasis control program.

(4) Increased Demand for "Cold" Meat in the South

The next experiment was run to find the optimum slaughter location and shipment pattern resulting if the demand for cold meat increased to 40% of the total demand for beef in areas 14 and 15. This would require favorable price ratios between hot and cold meat as well as a network of retail outlets in the cities. These factors would probably

[3] Personal communication from Dr. B. K. Na'isa of the Testse and Trypanosomiasis Division, Federal Ministry of Agriculture and Natural Resources.

influence heavily the change in tastes between the two types of meat. Because of butchers' unions and other groups, the establishment of easily accessible retail outlets for cold meats is no small problem as experience has shown.

The results of this model trial are given in Table IV-10. An interesting point is that the meat shipment originates only from abattoirs that can ship by rail, illustrating the comparative advantage that refrigerated rail car shipment has over refrigerated trucks.

Area 14 receives cold meat from the abattoirs at Kano, Nguru, and Maiduguri. The transhipment feature is illustrated in this run where area 5 ships approximately 40,000 cattle to Kano to be slaughtered and shipped as frozen meat to the west. Eighteen refrigerated rail cars would be needed to evacuate the meat to the west. Nine would travel the Kano-west route, 8 would be needed for the Nguru-west route, and one for the Maiduguri-west trip.

The Bauchi and Maiduguri abattoirs furnished the refrigerated meat for area 15. Since the abattoir at Maiduguri was operating at its allotted capacity, cattle were walked from area 4 to Bauchi to be slaughtered and subsequently shipped to area 15. A total of 12 refrigerated rail cars would be needed to ship the meat to the eastern areas with 10 assigned to Maiduguri and two to Bauchi. In total, 30 refrigerated railcars would be needed to distribute the carcasses of 150,000 cattle to the two southern areas.

The abattoirs in Maiduguri and Nguru (areas 4 and 5 respectively) would operate at full capacity. Moreover, cattle are transported from both of these areas to other plants to be processed. Area 4 provides approximately 1/3 of the cattle to the abattoir at Bauchi and area 5

Table IV-10: Optimum Transportation Pattern with Increased Cold Meat Demand

	Wet Season Supply Dist.			Dry Season Supply Dist.		
	Railcar Live Cattle	Railcar Meat	No. of Cattle	Railcar Live Cattle	Railcar Meat	No. of Cattle
X341 Frozen Meat Shipment by Rail-Kano-West	--	9	54,800	--	9	52,187
X851 Frozen Meat Shipment by Rail-Bauchi-East	--	2	11,200	--	3	13,813
X541 Frozen Meat Shipment by Rail-Nguru-West	--	8	42,000	--	8	42,000
X441 Frozen Meat Shipment by Rail-Bornu-West	--	1	3,200	--	2	5,813
X451 Frozen Meat Shipment by Rail-Bornu-East	--	10	38,800	--	9	36,187
SC-B Modern Slaughter at Maiduguri	--	-	42,000	--	-	42,000
SCN Modern Slaughter at Maiduguri-Nguru	--	-	42,000	--	-	42,000
SCKA Modern Slaughter at Maiduguri-Kano	--	-	54,800	--	-	52,187
SCBA Modern Slaughter at Maiduguri-Bauchi	--	-	11,200	--	-	13,813
W110 Live Animal Trek-Sokoto-Ilorin	--	-	6,592	--	-	7,167
W114 Live Animal Trek-Sokoto-West	--	-	86,466	--	-	67,566
W48 Live Animal Trek-Bornu-Bauchi	--	-	--	--	-	11,563
W53 Live Animal Trek-Nguru-Kano	--	-	39,816	--	-	46,203
W57 Live Animal Trek-Nguru-Zaria	--	-	14,377	--	-	4,452
W912 Live Animal Trek-Adamawa-Benue	--	-	27,517	--	-	14,992
W915 Live Animal Trek-Adamawa-East	--	-	12,460	--	-	39,910
W112 Live Animal Trek-Plateau-Benue	--	-	3,386	--	-	12,286
W1312 Live Animal Trek-Sardauna-Benue	--	-	13,989	--	-	9,489
R214 Live Animal Rail-Katsina-West	20.9	-	23,283	17.4	-	19,384
R414 Live Animal Rail-Bornu-West	45.5	-	32,260	50.3	-	35,663
R415 Live Animal Rail-Bornu-East	40.4	-	35,027	8.7	-	7,543
R614 Live Animal Rail-Niger-West	--	-	--	10.7	-	20,865
R26 Live Animal Rail-Katsina-Nguru	4.4	-	8,850	--	-	--
R514 Live Animal Rail-Nguru-West	1.3	-	1,448	--	-	--
Total Rail cars used	102	30		87	31	
Total cost of Distribution		₦4,233,000			₦4,140,000	

supplies 80% of the cattle slaughtered at the large abattoir in Kano. The abattoirs at Maiduguri and Nguru operate at full capacity because both areas have large excess supplies. No inshipments are required to furnish the cattle to be slaughtered for cold meat shipment.

These results also show that it is more economical to slaughter cattle at points of origin and ship in refrigerated rail cars to the south than to walk or rail live cattle to intermediate areas for slaughter and meat shipment to the south. In general, it seems that the advantage of cold meat trade relative to the traditional trade is in the transportation costs, while slaughter, storage, and retailing costs are higher.

Successful refrigerated rail hauling of frozen carcasses requires dependable rail service and a relatively sophisticated organization for maintenance and provision of refrigeration units. A delay of only a few hours in replacing a freezer unit can result in a loss of several tons of meat. Much more information is needed on the costs of providing adequate support activities for refrigerated meat shipment before policies of this type are instituted.

Since approximately 40% of the southern demand was supplied by frozen meat, fewer rail cars were needed for live cattle shipment. (Approximately 100 of 212 available). Their route allocation is given in Table IV-10. This shows that if the private meat companies in the south are successful in marketing cold meat to a large number of consumers in the urban areas in the south, additional investments in live cattle transportation to the south can be curtailed. However, the stress on the transportation system for beef will be shifted somewhat to interarea transfers within the northern part of the country.

This would probably mean more support of the northern trek routes as trekking becomes more attractive relative to rail transportation for shorter distances through tsetse-free areas.

The costs of processing and distributing beef under the assumptions of this experiment were Ŀ4,300,000 for the wet season supply distribution. This is approximately Ŀ340,000 less than the costs associated with the assumptions for the first experiment (a 7% reduction).

(5) Increased Speed of Rail Service

As stated, the results of this transhipment model are sensitive to the relative transfer costs estimated for trekking and railing between a few large excess supply and demand areas (areas 1 and 14 being the most important). Therefore, an additional model trial was conducted assuming the turnaround times between the large excess supply and excess demand areas could be reduced by 1/5 (e.g. turnaround time of 10 days would be reduced to 8 days--see Table IV-11). This resulted in lower per animal rail costs as shrinkage and death losses were reduced because of shorter travel times.

This increased efficiency in turnaround times for rail cars had two primary effects on the demand for rail cars--one partially offsetting the other. First, with increased transit speed, one rail car could transport more cattle per year between two areas--tending to decrease the requirement for rail cars. However, because of the decreased cost of rail transportation, more shippers would want to use this shipping method, thereby increasing the demand for rail cars. This latter effect was stronger than the former, causing a net increase in the number of rail cars demanded.

Table IV-11: Turnaround Time and Number of Cattle that May be Shipped by One Railcar Between Areas--Increased Rail Speed

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	--	3900	1950	780	1300	1950	3900	1114		1114	1300	1114		1300	1114
2	2	--	3900	867	1950	1950	3900	1300		1300	1950	1300		1418	1114
3	4	2	--	975	3800	1950	3900	1560		1560	1950	1560		1733	1114
4	10	9	8	--	780	975	1114	1733		821	1300	975		867	1040
5	6	4	2	10	--	1300	1950	1114		1300	1300	975		1418	975
6	4	4	4	8	6	--	2600	1300		1950	1560	1300		2229	1200
7	2	2	2	7	4	3	--	1560		1560	1950	1560		1733	1200
8	7	6	5	4.5	7	6	5	--		1040	3900	1560		1200	1733
9															
10	7	6	5	9.5	6	4	5	7.5		--	1300	1114		2600	709
11	6	4	4	6	6	5	4	2		6	--	1950		1300	1950
12	7	6	5	8	8	6	5	5		7	4	--		709	2600
13															
14	6	5.5	4.5	9	5.5	3.5	4.5	6.5		3	6	11		--	600
15	7	7	7	7.5	8	6.5	6.5	4.5		11	4	3		13	--

Source: See Table III-7.

Note: Numbers in lower left half of the square are the number of days required to go from the departure area to destination and back to the departure area, e.g. from area 4 to area 14 and back to area 4 takes 9 days.
The entries in the upper right half of the square are the number of cattle that can be hauled by one rail car in a year between two areas given the turnaround times e.g. one rail car can haul 867 cattle between area 4 and 14 in one year.

Table IV-12 shows the results of the trial in which the number of rail cars was constrained to the 212 estimated to be presently available in Nigeria. Comparing these results with Table IV-7 (transportation pattern under present conditions) shows that, by decreasing the time of transit, it becomes cheaper to ship cattle by rail from area 1 to area 14 even though the rail distance is approximately 200 miles longer than the trek distance. Therefore, the allocation of the rail cars is changed even though the total number is not.

During the dry season, 53 rail cars are utilized on the Sokoto-west route with the cattle loading at Kaura-Namoda. Therefore, fewer cars are utilized at Funtua (area 2), Bornu (area 4), and Nguru (area 5). However, in each of these areas the same number or more cattle are shipped by fewer rail cars, except on the Bornu to the west route over which fewer cattle are railed. An additional supply area (area 8) enters this solution railing cattle to the western area.

There are still substantial numbers of cattle trekked to the southern areas. Area 14 receives a substantial number of cattle trekked from area 1, and area 15 is the destination of several thousand cattle trekked from area 9. Areas 9 and 13 walk many cattle to area 12. It is becoming clear that these trek routes will be heavily utilized by trade cattle even if rail service is improved. This model experiment gives an indication of where long-term improvements in trek routes will be beneficial even if improvements in rail transport occur (given the current pattern of rail locations).

By increasing the efficiency of turnaround times, an average of 65% of the cattle were hauled by rail compared to 55% for those in which longer turnaround times were assumed. The total cost of distribution decreased from Ł4,640,000 to Ł4,485,000--a drop of 3%.

Table IV-12: Optimum Transportation Pattern with Increased Rail Efficiency and Limited Rail Cars Available

Activity	Wet Season Dist.		Dry Season Dist.	
	Rail cars Live Cattle	No. of Cattle	Rail Cars Live Cattle	No. of Cattle
X441 Frozen Meat Shipment-Bornu-West	--	13,860	--	13,860
X451 Frozen Meat Shipment-Bornu-East	--	8,140	--	8,140
W110 Live Animal Trek-Sokoto-Ilorin	--	6,592	--	5,263
W114 Live Animal Trek-Sokoto-West	--	50,822	--	--
W37 Live Animal Trek-Kano-Zaria	--	14,377	--	4,452
W614 Live Animal Trek-Niger-West	--	--	--	18,984
W912 Live Animal Trek-Adamawa-Benue	--	27,517	--	14,992
W915 Live Animal Trek-Adamawa-East	--	12,460	--	39,910
W1112 Live Animal Trek-Plateau-Benue	--	3,386	--	12,280
W1312 Live Animal Trek-Sardauna-Benue	--	13,989	--	9,487
W36 Live Animal Trek-Kano-Niger	--	607	--	--
W610 Live Animal Trek-Niger-Ilorin	--	--	--	1,903
R314 Live Animal Rail-Kano-West	--	--	1	1,265
R414 Live Animal Rail-Bornu-West	12	10,404	29	25,316
R415 Live Animal Rail-Bornu-East	74	76,856	48	49,402
R514 Live Animal Rail-Nguru-West	69	97,700	65	92,598
R814 Live Animal Rail-Bauchi-West	9	11,160	2	2,284
R114 Live Animal Rail-Sokoto-West	21	27,690	53	69,420
R16 Live Animal Rail-Sokoto-Niger	4	7,800	--	--
R214 Live Animal Rail-Katsina-West	23	31,905	14	19,427
Total Number of Rail Cars Used	212		212	
Total Cost of Distribution		Ƚ4,485,000		Ƚ4,307,500
Percent hauled by rail	67%		65%	
Percent trekked	33%		35%	

(6) Increased Speed of Rail Service and Unlimited Rail Car Availability

Table IV-13 shows the results of the model experiment with reduced turnaround times and unlimited rail car availability. In this outcome, an average of 236 rail cars were used with 251 and 222 employed during the wet and dry seasons respectively. This represents about 18% more rail cars than are presently available in Nigeria. Approximately 73% of all cattle involved in interarea shipment are carried by the rail cars. All the cattle arriving in the west are shipped by rail, while 2/3 of the east's excess demand is delivered by rail. The trek routes connecting areas 9, 12, 13, and 15 are still heavily utilized by the trade cattle, but, the pressure on the western trek routes has been relieved considerably.

Kaura-Namada in area 1, Maiduguri in area 4, and Nguru in area 5 become important rail heads with approximately 60, 80, and 67 rail cars per year respectively being loaded, sent to the south and returned. Given the turnaround times for these routes, 10 rail cars would be loaded each day (260 cattle) for 300 days in Kaura-Namada for shipment to the west. There would be 12.5 rail cars loaded per day (325 cattle) for 300 days in Nguru. In Maiduguri, 11 rail cars would need to be loaded per day with 3 going to the west and 8 going to the eastern area.

The total distribution charge for this experiment averaged Ł4,392,500—only about 3 1/2% less than the cost calculated for the case of no increased rail efficiency or number of rail cars.

Table IV-13: Optimum Transportation Pattern with Increased Rail Efficiency and Unlimited Rail Cars Available

Activity	Wet Season Dist.		Dry Season Dist.	
	Rail Cars Live Animal	No. of Cattle	Rail Cars Live Animal	No. of Cattle
X441 Frozen Meat Shipment-Bornu-West	--	13,860	--	13,860
X451 Frozen Meat Shipment-Bornu-East	--	8,140	--	8,140
W110 Live Cattle Trek-Sokoto-Ilorin	--	6,592	--	--
W36 Live Cattle Trek-Kano-Niger	--	607	--	--
W37 Live Cattle Trek-Kano-Zaria	--	14,377	--	4,452
W610 Live Cattle Trek-Niger-Ilorin	--	--	--	7,167
W912 Live Cattle Trek-Adamawa-Benue	--	27,517	--	14,994
W915 Live Cattle Trek-Adamawa-East	--	12,460	--	39,918
W1112 Live Cattle Trek-Plateau-Benue	--	3,386	--	12,283
W1312 Live Cattle Trek-Sardauna-Benue	--	13,989	--	9,487
R1612 Live Cattle Rail-Sokoto-Niger	4	7,800	--	--
R114 Live Cattle Rail-Sokoto-West	60	78,520	57	74,751
R214 Live Cattle Rail-Katsina-West	23	31,905	14	19,428
R314 Live Cattle Rail-Kano-West	--	--	1	1,266
R414 Live Cattle Rail-Bornu-West	12	10,404	29	25,319
R415 Live Cattle Rail-Bornu-East	74	76,856	48	49,402
R514 Live Cattle Rail-Nguru-West	69	97,700	65	92,593
R614 Live Cattle Rail-Niger-West	--	--	6	13,375
R814 Live Cattle Rail-Bauchi-West	9	11,160	2	2,287
Total Rail Cars Used	251		222	
Total Cost of Distribution		Ƚ4,467,500		Ƚ4,305,500
Percent hauled by rail	77%		73%	
Percent trekked	23%		27%	

(7) No Differentiation between "Hot" and "Cold" Meat Demand in the South

The last two model trials were run without the assumption that hot and cold meat were differentiated products in the two large excess demand areas in the south. Therefore, the demand for beef in areas 14 and 15 can be satisfied by either live cattle shipment and subsequent slaughter, or by slaughter in other areas and meat shipment to these two areas. Table IV-14 presents the results.

The results show that where refrigerated rail cars are available, the total slaughter and transportation charge of meat shipment is less than by walking or railing live animals to the south and then slaughtering them there. However, if the meat must move by truck, it is cheaper to ship live cattle. As shown in Table IV-14, no slaughter for meat shipment to the south is undertaken at Sokoto for either of the two supply distributions.

It is also interesting to note that the most efficient abattoir location is near the cattle supply areas rather than the demand centers or points in between, because transportation costs of shipping carcasses by rail are less than moving cattle on rail cars or treks. Therefore, the location of abattoirs in the north in areas of large excess supply is wise from an economic point of view.

The western area received 68% of its excess demand in the form of frozen meat shipment principally from the abattoirs at Kano, Maiduguri, and Nguru. Cattle from areas 2 and 5 were shipped to the large abattoir at Kano for slaughter and subsequent shipment to the west. The live cattle shipped to the west came from area 1 by trek and area 6 by rail.

Table IV-14: Optimum Transportation Pattern with no Differentiation in Hot and Cold Meat Demand

Activity	Wet Season Supply Dist.			Dry Season Supply Dist.		
	Railcar Live Cattle	Railcar Meat	No. of Cattle	Railcar Live Cattle	Railcar Meat	No. of Cattle
X341 Frozen Meat Shipment-Kano-West	--	13	84,000	--	12	76,053
X441 Frozen Meat Shipment-Maiduguri-West	--	10	35,445	--	12	41,445
X451 Frozen Meat Shipment-Maiduguri-East	--	2	6,555	--	1	555
X541 Frozen Meat Shipment-Nguru-West	--	8	42,000	--	8	42,000
X741 Frozen Meat Shipment-Zaria-West	--	1	4,176	--	-	--
X851 Frozen Meat Shipment-Bauchi-East	--	7	42,000	--	7	42,000
SCKH Modern Slaughter-Kano	--	-	84,000	--	-	76,053
SCB Modern Slaughter-Maiduguri	--	-	42,000	--	-	42,000
SCN Modern Slaughter-Nguru	--	-	42,000	--	-	42,000
SCZ Modern Slaughter-Zaria	--	-	4,176	--	-	--
SCBA Modern Slaughter-Bauchi	--	-	42,000	--	-	42,000
W110 Live Animal Trek-Sokoto-Ilorin	--	-	6,592	--	-	7,167
W114 Live Animal Trek-Sokoto-West	--	-	77,879	--	-	63,114
W23 Live Animal Trek-Katsina-Kano	--	-	13,361	--	-	19,414
W27 Live Animal Trek-Katsina-Zaria	--	-	18,553	--	-	--
W48 Live Animal Trek-Bornu-Bauchi	--	-	30,800	--	-	39,750
W53 Live Animal Trek-Nguru-Kano	--	-	55,655	--	-	50,655
W912 Live Animal Trek-Adamawa-Benue	--	-	27,517	--	-	14,992
W915 Live Animal Trek-Adamawa-East	--	-	12,460	--	-	39,910
W1112 Live Animal Trek-Plateau-Benue	--	-	3,386	--	-	12,286
W1312 Live Animal Trek-Sardauna-Benue	--	-	13,989	--	-	9,489
R16 Live Animal Rail-Sokoto-Niger	5	-	8,580	--	-	--
R17 Live Animal Rail-Sokoto-Zaria	--	-	--	1	-	4,446
R415 Live Animal Rail-Bornu-East	42	-	36,414	18	-	15,000
R614 Live Animal Rail-Niger-West	--	-	--	11	-	20,865
Total rail cars utilized	47	41		30	40	
Total cost of distribution		Ł4,158,000			Ł4,098,000	

Several refrigerated rail cars would be needed to evacuate the frozen meat to the western area. Thirteen cars, each with a six-day turnaround time, would be sufficient for the Kano-west route. The Maiduguri-west route would require 12 rail cars having turnaround times of 11 days, while eight rail cars would be needed for the Nguru-west route, each with 7-day turnaround times. Altogether, 33 refrigerated rail cars would be required to ship 165,820 carcasses to area 14 during one year.

In the eastern area, only 46% of the excess demand was satisfied by frozen meat shipment from the abattoirs at Maiduguri and Bauchi. Most of the cattle slaughtered at Bauchi for meat shipment to the eastern area were trekked from area 4. The majority of the excess demand in the eastern area was satisfied by live cattle trekked from area 9 and railed from area 4.

The abattoir at Maiduguri would send one refrigerated rail car to the eastern area every nine days to export the frozen meat it had slaughtered for that market. Seven cars would be utilized on the Bauchi-east route with each car having a six-day turnaround time. Therefore, a total of eight refrigerated rail cars would be required to export 44,180 carcasses to area 15 in one year.

For areas 14 and 15 together, a total of 41 refrigerated rail cars would be needed to haul the 210,000 carcasses demanded in one year.

If an effort is going to be made to establish a significant market for "cold" meat in the two southern areas, the abattoirs at Nguru and Maiduguri should be used since they represent the least cost locations in terms of assembly, slaughter, and transportation costs.

The two primary reasons for this are (1) they are in the large production regions and (2) both are situated on rail lines allowing economical shipment of frozen meat by refrigerated rail cars.

The total distribution charge for this trial was ₤4,232,000, a savings of about 8.5% over the total cost of distribution separating cold and hot meat demand (see Table IV-7).

(8) Trypanosomiasis Vaccination Program--No Differentiation in Demand

The last experiment was made to investigate the transportation pattern resulting from a trypanosomiasis vaccination program while assuming no differentiation in cold or hot meat demand. The results of this run are given in Table IV-15.

The vaccination program's estimated cost savings on treks (about 1/3) has a significant effect on the relative attractiveness of live cattle versus frozen meat shipment. Only 34% of the demand in the western area is furnished by cold meat shipment as compared to 68% for the trial with no vaccination program. Almost all the meat shipment to this area originates at the abattoirs in Nguru and Maiduguri. The eastern area receives only 2% of its demand in the form of frozen meat illustrating that frozen meat shipment cannot compete with live cattle transfers except over long hauls that originate in large excess supply areas such as Nguru and Maiduguri.

Naturally, the requirement for refrigerated rail cars would be substantially lower if a vaccination program were instituted. The Kano-west route would utilize only 1 car while the Maiduguri and Nguru abattoirs would need 12 and 8 cars per year respectively. Only one car would be dispatched from Maiduguri to the east for hauling the

Table IV-15: Optimum Transportation Pattern with a Trypanosomiasis Vaccination Program and No Differentiation in Hot and Cold Meat Demand

Activity	Wet Season Supply Dist.			Dry Season Supply Dist.		
	Railcar Live Cattle	Railcar Meat	No. of Cattle	Railcar Live Cattle	Railcar Meat	No. of Cattle
X341 Frozen Meat Shipment-Kano-West	--	1	607	--	1	1,532
X441 Frozen Meat Shipment-Maiduguri-West	--	10	35,445	--	12	41,440
X451 Frozen Meat Shipment-Maiduguri-East	--	2	6,555	--	1	555
X541 Frozen Meat Shipment-Nguru-West	--	8	42,000	--	8	42,000
SCKA Modern Slaughter-Kano	--	--	607	--	--	1,532
SCB Modern Slaughter-Maiduguri	--	--	42,000	--	--	42,000
SCN Modern Slaughter-Nguru	--	--	42,000	--	--	42,000
W114 Live Animal Trek-Sokoto-West	--	--	93,058	--	--	74,733
W210 Live Animal Trek-Katsina-Ilorin	--	--	6,592	--	--	7,167
W214 Live Animal Trek-Katsina-West	--	--	25,322	--	--	12,240
N37 Live Animal Trek-Kano-Zaria	--	--	14,377	--	--	4,450
W412 Live Animal Trek-Bornu-Benue	--	--	1,529	--	--	--
W415 Live Animal Trek-Bornu-East	--	--	65,756	--	--	54,785
W514 Live Animal Trek-Nguru-West	--	--	47,068	--	--	50,655
W614 Live Animal Trek-Niger-West	--	--	--	--	--	20,888
W815 Live Animal Trek-Bauchi-East	--	--	11,200	--	--	2,250
N912 Live Animal Trek-Adamawa-Benue	--	--	39,977	--	--	24,481
N1915 Live Animal Trek-Adamawa-East	--	--	--	--	--	30,421
W1112 Live Animal Trek-Plateau-Benue	--	--	3,386	--	--	12,286
W1315 Live Animal Trek-Sardauna-East	--	--	13,989	--	--	9,489
R56 Live Animal Trek-Nguru-Niger	7	--	8,580	--	--	--
Total rail cars needed	7	21		0	22	
Total cost of distribution		₦3,594,000			₦3,400,000	

frozen meat demanded in area 15. A total of 22 refrigerated rail cars were utilized in this trial compared to 44 in the previous experiment.

This trial indicates that more meat would be shipped only if the capacities of the abattoirs in Nguru and Maiduguri were expanded. The slaughter houses in both these locations were operating at full capacity in this solution.

A total slaughter and transportation costs of this trial are ₦3,594,000, a reduction of 23% over the optimum shipment pattern costs in the first experiment. However, this is only a 3% reduction in distribution charges when compared to the trial run assuming a vaccination program and differentiation between "hot" and "cold" meat demand. The 23% reduction is primarily the result of cheaper trek costs rather than increased frozen meat shipment.

Additional Model Experiments

The model structure is flexible enough to allow further experiments as more information is made available or conditions change. For example, as empirical estimates of abattoirs economies of scale become available, this model component can give the least cost location and size of operation of slaughter houses in Nigeria for both cold and hot meat processing.[4] The results would be the location of abattoirs among the areas and the level of output at each location.

The locations of beef production in Nigeria may change when more areas are cleared of tsetse fly, modern grazing reserves are introduced,

[4]See {24} for a procedure that can be easily adapted to the model presented in this chapter.

or use of improved management practices allowing cattle to be produced in tsetse-infested high forage areas. This model component can show the effects of these changes on the requirements placed on the beef distribution system.

Additional model experiments can be run to determine the effects on the beef distribution system of changes in demand preferences between "hot" and "cold" meat in various locations within Nigeria.

Summary of Major Conclusions

Several conclusions drawn from the results given in this chapter can be summarized. Due to the lack of accurate data on many aspects of the distribution system, these results should be considered tentative hypotheses to be tested further as new information is made available.

None of the eight model experiments gave truck shipment of "cold" or "hot" meat as part of the solution set of alternatives. Rail transport of live animals for longer distances was less costly than truck hauling while, trekking appears to be more economic for shorter distances. The high freight charges levied by truck owners were primarily responsible for this result.

The number of rail cars available for live cattle shipment is a constraining factor on the present system of beef distribution. The number available (212) is about 18 percent less than the number that could be economically used (250). Part of the reason more rail cars can not be economically utilized is that some major production areas are not adequately served by the Nigerian Railway. For this reason, the percentage of cattle marketed in the two southern areas that were trekked was never below 25 percent. In most solutions, the percentage trekked to market was between 33-45 percent. Therefore, trekking will continue to be an important method of moving cattle to market. Any proposed policies to improve transportation methods should consider trekking as a potential area for improvement.

Policy runs indicated that total distribution costs would not be decreased much by increasing the speed of rail service by 20%. An improvement of only 3.5 percent was achieved in this experiment. However, significant reduction in the total distribution costs (20 percent) resulted by instituting a trypanosomiasis control program for trekked cattle. A more detailed investigation on the benefits and costs of this type of program seems to be warranted. A trypanosomiasis control program could offer significant benefits to the beef industry as it is presently operating. However, additional improvements in beef transportation will need to be made as the quality and quantity of cattle produced in Nigeria increase. Trekking will surely not be economic for movement of higher quality younger cattle in the future.

The optimum locations of abattoirs for processing frozen carcasses shipped to southern consuming regions are at Maiduguri, Nguru, and Bauchi. These locations are in areas with large excess supplies of cattle, therefore, incoming shipments are not needed. In major cities where facilities are available, "cold" meat shipment can compete with live animal shipment. However, much more basic data on the dependability of refrigerated rail shipment and cost of providing and operating the facilities is needed before this hypothesis can be accurately tested.

CHAPTER V

SPATIAL EQUILIBRIUM FLOWS OF BEEF THROUGH TIME

Introduction

As supply and demand conditions for beef change through time within and among areas in Nigeria, the distribution system will need to adjust to accomodate these changing flows of beef. To guide policy decisions in beef distribution both now and in the future, ideas about the likely interarea flows and their changes through time are important. Investments directed toward improving the beef distribution system will probably alter the transfer charges of transporting beef among these areas. As these transfer charges change, relative prices among the areas will adjust. This causes the quantities demanded and supplied within the areas to change which alters the quantities of beef that flow among areas. Therefore, investments in the beef distribution system actually influence the level of demand for services placed on the system. In other words, policy makers should realize that the number of cattle that will utilize the services of the beef distribution system depends in part on what investments are made to improve the system.

In this chapter, a spatial equilibrium model is developed that estimates the results of interactions among changing demand and supply conditions within areas and alternative transportation policies. This model estimates through time the (1) competitive equilibrium prices in each area, (2) the amount supplied and demanded in each area, and (3) the level of exports and imports among the locations for three alternative investment policies in the transportation of beef. This kind of information should aid policy makers in making decisions regarding investments in the transportation system and the likely demands that will be placed on the system through time as a result of their decisions.

First, the theoretical basis for the model is stated. Appendix IV outlines in more detail the theoretical and mathematical basis of the model. Then, demand and supply parameters and relationships are estimated from Nigerian data and applied to the 15 area structure that is utilized throughout this study. Finally, the equilibrium area prices, quantities demanded and supplied, and interarea flows are given at five year intervals for a 20-year time span for three alternative investment policies in beef transportation.

Spatial Price Equilibrium Model

For this model, the assumed problem setting consists of a single product multi-regional competitive economy. The demand and supply functions are assumed known for each region as well as the transportation costs necessary to transfer the product between all combinations of regions.

Under this specification, one would like to know what will be the (1) competitive equilibrium prices in each area, (2) the amounts supplied and demanded in each of the areas, and (3) the level of exports and imports among areas.

To develop the model used to answer these questions, equilibrium spatial market conditions will be defined in this chapter. In Appendix IV, these conditions will be cast as an extremum problem to be solved by quadratic programming in order to obtain the optimum set of prices, quantities and interarea flows. The solution to this problem will then be shown to satisfy the conditions of a spatial market in equilibrium.

Equilibrium Spatial Market Conditions

An economic state is said to be in a stable price equilibrium if the following conditions are met: {19}

(1) Market Equilibrium

No excess demand and excess supply conditions:

(a) $$\bar{y}_i - \sum_j \bar{x}_{ji} \leq 0 \; . \qquad \text{over all } i$$

$$\bar{\rho}_i \left(\bar{y}_i - \sum_j \bar{x}_{ji}\right) = 0 \; .$$

where:

$\bar{y}_i$ = optimum consumption in area i.

$\bar{x}_{ji}$ = optimum interarea flow from area j to area i.

$\bar{\rho}_i$ = equilibrium market demand price in area i.

i,j = 1,2 ... N = number of areas in the entity being considered.

(b) $$\bar{x}_i - \sum_j \bar{x}_{ij} \geq 0$$

$$\bar{\rho}^i \left(\bar{x}_i - \sum_j x_{ij}\right) = 0 \quad \text{over all } i\text{'s.}$$

where

$\bar{x}_i$ = optimum supply in area i

$\bar{\rho}^i$ = equilibrium market supply price in area i

The market equilibrium condition (a) stipulates (1) that if the equilibrium market price is positive, $\bar{\rho}_i > 0$, then the equilibrium amount of consumption, $\bar{y}_i$ must equal the equilibrium amount supplied to region i from all other regions including its own supply and (2) if the amount consumed in equilibrium in area i, $\bar{y}_i$, is less than the amount supplied to area i, $\sum_j x_{ij}$, the equilibrium market demand price must be equal to zero.

The market equilibrium condition (b) stipulates that (1) if the equilibrium market supply price is positive, $\bar{\rho}^i > 0$, then the amount supplied in area i, $\bar{x}_i$, must be equal to the shipments to all regions including itself, $\sum_j x_{ij}$, and (2) if what is produced in region i, $\bar{x}_i$, is greater than what is exported to all regions, $\sum_j x_{ij}$, the equilibrium market supply price is zero, $\bar{\rho}^i = 0$.

(2) Area Consumer Equilibrium

$$\bar{\rho}_i - \bar{P}_i \geq 0$$

and

$$\bar{y}_i \, (\bar{\rho}_i - \bar{P}_i) = 0 \quad \text{for all i.}$$

where

$\bar{P}_i$ = the maximum price the community is willing to pay for the consumption of the quantity of the commodity, $\bar{y}_i$.

The consumer equilibrium condition (2) stipulates that (1) when there is a positive area consumption in the ith area, $\bar{y}_i > 0$, the area market demand price $\bar{\rho}_i$, must be equal to the area demand price $\bar{P}_i$, the maximum price the area is willing to pay for $\bar{y}_i$ and (2) when $\bar{\rho}_i$, is higher than the demand price $\bar{P}_i$, there must be no consumption in that area.

(3) Area Producer Equilibrium

$$\bar{\rho}^{i} - \bar{P}^{i} \leq 0$$

and

$$\bar{x}_{i} \, (\bar{\rho}^{i} - \bar{P}^{i}) = 0 \text{ for all } i$$

where:

$\bar{P}^{i}$ = the minimum price at which the producer in the area are willing to supply $\bar{x}_{i}$.

This area producer equilibrium states that (1) when the area supply quantity is positive, $\bar{x}_{i} > 0$, the area market supply price, $\bar{\rho}^{i}$, must be exactly equal to the regional supply price, $\bar{P}^{i}$, the minimum price at which the area is willing to supply $\bar{x}_{i}$, and (2) when the area market supply price, $\bar{\rho}^{i}$, is lower than the minimum supply price, $\bar{P}^{i}$, there must be no supply.

(4) Locational Price Equilibrium

$$\bar{\rho}_{j} - \bar{\rho}^{i} - t_{ij} \leq 0$$

and

$$x_{ij} \, (\bar{\rho}_{j} - \bar{\rho}^{i} - t_{ij}) = 0 \text{ for all } i \text{ and } j$$

where:

t_{ij} = transfer charge for the commodity to flow between area i and area j.

The locational price equilibrium condition stipulates that (1) when the interarea flow is positive, $\bar{x}_{ij} > 0$, then the equilibrium area market demand price in j must equal the area market supply price in i plus the transfer charges from i to j and (2) when the area market demand price in j is lower than the region market supply price in i plus transfer charges from i to j, there must be no interarea flow, $\bar{x}_{ij} = 0$.

Given these spatial equilibrium market conditions, the task now is to specify the problem in a manner that may be solved by mathematical programming to derive the optimum prices, quantities and interarea flows and show that this solution fulfills the spatial equilibrium market conditions. This process is given in Appendix IV.

The information required by the model is:

(1) demand functions in each area through time,

(2) supply functions in each area through time, and

(3) transfer charges among all combinations of areas.

Demand Functions

The model requires a linear demand function of the following form:

$$Q = a + bP$$

where Q = quantity of beef consumed

P = price of beef

However, since the model is to be run through time, population and income influences on demand need to be included. Therefore, the following regression equation was estimated from data taken from consumer surveys in Nigeria {6}.

$$\log Q = a + b_1 \log I + b_2 \log P + e$$

Where Q = pounds of beef consumed per capita per year

I = income per capita per year

P = price of beef per pound in pence per pound.

Each of these surveys contain average income levels of three classes of people along with their consumption of beef. The prices for the beef in these areas was taken from the Annual Abstract of Statistics in Nigeria for the time period during which the survey was conducted {5}. There were 20 observations used in the regression analysis. Table V-1 lists these areas and the data from each location.

The results are given below with the standard errors in parentheses below the estimated coefficients.

$$\log Q = \underset{(.26)}{2.938} + \underset{(.06)}{.367} \log I - \underset{(.172)}{1.54} \log P \qquad R^2 = .863 \quad \bar{R}^2 = .846$$

All coefficients were significantly different from zero at the 99 percent confidence level. The usual assumptions of ordinary least squares estimation apply to this equation.

This way of estimating the demand function assumes that the quantity variable is the dependent or "adjusting" variable to price. An alternative formulation would have assumed that the prices adjusted to the quantity variable. The results of this formulation would have been an estimate of price flexibility instead of price elasticity. In addition, the coefficient of the income variable in this formulation would have been the percentage change in prices for a one percent change in income. To convert these coefficients to price and income elasticities needed in the spatial equilibrium component would require additional assumptions {see 2, 10, 11, 34 for a detailed discussion of this problem}. In general, arguments can be made for either formulation. The quantity variable was assumed to be dependent since the elasticities required by the spatial equilibrium component could be obtained more directly.

Table V-1: Beef Consumption Data Taken from the Urban Consumer Surveys

Location	Quantity (lbs./capita/year)	Income (£/year)	Price (d/lb.)
Kaduna			
a	50.5	39.4	18.8
b	58.2	78.8	18.8
c	68.2	179.3	18.8
Gusau-Sokoto			
a	31.5	25.7	15.6
b	54.1	50.2	15.6
c	63.7	135.5	15.6
Enugu			
a	14.6	29.8	29.3
b	17.1	61.1	29.3
c	29.5	173.0	29.3
Onitsha			
a	16.2	46.6	31.7
b	17.1	63.1	31.7
c	30.9	145.4	31.7
Akure-Ondo-Owo			
a	13.7	23.5	30.8
b	23.7	57.5	30.8
c	21.7	139.2	30.8
Oshogbo-Ife-Ilesha			
a	22.5	19.3	23.0
b	32.3	44.8	23.0
c	39.4	137.0	23.0
Lagos			
b	33.0	68.0	28.0
c	36.6	108.2	28.0

NOTE: These are the only areas from which consumer surveys were available. However, they are distributed in the three major cultural areas of the country. (See Figure 10). The survey defined a, b and c as:
a = self-employed workers
b = wage earners
c = middle income

An alternative approach to the estimation of the demand coefficients would have been to specify the quantity and price variables as endogenous in a simultaneous two equation system as given below.

$$(1) \quad Q = a_1 + b_{11}P + b_{12}I + u_1$$

$$(2) \quad P = a_2 + b_{21}Q + u_2$$

where

Q = quantity of beef

P = price of beef

I = income

u_1, u_2 = disturbance terms

If this were the "true" model, P and u_1 in equation (1) would be correlated. This violates an assumption of ordinary least squares estimation in dependence between the independent variables and the disturbance term. Therefore, the direct application of least squares will not yield unbiased or consistent estimates of the regression coefficients.[5] However, Johnston points out that "This fact alone will not necessarily rule out the use of ordinary least squares as an estimating method, since the choice of a method in practice has to be made on a balance of the properties of the method and computational simplicity. Moreover, bias is not necessarily the most important property of an estimator, but has to be judged in conjunction with

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[5]Jean Bronfenbrenner gives a thorough verbal and mathematical explanation of this in her article "Sources and Size of Least-Square Bias in a Two-Equation Model" in W. C. Hood and T. C. Koopman's book Studies in Econometric Method, J. H. Wiley and Sons, New York, 1953, pp. 221-235.

variance".[6] Johnston continues by giving a concise survey of results of Monte Carlo studies that are directed to comparing four different methods of estimating simultaneous equation systems. The methods compared were ordinary least squares (OLS), limited-information single-equation (LISE), two-stage least-squares (TSLS), and full-information maximum-likelihood (FIML). The first study (done by Summers) included in this survey compared these four estimation methods in terms of bias, variance of the estimates around their means, (SD), and the variance of the estimates around the true value of the parameter being estimated (called mean-square error--MSE). OLS performed poorest relative to the other methods in terms of bias in the estimates. However, the OLS estimates had the lowest variance and were second to FIML estimates in terms of minimum MSE. If specification errors are included in the equations, OLS estimates had as high or higher frequency of best results in bias, variance, and mean-square error as compared to the other three estimation methods. In general, the ranking of OLS estimates was below the other three when no specification errors were made, but was close to the top in MSE ranking if specification errors were present.

The next study (done by Basmann) summarized by Johnston involved comparing OLS estimation with TSLS and LISE. The results were that OLS estimates had the worst bias, but on the mean square deviation and variance they were better than TSLS in four cases out of five, and

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[6] Johnston, J., Econometric Methods, McGraw-Hill Book Company, Inc., New York, 1963 p. 253. Johnston gives a concise account of some of the alternative methods of estimating simultaneous equations and comparative results in the last two chapters of this book.

both were substantially better than LISE. Wagner compared OLS with LISE and concluded that OLS showed a greater bias but smaller variance and mean square error. Other studies included in this survey also had mixed results when comparing these simultaneous equation estimation methods.

Karl Fox compared the estimates obtained from reduced form estimation with the OLS estimates of a pork demand function with the same dependent and independent variables as the beef demand function estimated in this study. He found the structural coefficients to be within less than two standard errors of the OLS estimates: the differences were not statistically different.[7] Fox also compares OLS estimates of the coefficients of a simultaneous model of the U.S. economy with the structural coefficients obtained. He found that 32 of the OLS coefficients were within one standard error, and 45 within two standard errors, of the corresponding coefficients.

In general, it is not clear which estimation procedure is "best" for estimating systems of simultaneous equations. Also, it does not appear that one method is uniformly worse than the others. Additional research on estimating demand functions for beef in Nigeria should be directed first to acquisition of more data and secondly to estimation procedure and form.

The cross section consumer surveys were the only source of information on beef demand that could be located for use in this study.

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[7]Ezekiel, M. and K. Fox, Methods of Correlation and Regression Analysis, J. H. Wiley & Sons, Inc., New York, 1959, p. 424. Chapter 24 gives an interesting example of the simultaneous equation problem in terms supply and demand for an agricultural commodity.

An analysis of time series data would have been useful for comparing results. However this was not available for Nigeria. For a detailed discussion of time series versus cross section data see Klein {20} and Manderscheid {26}.

An examination of the data in Table V-1 indicates that the income levels among the locations where the surveys were taken overlap considerable while price differences among locations are much larger. If there are differences among cities in tastes and customs affecting beef consumption, the effects of these differences will probably be reflected in the price coefficient. If these differences are uncorrelated with the prices, no bias will result in the coefficient estimated for price. If they are correlated, there will be a bias although the direction of the bias would not be known *a priori*.

The price elasticity of -1.54 appears reasonable as different kinds of meat are available to substitute for beef in the Nigerian diets (e.g., goat meat, mutton, fish and "bush" meat from undomesticated animals). Beef is considered somewhat of a luxury in the diets of most Nigerians although since the quality is so low this point could be easily over emphasized. Both of these characteristics would lead one to think that the demand price elasticity for beef is somewhat elastic.

The income elasticity for beef of 0.37 is somewhat lower than what might be expected. However, this estimate was utilized in this study because no other comparable estimates were available. In addition, the estimate of the percentage increase in demand through time is relatively insensitive to the income elasticity assumed. Given the population growth rates in the areas defined in this study (see Table V-2), if the income elasticity was underestimated by 50 percent, the increase in demand would be only 10 percent higher. For example, if the population growth rate in an area is 3.5 percent annually and per capita income increases 2 percent annually, an assumed income elasticity of .37 would cause the demand for beef to increase approximately 4.24 percent per year. If the income elasticity was actually 50 percent higher (.55), the demand for beef would increase approximately 4.6 percent per year.

The demand price elasticity (-1.54) was incorporated in each area demand equation which had to be arithmetically linear in the following manner. Since price elasticity is equal to $\frac{\partial q}{\partial P} \cdot \frac{P}{q}$, the coefficient for the price variable in a linear demand function $\frac{\partial q}{\partial P}$ is equal to $-1.54 \times \frac{q}{P}$. The prices and quantities demanded in each area were taken from Tables III-1 and IV-4 respectively for each area. From the known values of q, b and P the intercept value of a was derived by

$$a_i = Q_i - bP_i \text{ for } i = 1, 2 \ldots\ldots 15.$$

Since the model is to be run through time, the influence of population growth rates for the areas in this study were taken from data reported by the Centre for Population Studies {30}. These figures are shown in Table V-2. It is assumed in this study that these rates of growth will continue at the same magnitude throughout the time the model is run. The high population growth rates in the two large southern consuming areas (14 and 15) indicate that the beef distribution system will have to expand its ability to transport quantities of beef from the producing areas to these consumption areas.

Table V-2: Population Increases in 15 Designated Areas of Nigeria

Area	Population Percentage Increase Per Year
1-Sokoto	2.2%
2-Katsina	2.4%
3-Kano	2.4%
4-Bornu	3.2%
5-Nguru	3.2%
6-Niger	3.4%
7-Zaria	2.5%
8-Bauchi	2.8%
9-Adamawa	1.6%
10-Ilorin	5.7%
11-Plateau	2.4%
12-Benue	3.2%
13-Sarduana	2.5%
14-West	6.6%
15-East	6.0%

Source: Okonjo, C. "A Preliminary Medium Estimate of the 1962 Mid-Year Population of Nigeria" in The Population of Tropical Africa Ed. by J. C. Caldwell and C. Okonjo, Longmans of Nigeria LTD, Ikeja, pp. 86-97.

Per capita income is assumed to grow at 2 percent per capita per year in all areas through time. This growth rate was obtained from the FAO study on Nigerian agriculture {8}. This assumption was made because there is really no good data on which to base an alternative one. Demand functions in each area were calculated at 5-year intervals for a 20-year period incorporating these assumptions on population growth, income elasticity, and per capita income growth. Therefore, each area was represented by demand functions at time zero, five, ten, fifteen, and twenty years.

Supply Estimates

The spatial equilibrium model requires arithmetic linear supply functions for each area. The same general procedure was used to derive the area supply functions as was used for the demand functions.

The supply function was estimated from data on number of cattle marketed in Nigeria from 1956/57 to 1964/65 and the corresponding annual prices. These data and their sources are given in Table V-3. The following relationship resulted.

$$\log q = \underset{(.288)}{1.395} + \underset{(.3)}{.92} \log P \qquad R^2 = .79 \quad \bar{R}^2 = .76$$

where:

q = number of cattle marketed

p = price in pence per pound.

All coefficients were significantly different from zero at the 95 percent confidence level. The standard errors are in parentheses below the estimated coefficient.

Table V-3: Prices and Quantities of Cattle Marketed in Nigeria 1956/57-1964/65

Year	Number of Cattle	Average Price (d/lb.)
1956/57	682,000	17.6
1957/58	665,000	16.3
1958/59	635,000	17.8
1959/60	725,000	18.0
1960/61	752,000	17.9
1961/62	805,000	19.2
1962/63	795,000	20.0
1963/64	839,000	20.3
1964/65	860,000	21.0

SOURCE: Number of cattle marketed was taken from Ferguson, {7}, Table 6, p. 78.

The average price in Nigeria was taken from Ferguson, {7}, Table 28, p. 169. The price was derived by taking the proportion of cattle sold in North times the northern price plus the proportion of cattle sold in the South by the southern price.

The supply price elasticity (.92) was incorporated in each area supply function in the same manner as described for the demand functions, but using the prices and supplies given in Table III-1 and IV-3. A problem arises from estimating an annual supply response function from time series data. If, through time, the supply function does not shift while the demand function moves, the observed data points would approximate the stationary supply function. However, this may not have been the situation during the time period over which the supply response was estimated. Ferguson {7,p.69} estimated the maximum growth rate of the cattle population at about 1 percent per year. Others feel that there has been no growth in population. Demand probably grew at about 3 - 3 1/2 percent per year during this time period from population and income increases. Therefore, it is clear that the demand curve shifted farther than the supply function. However, if the cattle population did increase during the observed time period, the estimated supply response would be more elastic than the annual supply functions. Therefore, the estimated quantities supplied would be slightly over estimated for prices higher than the equilibrium observed price and slightly under estimated for prices lower than the observed equilibrium price. In this study, it is assumed that total herd size will continue to change in the same magnitude and direction through the time the model is run as occurred during the time of the observations.

More data relevant to supply response analysis for the Nigerian beef industry is badly needed. Some useful new theoretical concepts have been developed that can aid in gathering data pertinent to the problem. Glenn Johnson {16,17} has developed an extension of cost and

production theory that is directly related to supply response analysis. He observed that the price of acquiring more of a resource for use in production (acquisition price) was higher than the price a producer would receive if he wanted to sell the resource (salvage price). This situation occurred for farm produced durables such as breeding stock and pasture stands; for nonfarm durables; and for resources like farm labor. This situation holds for resource movement into and out of a particular farm and for the farming industry as a whole. Within this framework, to maximize profits, more of a resource would be purchased if its marginal value product (MVP) was higher than the acquisition price. The resource would be sold if the MVP became less than the salvage price. Since the price of acquisition is greater than the salvage value, the MVP can fluctuate between the two and not cause a change in the level of resource use or product output. Obviously, a profit maximizing farmer would not intentionally invest in a resource to the point of lowering its MVP below the acquisition cost. However, a decline in the product price in a subsequent period will cause the MVP to drop from being equal to being less than the acquisition cost. If this decline in output price was not sufficient to lower the MVP below the salvage value, no change in input useage or output would occur. Additionally, a consequent increase in product price would not induce an increase in output until the MVP was raised above the acquisition price. These two situations would be plotted as completely inelastic portions of the supply function. This theoretical extension helps to explain the overcommitment of resources to agriculture at rates of return below nonfarm earnings, the seemingly irreversibility of supply functions from output price decreases and other phenomenon.[8]

It is likely that some of the resources used in cattle production in Nigeria might exhibit significant differences in acquisition costs and salvage values. Given the social structure of the Fulani and their employment opportunities in areas other than cattle production, the salvage value for their labor must be quite low. The salvage values for the young breeding stock is low relative to slaughter cattle prices since the costs of moving young cattle to market are substantial. For the cattle producers as a group, the salvage value of the range land is zero since almost none of it is owned and hence can not be sold. The acquisition prices of land that could be added to the grazing area would be relatively high since this would entail buying farm land or eliminating the tsetse fly.

Given the situations of these three important resources, it appears that Johnson's fixed asset theory would be useful in analyzing the supply response of the Nigerian beef industry. In order to apply these concepts, more data is needed on the acquisition and salvage prices of these inputs, opportunities of employing these resources outside cattle production, basic price and quantities supplied observations, and input-output relationships of cattle production. The relationships between quantities supplied and changing transportation and range conditions are also inportant. Some of these relationships could be internalized by merging the beef distribution and production models.

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[8]See Johnson {16,17} for a full theoretical development of these ideas and a discussion of their ramifications.

Transportation Policies

The model allocates supplies among areas so that the price difference between two areas is less than or equal to the transfer charge. Therefore, the transfer charge limits the price spreads and hence affects the supply and demand in each area. This, in turn affects the interarea shipment requirements placed on the transportation system. All this means that the size of the interarea shipments that the distribution system will be required to service will depend in part on how that system is organized for the task. Figure 13 illustrates this simple concept in the static sense. If t_{12} denotes the initial transfer charge, the interarea shipment quantity is $x_1-y_1=y_2-x_2$. However, if the transfer charges are altered to say t'_{12}, the interarea shipment increases to $x_1'-y_1' = y_2'-x_2'$ (see Figure 13).

This model was built to estimate the demands on the distribution sector of increases in population and per capita incomes and of following alternative investment programs through time. Three policy options are analyzed for the transportation sector. First, a policy that closely parallels the present one which is that of furnishing fewer rail cars than can be economically utilized. This means transfer charges between areas are essentially the costs of trekking since the number of rail cars is limited. The second alternative is to furnish as many rail cars as are demanded so that the transfer charge between areas is the cheaper of the trekking or railing costs. The third is to start a trypanosomiasis control program for trekking cattle and reducing the turnaround time of rail cars between points by one-fifth. The cheaper of these two resultant transfer costs is used as the t_{ij} for

$d_1(y_1)$, $d_2(y_2)$ = Demand functions in areas 1 and 2 respectively

$s_1(x_1)$, $s_2(x_2)$ = Supply functions in areas 1 and 2 respectively

t_{12}, t'_{12} = transfer charges between areas 1 and 2

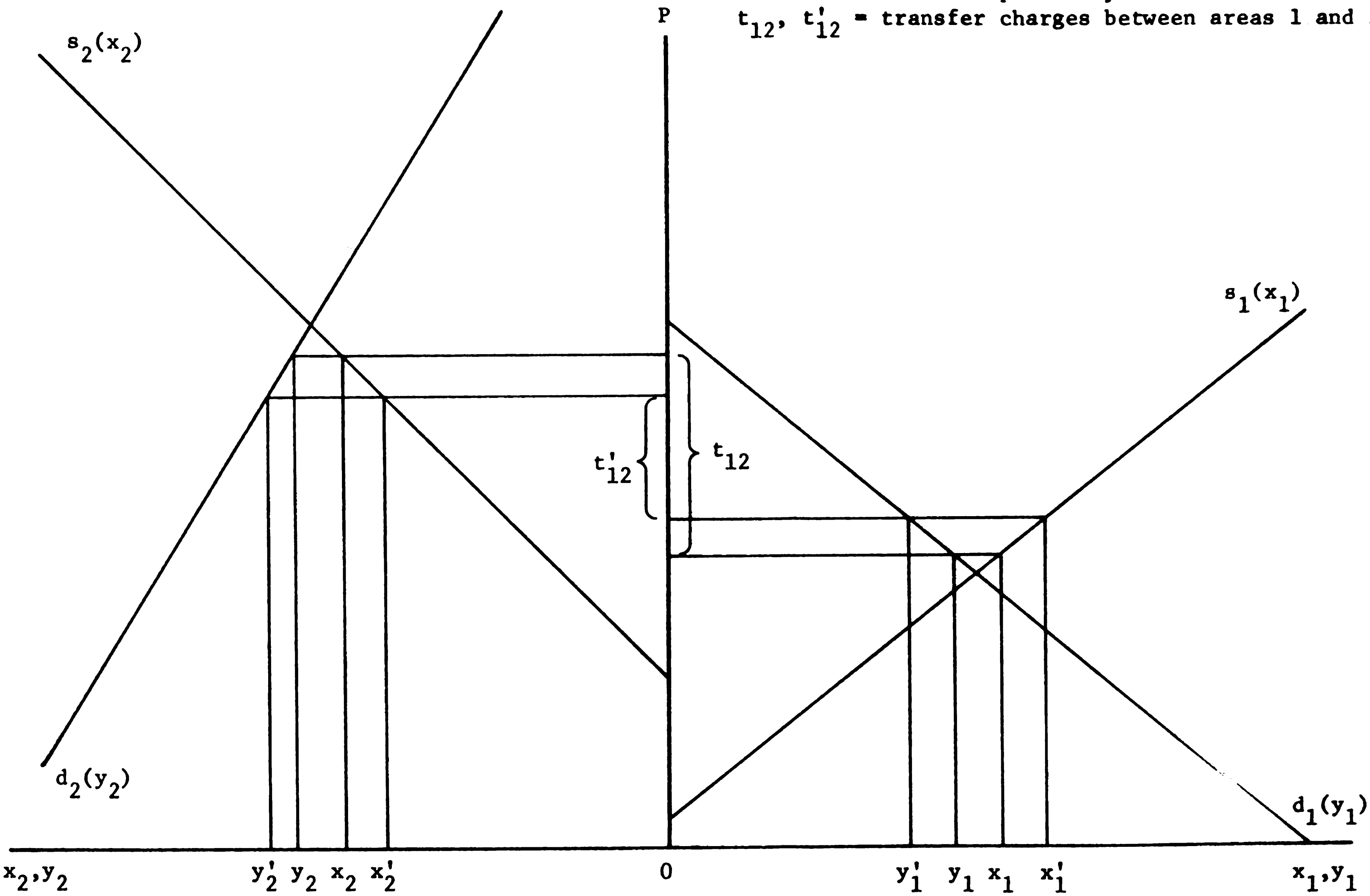

Figure 13: Equilibrium Interarea Flows with Two Different Transfer Charges

that particular route. In the following results section, the first situation is denoted as I, the second, II, and the third, III. These three sets of transfer costs were generated by the TRNSCST model using the equilibrium price arrays given by this spatial equilibrium model. As explained in the procedures section of Chapter I, the estimation of these interarea distribution costs and price arrays is done in a recursive way. The prices calculated for year t are used to calculate the transfer charges for year t+1 which are inputs to the component that estimates prices for year t+1. These prices are then used to calculate the transfer charges for year t+2, etc. Therefore, as prices increase, the transfer charges calculated for each year will be biased downward. The elasticity of transfer costs with respect to price is about 0.5. This means that if prices increase 1 percent, the transfer charges increase about .5 percent. The results from the model runs indicate prices of beef are increasing 2 - 3 percent per year. Therefore, the transfer costs for any one year may be underestimated by about 1 - 1.5 percent.

Results

This spatial equilibrium model was run at five year intervals for twenty years for each of the three transportation investment options. The results are the equilibrium prices, quantities demanded, quantities supplied, and excess supply or demand in each area and the equilibrium interarea flows among the areas. Tables V-7 to V-21 present these data along with total area beef expenditures and receipts in tabular form. Appendix III gives most of these results in graphical form by comparing the prices, quantities supplied and demanded and excess supplies or demands within most areas for the three transportation investment options.

A preliminary model run was made to check the spatial equilibrium model results with the estimated supplies, demands, and prices given in Chapter III and IV. These results are given in Table V-4. In general, the model results were reasonably close to the previous estimates. The results for area 6 and area 10 were farther from the estimates in percentage terms than any of the other areas. Prices reported for area 10 in Nigerian statistical references are somewhat lower than one would expect from the prices in areas surrounding it. This can partially be explained by the fact that this is the area where many of the sick trek cattle are sold at low salvage prices that were to be trekked to the Ibadan and Lagos markets. This large number of lower quality cattle could tend to depress the price of beef in this area.

Interarea Flows Through Time

The model results show that the number of cattle moving to the southern areas (14 and 15) will be increasing fairly rapidly irregardless of the beef transportation investment strategy followed. Table V-5 shows the percent increases in shipments to areas 14 and 15 under all three options through time. In year zero, the percent of cattle moving south is around 39% if no investment is made in a trypanosomiasis control program or improved rail service-option I and 43% if both these programs are instituted-option III. The estimates in Chapter IV indicate that about 47% of the total number of cattle marketed in 1963 were shipped to the south. This model's estimates are lower because of

Table V-4: Comparison of Model Results with Previous Estimates of Price, Demands and Supplies in the 15 Areas

Area	Table III-1 Price	SEM Price	Table IV-3 Supply	SEM Supply	Table IV-4 Demand	SEM Demand
	(Ł's per cow)	(Ł's per cow)	----------	No. of Cattle	----------	----------
1	17.8	18.5	162,500	167,350	77,942	74,927
2	20.8	21.0	70,000	70,700	43,586	43,068
3	20.8	21.1	112,000	113,089	101,016	100,625
4	16.0	15.5	132,000	128,016	28,715	30,483
5	17.5	17.0	110,000	106,714	13,845	14,952
6	27.4	25.9	25,300	24,200	23,587	25,913
7	22.6	21.5	16,800	15,600	26,152	28,547
8	17.5	17.3	51,000	49,559	44,100	44,915
9	16.0	16.9	70,000	78,753	21,023	20,514
10	22.2	23.9	25,000	26,821	31,992	30,332
11	17.5	18.5	32,550	34,150	24,614	23,241
12	24.5	24.0	14,075	13,835	55,892	57,529
13	16.0	16.0	32,550	32,550	20,511	20,511
14	31.5	32.3	2,500	2,560	246,000	245,640
15	31.0	31.0	12,500	12,500	110,000	110,000
Total	----	----	868,775	870,397	868,775	870,397

Table V-5: Total Number of Cattle Produced and Exported to Areas 14 and 15 for 20 Years Under the Three Options

Time (a)	Total Production (b)	% Increase of (b) in a 5 year period	Number of Cattle Moving to 14&15 (c)	% Increase of (c) in a 5 year period	% of (b) Moving to Areas 14&15
Option I	(No. of cattle)				
0	850,118		328,584		39%
		17%		41%	
5	993,604		463,595		47%
		13.5%		28%	
10	1,128,083		595,354		53%
		12.5%		25%	
15	1,270,871		743,148		58%
		11%		21%	
20	1,415,321		896,591		63%
Option II					
0	862,694		348,409		40%
		17.1%		40%	
5	1,010,471		488,494		48%
		13.8%		29.5%	
10	1,150,441		633,258		55%
		13.0%		26%	
15	1,300,040		799,087		61%
		11.7%		22.5%	
20	1,452,948		981,201		67%
Option III					
0	881,015		376,605		43%
		17.2%		40%	
5	1,033,248		532,578		51%
		14.1%		29%	
10	1,179,904		688,616		58%
		13.7%		27.4%	
15	1,342,588		877,614		64%
		12.2%		23.3%	
20	1,506,738		1,082,973		71%

the loss of 1/2 of the market in area 15 in year zero. However, the percentage of total marketings going to areas 14 and 15 increase steadily through the twenty year time span. In year 20, it is estimated that 63% will be marketed in the two southern areas even if no substantial improvements are made in interarea transportation. This figure increases to 71% under option III which reduces interarea transfer charges significantly. This means that the demand for interarea transportation services will increase over 2.8 times in the 20 year period. This represents an increase of about 5.3 percent per year. This percentage would probably increase for a few years if one moved from option I to option III during the 20 year time span. Ferguson estimated that supplies to the two southern areas had increased at about 5.2% per year from 1955/56 to 1964/65 {7,p.174}.

Because the lower transfer charges among areas, more cattle are distributed for option III to areas 14 and 15 than any of the other two options. Under option III, a total of 1,082,973 cattle are allocated to areas 14 and 15 in year 20 costing consumers about Ƚ34 per head. Option I provides 896,591 cattle at about Ƚ37 per head. Therefore under option III, 20 percent more cattle are provided at about 9% cheaper prices to consumers in areas 14 and 15.

Table V-6 shows the major importing and exporting areas and interarea flows through time for all the options. The major exporting areas are 1, 2, 3, 4, 5, 8, 9, 11, and 13 with areas 12, 14, and 15 being large importers. Areas 6, 7, and 10 are neither large exporters or importers in any case. Sokoto, Katsina, Bornu, and Nguru (1, 2, 4 and 5) are the major export areas of cattle to the western area. Through

Table V-6: Major Interarea Flows of Cattle, Among Areas in a 20 Year Time Period Under All Three Options

Option I

	Import														
	Year Zero			Year 5			Year 10			Year 15			Year 20		
Export	12	14	15	12	14	15	12	14	15	12	14	15	12	14	15
1	--	125,355	--	--	155,762	--	--	186,069	--	--	218,140	--	--	250,200	--
2	--	15,311	--	--	26,778	--	--	34,758	--	--	47,376	--	--	59,274	--
3	--	--	--	--	7,475	--	--	19,727	--	--	40,313	--	--	59,956	--
4	25,666	29,312	986	--	35,574	48,651	--	64,985	43,456	--	76,276	51,140	--	87,121	63,354
5	--	90,373	--	--	111,711	--	--	128,329	--	--	148,448	--	--	167,051	--
8	3,844	--	--	--	--	12,901	--	--	23,360	--	--	31,790	--	--	43,370
9	--	--	51,128	43,040	--	20,898	42,451	--	36,807	42,457	--	49,840	42,375	--	65,070
11	--	--	11,484	--	--	18,259	--	--	26,113	--	--	32,878	--	--	41,732
13	10,904	--	--	--	--	18,202	--	--	25,550	--	--	31,851	--	--	39,651

Option II

Export	12	14	15	12	14	15	12	14	15	12	14	15	12	14	15
1	--	101,715	--	--	126,234	--	--	156,290	--	--	186,972	--	--	218,285	--
2	--	12,870	--	--	23,776	--	--	34,429	--	--	45,104	--	--	58,555	--
3	--	--	--	--	1,956	--	--	21,124	--	--	45,783	--	--	73,545	--
4	--	79,457	16,769	--	100,991	22,867	--	135,866	12,312	--	173,750	1,529	--	205,642	--
5	--	89,698	--	--	119,912	--	--	138,633	--	--	161,308	--	--	183,979	--
8	--	--	3,992	--	--	21,268	--	--	32,821	--	--	47,061	--	--	62,417
9	11,382	--	41,831	39,679	--	28,513	38,416	--	44,673	35,764	--	63,092	33,691	--	81,071
11	13,673	--	--	--	--	21,145	--	--	28,789	--	--	37,897	--	--	47,539
13	13,075	--	--	--	--	21,007	--	--	28,321	--	--	36,378	--	--	44,942

Option III

Export	12	14	15	12	14	15	12	14	15	12	14	15	12	14	15
1	--	115,507	--	--	145,993	--	--	180,473	--	--	212,562	--	--	251,229	--
2	--	16,272	--	--	28,859	--	--	37,622	--	--	52,723	--	--	70,032	--
3	--	--	--	--	2,274	--	--	24,529	--	--	54,066	--	--	89,763	--
4	15,712	85,281	--	--	107,136	25,254	--	141,046	17,184	--	185,029	3,136	--	213,455	10,572
5	--	90,055	--	--	121,434	--	--	141,544	--	--	164,724	--	--	190,378	--
8	6,421	--	--	--	--	24,551	--	--	37,013	--	--	53,075	--	--	68,375
9	1,629	--	54,963	17,783	--	54,188	10,077	--	77,802	--	--	105,870	--	--	123,253
11	--	--	14,557	--	--	22,889	--	--	31,403	--	--	41,985	--	--	52,880
13	17,414	--	--	25,085	--	--	32,469	--	--	39,635	--	4,444	40,240	--	13,036

all the years and for all the options, cattle are sent from these four areas to area 14. The pattern of exports from the large supply area 4 varies with investment options. Under option I, approximately 2/5 of the total export of area 4 goes to the eastern area. As the number of rail cars are increased (option II) area 4 exports almost exclusively to the western area. This occurred because rail transportation tends to be more economic than trekking over longer distances. Therefore, area 4 captured some of the western market from area 1 which trekked cattle to the south. The slack in demand left in area 15 was made up by increased shipments from areas 8 and 9. As trekking becomes cheaper (option III) area 1 exports more to 14 than under option I or II. Since the cattle in much of area 1 are quite far from rail points, an increase in the number of rail cars available tends to decrease the number of cattle being exported from that area, because other areas can better utilize the additional rail cars (e.g. area 4 increased exports as rail car numbers increased).

It is interesting to note that area 3 in year zero does not export any cattle. However, as demand increases in the southern areas, area 3 rapidly becomes a major exporter to area 14 under all options. How these rapid increases in exports are generated in the northern areas will be discussed later in this section.

Area 15 received cattle from area 9 under all options in every run. As this eastern area recovers from the war, areas 8, 11 and 13 become additional major sources of supply for it. The traditional pre-war exports of areas 8, 9, 11 and 13 to area 15 were diverted to area 12 or kept within these areas. As shown in Appendix Figure III-23 less cattle tend to be exported to area 15 under option II (increased number of rail cars) than under options I or III. Since two of the major export areas to area 15 are not served by rail (9 and 13), an improvement in trekking is important to consumers in this eastern area.

As the demand for beef rapidly increases in area 15 through the rehabilitation period, exports to area 12 are diverted to the eastern area. From year 5 on, area 12 is supplied by exports from either area 9 or 13. Again, neither of these areas is served by the rail system. Increasing the number of rail cars and improving trekking conditions both tend to decrease the number of cattle being exported to area 12 (see Appendix Figure III-21). As trekking becomes cheaper, cattle tend to move from area 13 to area 15 rather than area 12. As more rail cars are provided, area 11 exports to area 15 at the expense of area 12. Therefore, as a result of improving the transportation methods area 12 may pay higher prices for fewer cattle than if no improvements were made.

The importance of improvement in trek costs is emphasized by the fact that through time areas 1, 9 and 13 continue to be major exporting areas which are not served by the rail system.

Demand

Table V-5 shows that the percentage increase in exports of the northern areas to the southern areas is less than the percentage increase in production in these areas. Since increased production can not fulfill the expanding demands in the southern areas, many northern areas may actually retain fewer cattle for consumption within the area. This phenomenon occurs in areas 1, 2, 3, 4, 5, 8, 9, 11, and 13 (see

Appendix Figures III-16 to III-19). As transfer charges are lowered (especially option III) and demands increase rapidly in areas 14 and 15, more cattle are diverted from local markets and exported to the southern areas. This tends to increase local prices and hence decrease quantities demanded within these areas. Informed people in Nigeria feel that the population of cattle in Nigeria and surrounding countries is becoming a limiting factor. While this study does not look at the population of cattle, it does show that many areas within Nigeria may face declining numbers of cattle available for consumption purposes. It also indicates that an increasing percentage of this limited supply of market cattle will tend to be exported to the southern areas especially if transfer costs are lowered by investments in beef transportation. Appendix Figure III-36 shows the increase in cattle marketed through the 20 year period. These increases amount to about 2% increase per year. However, this does not imply an increase in the population of cattle. An increase in the extraction rate from around 7-8 percent to around 14% in 20 years would provide these increased marketings from a stable cattle population. This may not be unreasonable to expect as the extraction rate in the U.S. and other developed countries is around 27 percent.

Area Beef Expenditures and Receipts

Total expenditures and receipts increased at about 6 percent per year through the 20 year time span under all three options. In year 20, total beef receipts and expenditures were approximately Ł49,000,000 for option III, Ł48,300,000 for option II and Ł46,900,000 for option I. Over the 20 year time period, the estimated total receipts generated under option III would be about Ѣ11,500,000 more than the total received by the beef industry under option I. In other words, the beef industry would gain an average of Ѣ575,000 per year in total receipts for 20 years from investments to control trypanosomiasis and furnish adequate numbers of rail cars.

The increases in total receipts were not shared equally by all areas for all investment options. Table V-22 shows the total receipts and total receipts minus marketing charges for the nine large export areas in year 20 of the model run. All these areas had higher receipts under investment option III, after the marketing charges were subtracted than if option I had been followed. However, this is not the case for option II relative to option I. If an adequate number of rail cars had been furnished, but no trypanosomiasis control program implemented, areas 1 and 2 would have had lower total receipts in year 20 than they would have received under option I. This occurs because under option II, cattle from areas 4 and 5 move to area 14 at the expense of shipments from areas 1 and 2.

Summary

In this chapter, the interarea trade pattern for beef was estimated through time for three investment options in beef transportation. The results show that shipments to the southern consuming regions (14 and 15) are likely to increase fairly rapidly irregardless of the transportation investment strategy followed. In year 20, 63-71% of the total cattle marketed will be shipped to areas 14 and 15. If an effective trypanosomiasis control program is implemented and adequate rail service is provided, consumers in these two southern areas will be

Table V-7: Equilibrium Area Prices, Quantities, Expenditures, Receipts and Interarea Flows at Year Zero, Option I

Area	Price	Excess Demand	Demand	Total Expenditures	Supply	Total Receipts
	(Ŀ/cow)	(No. of cattle)	(No. of cattle)	(Ŀ's)	(No. of cattle)	(Ŀ's)
1	20.5	-125,355	59,933	1,228,627	185,288	4,951,670
2	19.0	- 15,311	49,115	933,147	64,424	1,387,884
3	19.9	+ 564	108,089	2,150,971	107,525	2,139,748
4	13.5	- 77,210	35,783	483,071	112,993	2,412,531
5	16.8	- 90,937	15,013	252,218	105,950	2,947,520
6	23.3	+ 7,172	28,991	675,490	21,819	508,383
7	20.7	+ 14,074	29,575	612,203	15,501	320,871
8	17.0	- 3,844	45,815	778,855	49,659	864,961
9	16.4	- 51,128	20,486	335,970	71,614	1,660,186
10	25.7	- 4,635	23,880	616,543	28,625	754,203
11	18.4	- 11,484	22,608	415,987	34,092	713,423
12	22.4	+ 40,414	53,379	1,195,690	12,965	290,416
13	15.7	- 10,904	21,084	331,019	31,988	575,268
14	29.7	+264,986	267,354	7,940,404	2,368	70,330
15	25.9	+ 64,598	68,905	1,784,845	5,307	137,451
Total	--	---	850,118	19,734,845	850,118	19,734,845

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-14	125,355	5-14	90,373
2-14	15,311	8-12	3,844
4-6	7,172	9-15	51,128
4-7	14,074	10-14	4,635
4-12	25,666	11-15	11,484
4-14	29,312	13-12	10,904
4-15	986		
5-3	564		

Table V-8: **Equilibrium Area Prices, Quantities, Expenditures, Receipts and Interarea Flows at Year 5, Option I**

Area	Price	Excess Demand	Demand	Total Expenditures	Supply	Total Receipts
	(ѣ/cow)	(No. of cattle)	(No. of cattle)	(ѣ's)	(No. of cattle)	(ѣ's)
1	22.3	-155,762	54,933	1,225,006	210,695	6,178,238
2	21.4	- 26,778	48,746	1,043,164	75,524	1,894,705
3	21.4	- 7,475	113,382	2,426,375	120,857	2,664,080
4	16.1	-104,390	35,145	565,835	139,535	3,506,325
5	19.2	-111,711	14,235	273,312	125,946	3,825,722
6	25.1	+ 8,224	32,754	822,125	24,530	615,703
7	23.0	+ 11,941	29,888	687,424	17,947	412,781
8	19.1	- 12,901	45,214	863,587	58,115	1,215,785
9	18.1	- 63,938	18,541	335,592	82,479	1,943,372
10	27.5	- 7,384	24,666	678,315	32,050	913,126
11	20.5	- 18,259	21,345	437,573	39,604	936,043
12	24.1	+ 43,040	57,612	1,388,449	14,572	351,185
13	17.9	- 18,202	19,758	353,668	37,960	850,583
14	31.8	+344,684	347,343	11,045,507	2,659	84,556
15	27.3	+118,911	130,042	3,550,147	11,131	303,876
Total	--	---	993,604	31,963,583	993,604	31,963,583

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-14	155,762	5-14	111,711
2-14	26,778	8-15	12,901
3-14	7,475	9-12	43,040
4-6	8,224	9-15	20,898
4-7	11,941	10-14	7,384
4-14	35,574	11-15	18,259
4-15	48,651	13-15	18,202

Table V-9: Equilibrium Area Prices, Quantities, Expenditures, Receipts and Interarea Flows at Year 10, Option I

Area	Price	Excess Demand	Demand	Total Expenditures	Supply	Total Receipts
	(ъ/cow)	(No. of cattle)	(No. of cattle)	(ъ's)	(No. of cattle)	(ъ's)
1	24.0	-186,069	51,234	1,229,616	237,303	7,518,748
2	23.0	- 34,758	50,092	1,152,116	84,850	2,326,936
3	23.0	- 19,727	116,070	2,669,610	135,797	3,336,383
4	17.8	-126,239	34,680	617,304	160,919	4,538,462
5	20.8	-128,329	14,264	296,691	142,593	4,634,211
6	27.2	+ 8,434	36,198	984,586	27,764	755,181
7	25.1	+ 9,364	29,822	748,532	20,458	513,496
8	21.0	- 23,360	43,374	910,854	66,734	1,588,294
9	20.0	- 79,258	15,891	317,820	95,149	2,497,439
10	29.4	- 6,200	29,643	871,504	35,843	1,081,064
11	22.4	- 26,113	19,110	428,064	45,223	1,185,667
12	26.2	+ 42,451	58,965	1,544,883	16,514	432,667
13	19.7	- 25,550	18,063	355,841	43,613	1,096,791
14	33.8	+440,068	443,027	14,974,313	2,959	100,014
15	29.0	+155,286	167,650	4,861,850	12,364	358,556
Total	--	---	1,128,083	31,963,583	1,128,083	31,963,583

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-14	186,069	5-14	128,329
2-14	34,758	8-15	23,360
3-14	19,727	9-12	42,451
4-6	8,434	9-15	36,807
4-7	9,364	10-14	6,200
4-14	64,985	11-15	26,113
4-15	43,456	13-15	25,550

Table V-10: Equilibrium Prices, Quantities and Interarea Flows at Year 15, Option I

Area	Price (Ł's)	Excess Demand (No. of cattle)	Demand (No. of cattle)	Total Expenditures (Ł's)	Supply (No. of cattle)	Total Receipts (Ł's)
1	26.0	-218,140	50,877	1,322,802	269,017	9,197,656
2	25.0	- 47,376	49,006	1,225,150	96,382	2,935,424
3	24.9	- 40,313	113,400	2,823,660	153,713	4,276,959
4	19.1	-144,730	35,885	685,404	180,615	5,512,669
5	22.6	-148,448	13,332	301,303	161,780	5,660,276
6	28.9	+ 9,529	40,389	1,167,242	30,860	891,854
7	26.7	+ 7,785	30,543	815,498	22,758	607,639
8	22.3	- 31,790	42,371	944,873	74,161	1,933,542
9	21.4	- 92,297	14,278	305,548	106,575	3,035,878
10	31.6	- 12,096	28,241	892,416	40,337	1,329,081
11	23.6	- 32,878	17,049	402,356	49,927	1,424,862
12	27.8	+ 42,457	61,534	1,710,645	19,077	530,341
13	21.1	- 31,851	17,042	359,586	48,893	1,350,152
14	36.1	+542,749	545,567	19,694,969	2,918	105,340
15	31.1	+197,499	211,357	6,573,203	13,858	430,984
Total	--	---	1,270,871	39,224,656	1,270,871	39,224,656

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-14	218,140	5-14	148,448
2-14	47,376	8-15	31,790
3-14	40,313	9-12	42,457
4-6	9,529	9-15	49,840
4-7	7,785	10-14	12,096
4-14	76,276	11-15	32,878
4-15	51,140	13-15	31,851

Table V-11: Equilibrium Prices, Quantities, and Interarea Flows at Year 20, Option I

Area	Price (Ƀ's)	Excess Demand (No. of cattle)	Demand (No. of cattle)	Total Expenditures (Ƀ's)	Supply (No. of cattle)	Total Receipts (Ƀ's)
1	27.6	-250,200	48,964	1,351,406	299,164	10,884,026
2	26.5	- 59,274	47,682	1,263,573	106,956	3,521,912
3	26.5	- 59,956	111,266	2,948,549	171,222	5,232,873
4	20.4	-165,738	36,121	736,868	201,859	6,590,863
5	24.0	-167,051	13,034	312,816	180,085	6,677,459
6	30.5	+ 10,705	44,788	1,366,034	34,083	1,039,532
7	28.2	+ 5,558	30,714	866,135	25,156	709,399
8	23.8	- 43,370	39,463	939,219	82,833	2,366,092
9	22.8	-107,445	11,642	265,438	119,087	3,652,066
10	33.5	- 20,804	23,980	803,336	44,784	1,595,962
11	25.4	- 41,732	14,493	368,122	56,225	1,741,105
12	29.4	+ 42,375	62,698	1,843,321	20,323	597,496
13	22.5	- 39,659	14,907	335,408	54,566	1,640,189
14	38.1	+644,406	648,041	24,690,362	3,635	138,494
15	32.9	+252,185	267,528	8,801,671	15,343	504,785
Total	--	---	1,415,321	46,892,252	1,415,321	46,892,252

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-14	250,200	5-14	167,051
2-14	59,274	8-15	43,370
3-14	59,956	9-12	42,375
4-6	10,705	9-15	65,070
4-7	5,558	10-14	20,804
4-14	87,121	11-15	41,732
4-15	62,354	13-15	39,659

Table V-12: Equilibrium Prices, Quantities, and Interarea Flows at Year Zero, Option II

Area	Price	Excess Demand	Demand	Total Expenditures	Supply	Total Receipts
	(ҍ's)	(No. of cattle)	(No. of cattle)	(ҍ's)	(No. of Cattle)	(ҍ's)
1	18.9	-101,715	70,069	1,324,304	171,784	4,192,667
2	18.7	- 12,870	50,625	946,688	63,495	1,309,622
3	19.9	0	107,525	2,139,748	107,525	2,139,748
4	15.3	- 96,226	30,452	465,916	126,678	3,147,628
5	18.0	- 99,372	13,521	243,378	112,893	2,990,527
6	24.0	+ 5,727	28,140	675,360	22,413	537,912
7	22.5	+ 9,674	26,406	594,135	16,732	376,470
8	17.9	- 9,719	42,354	758,137	52,073	1,000,574
9	16.7	- 53,213	19,612	327,520	72,825	1,688,324
10	24.3	- 77	27,098	658,481	27,175	660,653
11	19.0	- 13,673	21,447	407,493	35,120	720,605
12	22.9	+ 38,130	51,359	1,176,121	13,229	302,944
13	16.3	- 13,075	20,037	326,603	33,112	626,021
14	28.2	+285,817	286,076	8,067,343	2,259	63,704
15	26.3	+ 62,592	67,973	1,787,690	5,381	141,521
Total	--	---	862,694	19,898,917	862,694	19,898,917

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-14	101,715	8-15	3,992
2-14	12,870	9-12	11,382
4-14	79,457	9-15	41,831
4-15	16,769	10-14	77
5-7	9,674	11-12	13,673
5-14	89,698	13-12	13,075
8-6	5,727		

Table V-13: Equilibrium Prices, Quantities, and Interarea Flows at Year 5, Option II

Area	Price (Ⱡ's)	Excess Demand (No. of cattle)	Demand (No. of cattle)	Total Expenditures (Ⱡ's)	Supply (No. of cattle)	Total Receipts (Ⱡ's)
1	20.9	-132,276	66,001	1,379,421	198,277	5,336,156
2	21.0	- 23,776	50,446	1,059,366	74,222	1,775,024
3	21.6	- 10,202	111,700	2,412,720	121,902	2,671,973
4	17.8	-123,858	29,262	520,864	153,120	4,200,969
5	20.3	-119,912	12,723	258,277	132,635	3,867,628
6	26.0	+ 6,042	31,375	815,750	25,333	658,658
7	24.3	+ 8,246	27,128	659,210	18,882	458,833
8	20.2	- 21,268	39,948	806,950	61,216	1,402,454
9	18.9	- 68,192	17,680	334,152	85,872	2,116,555
10	25.9	- 825	29,482	763,584	30,307	788,417
11	21.1	- 21,145	19,539	412,273	40,684	1,004,333
12	24.8	+ 39,679	54,640	1,355,072	14,961	371,033
13	18.5	- 21,007	18,135	335,498	39,142	923,694
14	30.1	+373,694	376,222	11,324,282	2,528	76,093
15	28.0	+114,800	126,190	3,533,320	11,390	318,920
Total	--	---	1,010,471	25,970,740	1,010,471	25,970,740

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-6	6,042	5-14	119,912
1-14	126,234	8-15	21,268
2-14	23,776	9-12	39,679
3-7	8,246	9-15	28,513
3-14	1,956	10-14	825
4-14	100,991	11-15	21,145
4-15	22,867	13-15	21,007

Table V-14: Equilibrium Prices, Quantities, and Interarea Flows at Year 10, Option II

Area	Price (Ь's)	Excess Demand (No. of cattle)	Demand (No. of cattle)	Total Expenditures (Ь's)	Supply (No. of cattle)	Total Receipts (Ь's)
1	22.6	-162,751	61,500	1,389,900	224,251	6,587,071
2	23.0	- 34,429	50,421	1,159,683	84,850	2,264,854
3	23.5	- 26,991	111,553	3,621,496	138,544	3,453,291
4	19.6	-148,178	27,858	546,017	176,036	5,277,907
5	22.1	-138,633	12,268	271,123	150,901	4,721,242
6	27.9	+ 6,461	34,881	973,180	28,420	792,918
7	26.2	+ 5,867	27,156	711,487	21,289	557,772
8	22.1	- 32,821	37,173	821,523	69,994	1,809,435
9	20.6	- 83,089	14,734	303,520	97,823	2,681,568
10	28.3	0	34,584	978,727	34,584	978,727
11	23.0	- 28,789	17,569	404,087	46,358	1,270,636
12	26.9	+ 38,416	55,339	1,488,619	16,923	455,229
13	20.3	- 28,321	16,534	355,640	44,855	1,188,102
14	32.1	+486,342	489,163	15,702,132	2,821	90,554
15	30.1	+146,916	159,708	4,807,211	12,792	385,039
Total	--	---	1,150,441	32,514,345	1,150,441	32,514,345

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-6	6,461	5-14	138,633
1-14	156,290	8-15	32,821
2-14	34,429	9-12	38,416
3-7	5,867	9-15	44,673
3-14	21,124	11-15	28,789
4-14	135,866	13-15	28,321
4-15	12,312		

Table V-15: Equilibrium Prices, Quantities, and Interarea Flows at Year 15, Option II

Area	Price (ƀ's)	Excess Demand (No. of cattle)	Demand (No. of cattle)	Total Expenditures (ƀ's)	Supply (No. of cattle)	Total Receipts (ƀ's)
1	24.4	-193,063	60,276	1,470,734	253,339	8,065,995
2	24.7	- 45,104	50,199	1,239,915	95,303	2,786,983
3	25.4	- 48,075	108,525	2,756,535	156,600	4,391,526
4	21.3	-175,279	24,755	527,282	200,034	6,535,987
5	24.0	-161,308	10,077	241,848	171,385	5,774,712
6	29.9	+ 6,091	37,937	1,134,316	31,846	952,195
7	28.2	+ 2,292	26,241	739,996	23,949	675,362
8	23.9	- 47,061	32,083	766,784	79,144	2,277,442
9	22.3	- 98,856	11,936	266,173	110,792	3,321,429
10	29.9	- 213	38,079	1,138,562	38,292	1,145,868
11	24.8	- 37,897	14,417	357,542	52,314	1,574,035
12	28.8	+ 35,764	55,455	1,597,104	19,691	567,101
13	21.9	- 36,378	14,255	312,185	50,633	1,479,919
14	34.3	+613,130	615,581	21,114,428	2,451	84,069
15	32.1	+185,957	200,224	6,427,190	14,267	457,971
Total	--	---	1,300,040	40,090,594	1,300,040	40,090,594

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-6	6,091	5-14	161,308
1-14	186,972	8-15	47,061
2-14	45,104	9-12	35,764
3-7	2,292	9-15	63,092
3-14	45,783	10-14	213
4-14	173,750	11-15	37,897
4-15	1,529	13-15	36,378

Table V-16: Equilibrium Prices, Quantities and Interarea Flows at Year 20, Option II

Area	Price	Excess Demand	Demand	Total Expenditures	Supply	Total Receipts
	(Ŀ's)	(No. of cattle)	(No. of cattle)	(Ŀ's)	(No. of cattle)	(Ŀ's)
1	26.1	-224,122	59,597	1,555,482	283,719	9,664,260
2	26.2	- 58,555	47,267	1,238,395	105,822	3,363,942
3	27.1	- 73,545	101,317	2,745,691	174,862	5,415,374
4	23.0	-205,642	20,128	462,944	225,770	7,927,749
5	25.7	-183,979	8,106	208,324	192,085	6,886,762
6	31.7	+ 5,837	41,163	1,304,867	35,326	1,119,834
7	29.5	0	26,240	774,080	26,240	774,080
8	25.5	- 62,417	25,978	662,439	88,395	2,778,375
9	23.7	-114,762	8,550	202,635	123,312	3,978,517
10	31.8	- 5,226	37,409	1,189,606	42,635	1,379,310
11	26.3	- 47,539	10,567	277,912	58,106	1,889,484
12	30.5	+ 33,691	54,724	1,669,082	21,033	641,507
13	23.3	+ 44,942	11,453	266,855	56,395	1,790,389
14	36.3	+745,232	748,707	27,178,064	3,475	126,143
15	33.9	+235,969	251,742	8,534,054	15,773	534,705
Total	--	---	1,452,948	48,270,430	1,452,948	48,270,430

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-6	5,837	8-15	62,417
1-14	218,285	9-12	33,691
2-14	58,555	9-15	81,071
3-14	73,545	10-14	5,226
4-14	205,642	11-15	47,539
5-14	183,979	13-15	44,942

Table V-17: Equilibrium Prices, Quantities, and Interarea Flows at Year Zero, Option III

Area	Price (Ⱡ's)	Excess Demand (No. of cattle)	Demand (No. of Cattle)	Total Expenditures (Ⱡ's)	Supply (No. of cattle)	Total Receipts (Ⱡ's)
1	19.8	-115,507	63,873	1,264,685	179,380	4,290,969
2	19.2	- 16,272	48,772	936,422	65,044	1,362,749
3	19.9	0	107,525	2,139,748	107,525	2,139,748
4	15.9	-101,801	29,439	468,080	131,240	3,070,525
5	18.0	- 99,636	13,257	238,626	112,893	2,813,640
6	24.3	+ 5,123	27,791	675,321	22,668	550,832
7	22.5	+ 9,581	26,313	592,043	16,732	376,470
8	18.2	- 11,544	41,333	752,043	52,877	1,019,296
9	17.3	- 56,592	18,654	322,714	75,246	1,672,494
10	24.0	+ 838	27,702	664,848	26,864	644,736
11	19.2	- 14,557	20,906	401,395	35,463	749,308
12	22.2	+ 41,176	54,035	1,199,577	12,859	285,470
13	17.4	- 17,414	17,760	309,024	35,174	695,615
14	26.2	+307,198	309,198	8,100,988	2,113	55,361
15	23.9	+ 69,520	74,457	1,779,522	4,937	117,994
Total	--	---	881,051	19,845,254	881,015	19,845,254

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-14	115,507	8-6	5,123
2-14	16,272	8-12	6,421
4-10	838	9-12	1,629
4-12	15,712	9-15	54,963
4-14	85,251	11-15	14,557
5-7	9,581	13-12	17,414
5-14	90,055		

Table V-18: Equilibrium Prices, Quantities and Interarea Flows at Year 5, Option III

Area	Price (Ŀ's)	Excess Demand (No. of cattle)	Demand (No. of cattle)	Total Expenditure (Ŀ's)	Supply (No. of cattle)	Total Receipts (Ŀ's)
1	21.7	-145,993	59,380	1,288,546	204,373	5,420,148
2	21.7	- 28,859	47,642	1,033,831	76,501	1,850,541
3	21.9	- 14,573	108,897	2,384,844	123,470	2,760,624
4	18.5	-132,390	26,324	486,994	158,714	4,175,547
5	20.5	-121,434	12,418	254,569	133,852	3,691,151
6	26.4	+ 4,928	30,618	808,315	25,690	678,216
7	24.6	+ 7,371	26,468	651,113	19,097	469,786
8	20.6	- 24,551	37,792	778,515	62,343	1,416,841
9	19.4	- 71,971	16,021	310,807	87,992	2,148,266
10	25.7	0	30,089	773,287	30,089	773,287
11	21.5	- 22,889	18,515	398,073	41,404	993,187
12	24.1	+ 42,868	57,440	1,384,304	14,572	351,185
13	19.5	- 25,085	16,027	312,527	41,112	917,075
14	28.3	+405,696	408,085	11,548,806	2,389	67,609
15	26.0	+126,882	137,532	3,575,832	10,650	276,900
Total	--	---	1,033,248	25,990,363	1,033,248	25,990,363

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-14	145,993	5-14	121,434
2-14	28,859	8-15	24,551
3-6	4,928	9-12	17,783
3-7	7,371	9-15	54,188
3-14	2,274	11-15	22,889
4-14	107,136	13-12	25,085
4-15	25,254		

Table V-19: Equilibrium Prices, Quantities and Interarea Flows at Year 10, Option III

Area	Price (Ł's)	Excess Demand (No. of cattle)	Demand (No. of cattle)	Total Expenditures (Ł's)	Supply (No. of cattle)	Total Receipts (Ł's)
1	23.7	-180,473	54,033	1,280,582	234,506	6,766,961
2	23.4	- 37,622	48,597	1,137,170	86,219	2,280,879
3	23.9	- 33,260	107,481	2,568,796	140,741	3,555,122
4	20.4	-158,230	24,524	500,290	182,754	5,269,240
5	22.4	-141,544	11,274	252,538	152,818	4,555,475
6	28.6	+ 4,200	33,277	951,722	29,077	831,602
7	26.6	+ 4,531	26,123	694,872	21,592	574,347
8	22.6	- 37,013	34,463	778,864	71,476	1,815,228
9	21.3	- 87,879	13,064	278,263	100,943	2,720,737
10	28.3	0	34,584	978,727	34,584	978,727
11	23.5	- 31,403	15,901	373,674	47,304	1,252,958
12	26.2	+ 42,546	59,060	1,547,372	16,514	432,667
13	21.2	- 32,469	14,249	302,079	46,718	1,152,767
14	30.4	+525,214	527,897	16,048,069	2,683	81,563
15	28.0	+163,402	175,377	4,910,556	11,975	335,300
Total	--	---	1,179,904	32,603,574	1,179,904	32,603,574

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-14	180,473	5-14	141,544
2-14	37,622	8-15	37,013
3-6	4,200	9-12	10,077
3-7	4,531	9-15	77,802
3-14	24,529	11-15	31,403
4-14	141,046	13-12	32,469
4-15	17,184		

Table V-20: Equilibrium Prices, Quantities, and Interarea Flows at Year 15, Option III

Area	Price (ѣ's)	Excess Demand (No. of cattle)	Demand (No. of cattle)	Total Expenditures (ѣ's)	Supply (No. of cattle)	Total Receipts (ѣ's)
1	25.7	-212,562	53,515	1,375,336	266,077	8,283,601
2	25.6	- 52,723	45,817	1,172,915	98,540	2,886,413
3	25.9	- 57,463	102,024	2,642,422	159,487	4,503,501
4	22.3	-188,165	20,696	461,521	208,861	6,569,357
5	24.4	-164,724	9,348	228,091	174,072	5,581,621
6	30.8	+ 3,067	35,801	1,102,671	32,734	1,008,207
7	28.7	+ 330	24,676	708,201	24,346	698,730
8	24.5	- 53,075	27,937	684,457	81,012	2,282,014
9	23.2	-105,870	9,138	212,002	115,008	3,398,689
10	29.9	0	38,292	1,144,931	38,292	1,144,931
11	25.5	- 41,985	11,722	298,911	53,707	1,562,660
12	28.2	+ 39,635	58,958	1,662,616	19,323	544,909
13	23.3	- 44,079	9,601	223,703	53,680	1,475,175
14	32.5	+669,104	673,104	21,875,880	4,000	130,000
15	30.1	+208,510	221,959	6,680,966	13,449	404,815
Total	--	---	1,342,588	40,474,623	1,342,588	40,474,623

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-14	212,562	5-14	164,724
2-14	52,723	8-15	53,075
3-6	3,067	9-15	104,870
3-7	330	11-15	41,985
3-14	54,066	13-12	39,635
4-14	185,029	13-15	4,444
4-15	3,136		

Table V-21: Equilibrium Prices, Quantities and Interarea Flows at Year 20, Option III

Area	Price (Ł's)	Excess Demand (No. of cattle)	Demand (No. of cattle)	Total Expenditures (Ł's)	Supply (No. of cattle)	Total Receipts (Ł's)
1	27.7	-251,229	48,965	1,356,331	300,194	10,073,977
2	27.6	- 70,032	41,082	1,133,863	111,114	3,563,974
3	27.9	- 89,763	89,952	2,509,661	179,715	5,624,437
4	24.2	-224,027	13,081	316,560	237,108	8,059,638
5	26.4	-190,378	6,649	175,534	197,027	6,781,650
6	32.9	+ 1,218	37,787	1,243,192	36,569	1,203,120
7	29.5	0	26,240	774,080	26,240	774,080
8	26.1	- 69,593	20,765	541,967	90,358	2,756,364
9	24.7	-123,253	4,982	123,055	128,235	4,043,501
10	31.2	0	41,877	1,306,562	41,877	1,306,562
11	27.2	- 52,880	7,107	193,310	59,987	1,874,894
12	29.7	+ 40,240	60,757	1,804,483	20,517	609,355
13	24.7	- 53,276	6,319	156,079	59,595	1,765,752
14	34.7	+814,857	818,189	28,391,158	3,332	115,620
15	31.8	+268,116	282,986	8,998,955	14,870	472,866
Total	--	---	1,506,738	49,024,790	1,506,738	49,024,790

Interarea Shipments

Route	Number of Cattle	Route	Number of Cattle
1-14	251,229	8-6	1,218
2-14	70,032	8-15	68,375
3-14	89,763	9-15	123,253
4-14	213,455	11-15	52,880
4-15	10,572	13-12	40,240
5-14	190,378	13-15	13,036

Table V-22: Total Receipts and Receipts Minus Marketing Charges in Major Export Areas for Year 20 Under Three Transportation Options

Area	Option I		Option II		Option III	
	Total Receipts	Receipts Minus Marketing Charges	Total Receipts	Receipts Minus Marketing Charges	Total Receipts	Receipts Minus Marketing Charges
	(in Ł's)					
1	10,884,026	8,254,420	9,664,260	7,405,066	10,073,977	8,315,374
2	3,521,912	2,834,334	3,363,942	2,772,536	3,563,974	3,066,746
3	5,323,873	4,537,383	5,415,374	4,738,760	5,624,437	5,014,049
4	6,590,863	4,117,924	7,927,749	5,192,170	8,059,638	5,728,014
5	6,677,459	4,322,040	6,886,762	4,936,585	6,781,650	5,201,513
8	2,366,092	1,971,425	2,778,375	2,254,073	2,756,364	2,358,344
9	3,652,066	2,715,184	3,978,517	2,922,494	4,043,501	3,167,405
11	1,741,105	1,428,115	1,889,484	1,528,188	1,824,894	1,631,646
13	1,640,189	1,227,735	1,790,389	1,344,004	1,765,752	1,471,997

provided with 20 percent more cattle at 9 percent lower prices than if these investments in beef distribution were not provided. The beef producers in Nigeria would gain approximately ₦11,500,000 in total receipts from these investments over a 20 year period. However, consumers in many northern areas may face declining numbers of cattle available for consumption in local markets as demands increase in the southern areas and as transfer charges are lowered for cattle movement to these locations. Producers in area 1 and 2 would have lower receipts from the sale of cattle under investment option II relative to option I. However, all areas gain in terms of total receipts from implementing investment option III relative to options I or II.

These changes in total cattle marketed and location of originating shipments have important ramifications on the organization of the distribution system. The effects of these changes on the demands placed on the beef distribution system through time will be estimated in the following chapter.

CHAPTER VI

SUMMARY

Introduction

A review of the total model and the relationship among its three components is stated at this point so the results and summary given in this chapter can be placed in perspective. Figure 1 illustrates the integration of the components into the overall model framework. The transportation cost component (TRNSCST) calculated the costs of transporting an animal between all two area combinations possible among the 15 areas for five different transportation methods (truck, trek, and rail for live animals and refrigerated truck and rail for carcasses). This component was also used to estimate transportation costs resulting from programs to control trypanosomiasis and increase the speed of rail service.

The transhipment linear program component was constructed to find the configuration of transportation and slaughter facilities that would minimize the total cost of processing and shipping beef in Nigeria. The objective function of this component utilized slaughter and transportation costs calculated by the TRNSCST component. The constraints of the linear program were the number of rail cars available for live cattle shipment and the estimated quantities demanded and supplied in each of the 15 areas. Two supply constraints were incorporated to represent the wet and dry season supply distributions. Several modifications were made on this component to show the results of varying the number of rail cars available, increasing frozen meat shipments, instituting a trypanosomiasis control program, and increasing the speed of rail service. For each modification, the appropriate transportation costs taken from the TRNSCST component were entered in the objective function. All of these runs were made at one point in time assuming constant supplies and demands (given in Tables IV-3 and IV-4) in each area.

To estimate the consequences of alternative policies through time, a dynamic spatial equilibrium model (SEM) component was utilized. This component used the transportation costs estimated by the TRNSCST component and estimated supply and demand functions in each area as inputs. It allocated supplies among areas so that the transfer charge between any two areas was greater than or equal to the price difference. The demand functions were updated through the 20 year time span according to assumptions about income and population increases. The results of these runs were the equilibrium structure of area prices, quantities supplied and demanded, and the interarea trade flows among the 15 areas at 5 year intervals. After each run of the spatial equilibrium model component, the resulting equilibrium prices were used as an input to the TRNSCST component which in turn calculated new transportation costs to be used in the subsequent SEM run. The SEM component was run through the 20 year time span three times utilizing the appropriate set of transfer costs derived from TRNSCST resulting from three different transportation investment strategies.

The last step in the total model process involved finding the optimum transportation configuration through time for each investment option. To do this, the transhipment linear program component was utilized. The quantities demanded and supplied in each area through time for each investment option (taken from the SEM component) became constraints in the linear program while the appropriate set of inter-area costs derived from TRNSCST were entered in the objective function. Then, utilizing the appropriate costs, supplies, and demands, the linear program component was run at 5 year intervals for a 20 year time span. The results of these runs were the optimum transportation configurations for each investment option at 5 year intervals.

In this chapter, the results of this final model step are reported and analyzed. Then, a summary of the major results and conclusions derived in this study is given. Finally, a research agenda is proposed that will help to both improve the estimates of the model parameters and relationships used in this study and contribute to understanding how the system may be altered to improve its performance.

Requirements of the Three Investment Options on the Transportation System Through Time

In Chapter V, information about the probable effects of the three transportation investment strategies were given in terms of area equilibrium prices, quantities demanded and supplied, and interarea flows of beef through 20 years of simulated time. In addition to this kind of information, policy makers are also interested in the requirements placed on the distribution system by each of the alternative plans. Therefore, the results of the model component described in Chapter V are used as inputs to the transportation linear program component to derive these requirements. For each option, the estimated quantities demanded and supplied in each area at 5 year intervals (given in Tables V-7 and

V-21) are used as constraints in the transportation linear program. These constraints replace those given in Table IV-3 and IV-4. The rail car constraint varies with each option. For option I, the number of rail cars available increases at about 2 percent per year. Unlimited numbers of rail cars are available for options II and III.

The transportation cost entries in the objective function also change with the option being analyzed. The transfer costs for options I and II are the trek and rail costs with no increased speed of rail services or trypanosomiasis control program. For option III, the transportation costs are those that result from a trypanosomiasis control program and increased speed of rail service.

The price in the destination market influences the cost of transporting an animal to that market because shrinkage and death costs are evaluated at the destination market's current price. Since the area price structure at the 5 year intervals is different for each option, the set of transportation charges calculated by the TRNSCST components differ for each option. Therefore, the transportation cost entries in the linear program's objective function are different for each option at the same point in time. For example, the cost of trekking an animal from area 3 to area 14 at year 10 under option I is different than the trek cost for option II because the price in area 14 is not the same. Consequently, a separate run of the TRNSCST component was needed for each option at each 5 year interval to derive the proper transportation costs for use in the linear program's objective function.

The linear program was run five times representing years 0, 5, 10, 15 and 20 for each of the three options, making a total of 15. Each run utilized the appropriate area supplies and demands taken from the spatial equilibrium model component. The transportation costs used in the objective function were taken from the TRNSCST component which estimated the costs from the price structure given by the spatial equilibrium component.

The mathematical structure of the linear program component is given in Chapter IV. Basically, the objective is to find the least cost transportation configuration to service the interarea flows given by the spatial equilibrium model (Table V-7 to V-21). The results of this step are the optimum number of rail cars to be utilized, the allocation of these rail cars on particular routes, the location and number of cattle using trek routes, and the total distribution charge for each alternative investment option at five year intervals for 20 years.

Option I Investment Strategy

This option entails providing fewer rail cars than can be effectively utilized through time. The number of rail cars available for cattle transport are increased about 2.2 percent per year through the 20 year time span. This is about the rate of increase observed over the past 10 years in Nigeria. In years 0, 5, 10, 15, and 20, the number of rail cars available are 212, 236, 272, 302, and 332 respectively. No investments are made in option I for controlling the trypanosomiasis disease along the trek routes. The results of the linear program runs for option I at 5 year intervals are given in Tables VI-1 through VI-5.

For year 0, the number of rail cars utilized (174) is less than the number available (212) because of the assumption that the demand in area 15 is reduced significantly due to the civil war. Forty two

Table VI-1: Optimum Transportation Pattern for Year 0, Option I

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	-	125,355
"	4-7	-	14,074
"	5-3	-	564
"	8-12	-	3,844
"	9-15	-	51,128
"	10-14	-	4,635
"	11-15	-	11,484
"	13-12	-	10,904
Rail	2-14	14	15,311
"	4-6	8	7,172
"	4-12	27	35,666
"	4-14	42	29,312
"	4-15	2	986
"	5-14	81	90,373
Total Number of Rail Cars/Year		174	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 42%

Total Distribution Costs - Ⱡ4,168,915

Table VI-2: Optimum Transportation Pattern for Year 5, Option I

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	-	155,762
"	4-6	-	8,224
"	4-7	-	11,941
"	8-15	-	12,901
"	9-12	-	43,040
"	9-15	-	20,898
"	10-14	-	7,384
"	11-15	-	18,259
"	13-15	-	18,202
Rail	2-14	24	26,778
"	3-14	6	7,475
"	4-14	50	35,574
"	4-15	56	48,651
"	5-14	100	111,711
Total Number of Rail Cars/Year		236	

Percentage of Total Inshipments to Area 14 and 15 Hauled by Rail - 50%

Total Distribution Costs - Ŀ5,576,421

Table VI-3: Optimum Transporation Pattern for Year 10, Option I

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	-	186,069
"	2-14	-	34,758
"	4-6	-	8,434
"	4-7	-	9,364
"	8-15	-	23,360
"	9-12	-	42,451
"	9-15	-	36,807
"	10-14	-	6,200
"	11-15	-	26,113
"	13-15	-	25,550
Rail	3-14	15	19,727
"	4-14	91	64,985
"	4-15	51	43,456
"	5-14	115	128,329
Total Number of Rail Cars Per Year		272	

Percentage of Total Inshipments To Areas 14 and 15 Hauled by Rail - 43%

Total Distribution Costs - Ŀ7,067,324

Table VI-4: Optimum Transportation Pattern for Year 15, Option I

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	-	219,140
"	2-14	-	47,376
"	4-6	-	9,529
"	4-7	-	7,785
"	4-15	-	24,263
"	8-15	-	31,790
"	9-12	-	42,457
"	9-15	-	49,840
"	10-14	-	12,096
"	11-15	-	32,878
"	13-15	-	31,851
Rail	3-14	31	40,313
"	4-14	107	76,276
"	4-15	31	26,877
"	5-14	133	148,448
Total Number of Rail Cars Per Year		302	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 39%

Total Distribution Costs - Ł8,790,925

Table VI-5: Optimum Transportation Pattern for Year 20, Option I

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	-	250,200
"	2-14	-	59,274
"	4-6	-	10,705
"	4-7	-	5,558
"	4-15	-	51,083
"	8-15	-	43,370
"	9-12	-	42,375
"	9-15	-	65,070
"	10-14	-	20,804
"	11-15	-	41,732
"	13-15	-	39,659
Rail	3-14	46	59,956
"	4-14	123	87,121
"	4-15	13	11,271
"	5-14	150	167,051
Total Number of Rail Cars Per Year		332	

Percentage of Total Inshipments in Areas 14 and 15 Hauled by Rail - 36%

Total Distribution Costs - Ƀ10,688,088

percent of the total inshipments to areas 14 and 15 were hauled by rail during year 0. Almost none of the cattle shipped to area 15 were hauled by rail while about 1/2 of the cattle transported to area 14 were railed. This occurs because the major supply areas (9 and 11) are not served by the rail system or are relatively closer to area 15 than the supply areas for area 14. These factors combined makes trekking relatively more attractive to area 15 while railing is cheaper to area 14. This phenomenon in general holds for all the runs under option I. For year 0, only 1.2 percent of the total rail cars are used to ship cattle to area 15. Approximately 24 percent are utilized in this manner in year 5. For years 10, 15 and 20, the percent of total rail cars utilized to ship cattle to area 15 is 19, 10 and 4 respectively. This indicates that rail shipments to area 15 may decline substantially if the number of rail cars becomes a serious limitation.

Tables VI-1 to VI-5 also show that an increase in the number of rail cars of 2.2 percent per year will not be enough to meet the demand for rail shipments. From year 5 on through year 20, the percentage of total cattle being shipped to areas 14 and 15 by rail steadily declines from 50 percent in year 5 to 36 percent in year 20. This indicates that if rail car numbers are to be less than what could optimally be used, investments in trek routes leading to area 15 should be considered.

Since the percentage of cattle hauled by rail is decreasing under option I, the number of cattle using trek routes increases. The trek routes connecting areas 1 and 2 with area 14 and areas 4, 8, 9, 11 and 13 with area 15 are heavily utilized especially from year 10 on. Of these routes, only 1 to 14 and 9 and 13 to 15 are less expensive to travel by trek than by rail. Cattle trek over the remaining routes because the limited number of rail cars can be used more effectively on other longer routes.

Areas 3, 4 and 5 remain important rail loading points for shipment of cattle to areas 14 and 15.

Option II Investment Strategy

This second investment strategy consists of furnishing as many rail cars as are demanded for cattle shipment, but no investment is made for controlling the trypanosomiasis disease along the trek routes. Tables VI-6 through VI-10 shows the results obtained from applying the transportation linear program to the interarea flows given in Tables V-12 through V-16.

The demand for rail cars increases rapidly under option II. From year 0 to 20, the number of rail cars utilized increases from 227 to 643. This represents an average increase of about 5.4 percent per year or about 2.5 times as much as rail car numbers were allowed to increase under option I.

The percentage of total inshipments to areas 14 and 15 hauled by rail, is 59 percent in year 0 and increases to about 64 percent in year 20. It is interesting to note that in the model results, over 1/3 of the total inshipments to areas 14 and 15 are trekked no matter how many rail cars are provided. This occurs because major excess supply areas (1, 9 and 13) are not close to rail lines. Rail shipments comprise about 1/3 of the total inshipments to area 15 in year 0 and about 1/2 in year 20. For area 14, about 2/3 of the total imports are carried by rail in each year.

Table VI-6: Optimum Transportation Pattern for Year 0, Option II

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	-	101,715
"	5-7	-	9,674
"	8-6	-	5,727
"	9-12	-	11,382
"	9-15	-	41,831
"	10-14	-	77
"	11-12	-	13,673
"	13-12	-	13,075
Rail	2-14	12	12,870
"	4-14	112	79,457
"	4-15	19	16,769
"	5-14	81	89,698
"	8-15	3	3,992
Total Number of Rail Cars Per Year		227	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 59%

Total Distribution Costs - Ƀ4,360,492

Table VI-7: Optimum Transportation Pattern for Year 5, Option II

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-6	-	6,042
"	1-14	-	126,234
"	3-7	-	8,246
"	9-12	-	39,679
"	9-15	-	28,513
"	10-14	-	825
"	11-15	-	21,145
"	13-15	-	21,007
Rail	2-14	22	23,776
"	3-14	2	1,956
"	4-14	142	100,991
"	4-15	27	22,867
"	5-14	108	119,912
"	8-15	17	21,268
Total Number of Rail Cars Per Year		318	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 60%

Total Distribution Costs - Ѣ5,902,261

Table VI-8: Optimum Transportation Pattern for Year 10, Option II

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-6	-	6,461
"	1-14	-	156,290
"	3-7	-	5,867
"	9-12	-	38,416
"	9-15	-	44,673
"	11-15	-	28,789
"	13-15	-	28,321
Rail	2-14	31	34,429
"	3-14	16	21,124
"	4-14	192	135,866
"	4-15	14	12,312
"	5-14	124	138,633
"	8-15	25	32,821
Total Number of Rail Cars Per Year		402	

Percentage of Total Inshipments to Area 14 and 15 Hauled by Rail - 60%

Total Distribution Costs - Ƀ7,494,719

Table VI-9: Optimum Transportation Pattern for Year 15, Option II

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-6	-	6,091
"	1-14	-	186,972
"	3-7	-	2,292
"	9-12	-	35,764
"	9-15	-	63,092
"	10-14	-	213
"	13-15	-	36,378
Rail	2-14	41	45,104
"	3-14	35	45,783
"	4-14	245	173,750
"	4-15	2	1,529
"	5-14	145	161,308
"	8-15	36	47,061
"	11-15	24	37,897
Total Number of Rail Cars Per Year		528	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 64%

Total Distribution Costs - Ь9,415,280

Table VI-10: Optimum Transportation Pattern for Year 20, Option II

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-6	-	5,837
"	1-14	-	218,285
"	9-12	-	33,691
"	9-15	-	81,071
"	10-14	-	5,226
"	13-15	-	44,942
Rail	2-14	53	58,555
"	3-14	57	73,545
"	4-14	290	205,642
"	5-14	165	183,979
"	8-15	48	62,417
"	11-15	30	47,539
Total Number of Rail Cars Per Year		643	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 64%

Total Distribution Costs - Ŀ11,549,524

Areas 2, 3, 4, 5, 8 and 11 are important rail loading locations in year 20. However, area 11 does not rail cattle to area 15 until year 15. Previous to that, cattle were trekked along this route. This change in transportation method occurred because the price of beef increased in area 15 to the point that the large shrinkage and salvage losses from trekking raised the trek costs higher than the rail charges. This is an illustration of the phenomenon that trekking costs increase faster than railing costs as the price in the destination markets increase.

The major treks occur on the routes connecting areas 1 with 14, 9 with 12, and 9 and 13 with 15.

Option III Investment Strategy

Option III consists of instituting a trypanosomiasis control program along with increasing the speed of rail service by 1/5. An unlimited number of rail cars are available for cattle shipment. The interarea flows that result from this strategy are given in Tables V-17 to V-21. The results of applying the linear program to these flows are shown in Tables VI-11 through VI-15.

The number of rail cars demanded increases from 164 in year 0 to 390 in year 20. This represents an increase of about 4.4 percent per year. The percentage of total imports to areas 14 and 15 hauled by rail decreases slightly through time from 47 percent in year 0 to 38 percent in year 20. The percentage of imports arriving by rail to area 14 decline from 57 percent in year 0 to 50 percent in year 20. This decline occurs because exports to area 14 from areas 2 and 3 are trekked and rapidly expand over time. With an effective trypanosomiasis control program, these routes can be utilized at lower costs by trekking

Table VI-11: Optimum Transportation Pattern for Year 0, Option III

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	-	115,507
"	2-14	-	16,272
"	4-12	-	15,712
"	5-7	-	9,581
"	8-6	-	5,123
"	8-12	-	6,421
"	9-12	-	1,629
"	9-15	-	54,963
"	11-15	-	14,557
"	13-12	-	17,414
Rail	4-10	1	838
"	4-14	99	85,251
"	5-14	64	90,055
Total Number of Rail Cars Per Year		164	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 47%

Total Distribution Costs - Ł3,896,231

Table VI-12: Optimum Transportation Pattern for Year 5, Option III

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	-	145,993
"	2-14	-	28,859
"	3-6	-	4,928
"	3-7	-	7,371
"	3-14	-	2,274
"	8-15	-	24,551
"	9-12	-	17,783
"	9-15	-	54,188
"	11-15	-	22,889
"	13-12	-	25,085
Rail	4-14	124	107,136
"	4-15	24	25,254
"	5-14	86	121,434
Total Number of Rail Cars Per Year		234	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 48%

Total Distribution Costs - Ƀ5,182,618

Table VI-13: Optimum Transportation Pattern for Year 10, Option III

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	-	180,473
"	2-14	-	37,622
"	3-6	-	4,200
"	3-7	-	4,521
"	3-14	-	24,529
"	8-15	-	37,013
"	9-12	-	10,077
"	9-15	-	77,802
"	11-15	-	31,403
"	13-12	-	32,469
Rail	4-14	163	141,046
"	4-15	17	17,184
"	5-14	100	141,544
Total Number of Rail Cars Per Year		280	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 44%

Total Distribution Costs - Ŀ6,622,113

Table VI-14: Optimum Transportation Pattern for Year 15, Option III

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	-	212,562
"	2-14	-	52,723
"	3-6	-	3,067
"	3-7	-	330
"	3-14	-	54,066
"	8-15	-	53,075
"	9-15	-	105,870
"	11-15	-	41,985
"	13-12	-	39,635
"	13-15	-	4,444
Rail	4-14	213	185,029
"	4-15	3	2,136
"	5-14	116	164,724
Total Number of Rail Cars Per Year		332	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 40%

Total Distribution Costs - Ŀ8,316,539

Table VI-15: Optimum Transportation Pattern for Year 20, Option III

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	-	251,229
"	2-14	-	70,032
"	3-14	-	89,763
"	8-6	-	1,218
"	8-15	-	68,375
"	9-15	-	123,253
"	11-15	-	52,880
"	13-12	-	40,240
"	13-15	-	13,036
Rail	4-14	246	213,455
"	4-15	10	10,572
"	5-14	134	190,378
Total Number of Rail Cars Per Year		390	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 38%

Total Distribution Costs - Ŀ10,280,065

rather than rail hauling. The long routes connecting areas 4 and 5 with area 14 utilize rail cars for cattle shipments. All cattle arriving in area 15 from areas 8, 9, 11 and 13 are trekked while the cattle originating from area 4 are railed. The percentage of total inshipments to area 15 carried by rail cars declines from 20 percent in year 5 to only 4 percent in year 20.

Under option III, the number of cattle using trek routes increases substantially through time. The routes connecting area 1 with 14 and 9 and 13 with 15 will be required to accommodate a large number of cattle as was also the case for options I and II. However, because trek costs have been reduced, additional trek routes become important. The cattle produced in areas 2 and 3 to be exported to area 14 utilize trek routes as do the cattle moving from areas 8 and 11 to area 15.

It is apparent from these results that the number of cattle utilizing trek routes will increase if an effective program for controlling trypanosomiasis is implemented. If this program is to be effective, substantial investments will need to be made to furnish adequate feed and water for the cattle being trekked so that the savings in reducing disease losses are not lost to shrinkage from inadequate nutrition provision along the routes.

Comparison of the Three Policy Options

Comparative cost information for the three strategies is given in Table VI-16. The distribution cost per head is the average cost of transporting and slaughtering an animal that enters interarea trade. Under all three options, the cost increases through time because prices in general are rising. The average cost of distribution is slightly higher for option II relative to I because the cattle are transported

Table VI-16: Distribution Costs Through Time for Three Transportation Investment Options

Year	Option I			Option II			Option III		
	Inter-area trade	Total Distribution Cost	Distribution Cost Per Head	Interarea Trade	Total Distribution Cost	Distribution Cost Per Head	Interarea Trade	Total Distribution Cost	Distribution Cost Per Head
	(No. of cattle)	(Ŀ)	(Ŀ)	(No. of cattle)	(Ŀ)	(Ŀ)	(No. of cattle)	(Ŀ)	(Ŀ)
0	390,808	3,525,881	9.0	399,940	3,712,636	9.2	433,323	3,269,554	7.6
5	526,800	4,922,895	9.3	542,461	5,247,047	9.6	587,745	4,558,914	7.8
10	655,603	6,405,852	9.8	684,002	6,841,704	10.0	739,883	6,006,084	8.1
15	800,919	8,132,992	10.2	843,234	8,775,752	10.4	920,646	7,725,820	8.4
20	955,229	10,043,959	10.5	1,020,729	10,944,417	10.7	1,124,431	9,744,835	8.7

over longer distances. The availability of rail cars makes shipment over longer routes relatively more attractive than trekking over shorter routes. This encourages more production in the far northern areas which results in slightly higher transportation charges. The average distribution cost per head is significantly lower for option III relative to options I or II. The difference amounts to a reduction of about 18%. This decrease can be contributed to the reduction in trek and rail costs due to trypanosomiasis control and increased speed of rail service. Relative to option I, option III handles 15 percent more cattle in interarea trade at a reduction of 18 percent in average cost per head. Under option III, 9 percent more cattle enter interarea trade at a reduction of 18% average cost per head relative to option II.

Rail car requirements and percentage hauled by rail for the three options appear in Table IV-17. The percentage of total inshipments hauled by rail to area 14 is greater than area 15 for all three options. For reasons already stated, the locations supplying area 14 can utilize rail cars for shipment more effectively than the locations supplying area 15. If strategy II were implemented, 643 rail cars would be required in year 20. This represents an increase in rail car numbers of 5.7 percent per year over the present number of 212. Option III would require 390 rail cars in year 20--an increase of about 3.1 percent per year over 212. The decrease in trekking costs due to the control of trypanosomiasis is responsible for lower requirement of rail cars for option III relative to option II. It appears that

Table VI-17: Rail Car Requirements Through Time for Three Transportation Investment Options

Year	Option I			Option II			Option III		
	Rail Cars	Percentage of Imports to Area 14 Hauled by Rail	Percentage of Imports to Area 15 Hauled by Rail	Rail Cars	Percentage of Imports to Area 14 Hauled by Rail	Percentage of Imports to Area 15 Hauled by Rail	Rail Cars	Percentage of Imports to Area 14 Hauled by Rail	Percentage of Imports to Area 15 Hauled by Rail
	No.	%	%	No.	%	%	No.	%	%
0	174	51	2	227	64	33	164	57	0
5	236	53	41	318	66	38	234	56	20
10	272	48	28	402	68	31	280	54	11
15	302	49	14	528	69	46	332	52	2
20	332	49	4	643	70	47	390	50	4

implementation of a trypanosomiasis control program will significantly reduce the number of rail cars that must be purchased to accomodate the rapid increase in the number of cattle that will be moving to areas 14 and 15 in the next 20 years.

Summary of Results and Conclusions

This section provides a summary of the major findings and conclusions of this study. More detailed reporting of results is contained in the last parts of Chapters III, IV, V and the first section of this chapter.

Specification of Distribution Costs--TRNSCST

This model component was developed to identify the transportation costs of alternative methods of shipment between each pair of the 15 areas that were delineated for Nigeria. Trek movement and truck and rail hauling were the methods of transportation considered. Major cost categories were quantified for each shipment method over all the routes.

In general, truck shipment was the most expensive method of transporting live cattle. The primary reason for this was the high freight charges levied by truck owners--over 2 1/2 times the freight charges of rail service (see Tables III-10 through III-17). A major cause of high freight charges is the frequent occurrence of accidents due to heavy traffic on relative poor roads, poor mechanical condition and overloading of trucks, and driver stress from driving too long without rest. The survey of truck transportation costs (see Appendix I) indicated that the hauling time for lorries was about the same as for rail hauling. Over 1/2 of the drivers surveyed indicated that the cattle they were hauling showed severe road stress on trips between

Kano and Katsina to Ibadan and Lagos. Truck shipment does give cattle dealers an opportunity to react quickly to favorable price conditions in the southern markets. Higher quality cattle that can not withstand the rigors of trekking and for some reason can not get rail permits are often moved by truck. The drivers surveyed indicated that no stops were made and no feed or water given on the 3 to 4 day trips to the south. The questionnaire and results of the survey are given in Appendix I. Although truck shipment is the most expensive method considered in this study, future investments in improving the road structure in Nigeria might reduce these costs substantially. Present Nigerian development plans call for substantial investments in highway construction and improvement. If these investments are successfully completed, road conditions, turnaround time, and accident rates might be improved substantially. These improved conditions would probably be reflected in lower freight charges being levied by lorry owners. If adequate feed and water provision could be combined with these improved conditions, lorry transport of cattle may become very competitive with rail and trek methods, especially for higher quality cattle.

The major cost categories for rail shipment are shrinkage costs (44 percent) and freight charges (41 percent) (see Tables III-10 through III-17). The large shrinkage losses occurred because of the long time period on the rail cars (3 days to go 700 miles) and inadequate provision of feed and water for the cattle during that period. In general, rail shipment provides the least cost method of moving cattle from northern producing regions to southern consuming regions. The results show that for distances of 250 miles or greater, rail shipment is cheaper than trekking, especially if cattle are to be moved through tsetse infested areas. However, the distances between some important locations are much longer for rail travel than trekking. This is true for movement between many areas in the north since the rail lines are oriented to north-south travel. In addition, the costs of rail shipment between area 1 and 14 is higher than trekking costs because of the shorter trek distance as compared to rail mileage. No rail service is available for areas 9 and 13 (see Figure 10). Other than these exceptions, rail transport from northern excess supply regions to southern excess demand areas is less expensive than trekking.

If shrinkage losses could be reduced during rail shipment, this method of transportation would be especially attractive to dealers moving higher quality cattle. Reducing shrinkage on rail trips would entail provision of feed and water along the way and/or increasing the speed of rail service. Results of this study show that by increasing the speed of rail service by 1/5, the costs of rail shipments decreased by only 6.5 percent. It seems that feed and water must be provided with increased rail speed if significant reductions are to be realized in rail transportation costs. If these factors can be successfully implemented and adequate rail car numbers can be provided, rail service should be of increasing importance in beef distribution in the future as the quantity and quality of cattle to be marketed increases.

The major cost categories for trekking are salvage losses (11 percent) shrinkage costs (47 percent), drovers' fees (13 percent) and feed and water costs (12 percent). The shrinkage and salvage losses are mainly attributable to diseases and injuries contacted along the trek routes with trypanosomiasis being the major cause of these losses.

In general, trekking cattle is the most efficient method of moving cattle among areas in the northern tsetse free regions. It is also the most efficient method of transporting cattle from area 1 to 14 and areas 9 and 13 to area 15. These are important routes for cattle moving south. Therefore, even with no trypanosomiasis control program and an unlimited number of rail cars, trekking will continue to be an important method for moving range cattle to the southern consuming regions.

Data from limited research trials indicate that losses from this disease can be substantially curtailed. The results from these trials were mixed, but a conservative estimate is that salvage, shrinkage, and mortality losses could be reduced by 1/2 by controlling trypanosomiasis on the trek routes. If this occurred, trek costs could be reduced by 40 percent (see Tables III-18 and III-19). These preliminary estimates indicate that investments in a trypanosomiasis control program should be investigated thoroughly. However, even with a program to control trypanosomiasis, the losses from trekking higher quality cattle for several weeks will be very high. Therefore, if the quality of market cattle in Nigeria is to be broadly improved, alternatives to trekking must be developed.

Using estimates gathered for this model component, shrinkage and death losses were calculated for cattle moving to areas 14 and 15 over the 1954-1963 decade. It was estimated that 144,835 tons of live weight was lost from shrinkage and death in the railing and trekking of cattle over this decade (see Table III-23). While the proportion of cattle trekked to the south over these years was slightly less than 50 percent, trekking accounted for 57 percent of the total pounds lost.

Assuming an animal weighs 700 pounds, the total pounds lost over the 10 years is equivalent to 423,138 cattle which is over 42,000 cattle equivalents per year. The total pounds lost due to shrinkage and death was about 13 percent of the total pounds marketed. Each of the three methods discussed entail large losses due to shrinkage, death, and salvage of the animals as they are moved over long distances. Adequate feed and water provision must be provided if these losses are to be reduced and the transportation system is to contribute to increasing the quality and quantity of cattle to be marketed in Nigeria.

Additional detailed results and parameter and functional relationship estimates are contained in the tables and text of Chapter III. The interested reader is directed there for this additional information which is not included in this summary.

Optimum Transportation Patterns

The transportation pattern component utilizes the linear program technique to calculate the least cost organization of slaughter and transportation facilities. The quantity demanded and supplied in each of the 15 areas and the transportation costs of alternative methods of shipment are exogenous variables to this component. Eight model experiments were run to determine the consequences of using alternative assumptions and implementing various policies.

No truck shipments of live cattle or frozen carcasses occurred in any optimum distribution result. For live cattle shipment, rail hauling is cheaper relative to truck hauling over longer distance while trekking is less costly for shorter distances. Frozen meat shipment is more economical on refrigerated rail cars than refrigerated trucks. However, future planned investments in the road network in Nigeria might influence these results somewhat. This model framework is flexible enough to account for these changes. A discussion of how they might be included is given later in this chapter.

In general, the optimum transportation configuration is to rail cattle from the large excess supply regions of 2, 3, 4, 5 and i to the two southern excess demand areas and trek cattle from areas 1, 9, 11 and 13 to areas 12, 14 and 15. However, given the estimated number of cattle to be moved, the present number of rail cars (212) is inadequate especially during the rainy season when the cattle are farther north. The model results show that under present conditions about 230 rail cars could be effectively utilized--an increase of over 8 percent over the present number. Therefore, one way to improve the beef distribution system would be to increase the number of rail cars that could be utilized for cattle shipment.

The major trek routes utilized in the optimum solution are the ones connecting area 1 with 14, 9 with 15, and 11 and 13 with area 12 (see Tables IV-7 and IV-8). Since these routes are heavily used for treks, they would be the most productive locations for programs that control trypanosomiasis and provide additional feed and water.

A model experiment was conducted that assumed the speed of rail service could be increased by 20 percent. As noted in the TRNSCST component discussion, this reduces the shrinkage in transit and hence reduces rail costs. This increased efficiency in turnaround times had two primary effects on the demand for rail cars--one partially off setting the other. First, with faster turnaround times, one rail car could transport more cattle than previously, thus reducing the number of cars needed to haul a given quantity of cattle. Secondly, the increased speed reduced railing costs which made rail transport more attractive relative to trekking. The results show that the second effect outweighed the first. The number of rail cars demanded increased to 250 under this assumption. This represents an increase of 15 percent over the number of rail cars at the present time. Therefore, to take advantage of any improvement in rail service, additional rail cars must be provided. The total slaughter and transportation cost was reduced by 3.5 percent as a result of the improved rail service. However, there were still substantial numbers of cattle trekked to areas 14 and 15 (over 1/4 of the total inshipments). It seems that certain trek routes will be heavily utilized by trade cattle even if rail service is improved.

An additional model experiment was run assuming an effective trypanosomiasis control program was implemented for cattle walking through tsetse-infested areas. As can be seen in Table IV-9, this program had a significant effect on the optimum transportation configuration. No cattle were shipped by rail in the dry season. This means that the number of cattle utilizing the trek routes doubled relative to the number of cattle trekked with no disease control program. This would probably place a severe strain on the water and feed resources along the established trek routes. If these resources became depleted, the shrinkage, salvage and death losses due to inadequate nutrition might eliminate the original cost savings realized from the program. It is important that any trypanosomiasis control program be supported by plans to increase the availability of feed and water along the trek routes.

Assuming that adequate nutrition could be furnished, the savings in distribution costs due to the trypanosomiasis control program would be ₦944,000--a 20 percent reduction. These cost savings would need to be compared with the costs of implementing the program and providing more nutrition to judge its profitability. This calculation should also include the opportunity costs of funds that could be invested in other programs. A trypanosomiasis control program does appear to be a prospective action worthy of immediate consideration. It may likely be a method of reducing shrinkage and salvage losses quickly on the type of trade cattle marketed in Nigeria at the present time. However, other transportation methods will need to be utilized to enable the transportation system to accommodate higher quality cattle that are being and will be produced in the future.

Further model runs were conducted assuming the demand for beef in areas 14 and 15 could be satisfied by either live cattle shipment to the south and subsequent slaughter or by slaughter in other areas and the meat shipped to these areas in the south. The results showed that where meat shipment can be accomplished on refrigerated rail cars, the total slaughter and transportation charge is less than by walking or railing live animals to the south and then slaughtering them. However, if the meat must be moved by truck, it is cheaper to ship live cattle. The advantage of the carcass distribution system is in the transportation phase. For this reason, the most efficient locations for the abattoirs processing carcasses are in the excess supply regions of the north. Abattoirs in Maiduguri, Nguru and Kano represent the most efficient locations respectively. The abattoirs in Bauchi and Kaduna are also in the solution. However, no carcasses are shipped from the slaughter house at Sokoto because it is not served by the rail line and truck shipment is more expensive than trekking. The costs of distributing the meat to southern consumers after it has reached its destination is probably higher for frozen carcass shipment than the live cattle transporation methods. Therefore, the total cost of distribution from the northern producer to the southern consumer may not be lower for frozen meat shipment than for live animal shipment. Before frozen carcass processing becomes a major alternative distribution method, more facilities will need to be available to the meat dealers throughout the rural towns as well as the large urban centers. However, frozen meat shipment is superior in terms of the sanitation of meat handling and it does appear to be able to compete cost wise with live cattle shipment in urban areas where facilities are available to process the meat. Much more research is needed on the dependability of refrigerated rail shipment and costs of providing and operating the supporting facilities before this hypothesis can be accurately tested.

A much more detailed account of the results of the eight model trail runs is contained in the text and tables of Chapter IV.

Spatial Equilibrium Flows of Beef Through Time

This model component calculated through time the (1) competitive equilibrium price in each area, (2) number of cattle supplied and demanded in each area, (3) the level of exports and imports among locations for three alternative investment options in transportation of beef. The three investment options are: I. - a policy that closely parallels the present one of furnishing fewer rail cars than can be used and providing no program to control trypanosomiasis, II. - providing as many rail cars as needed but furnishing no protection against disease on the trek routes, and III. - implementation of an effective program to control trypanosomiasis and reducing the turnaround time of rail cars between points by one-fifth. This component was run at 5 year intervals through 20 years of simulated time with demand and supply functions that were constructed for each area through time. The demand functions changed through time according to assumptions about the changes in population and incomes in these areas. After the interarea shipments were determined through time, the transportation linear program was run to find the requirements placed on the transportation system by the three investment options to accommodate these flows. The results of these two steps are integrated and summarized together in this section.

The results of the spatial equilibrium model indicate that the proportion of total cattle marketed that go to areas 14 and 15 is going to increase through time irregardless of the investment strategy followed in the transportation of beef (see Table V-5). In year 0, 39 percent of the total cattle marketed move to areas 14 and 15 under option I, 40 percent for option II, and 43 percent for option III. These percentages increase in year 20 to 63 for I, 67 for II, and 77 for option III. The number of cattle moving to the two southern areas increases approximately 2.8 times in the 20 year period. This is an increase of approximately 5.3 percent per year. The method by which these cattle are transported depends on the investment strategy implemented. If rail car numbers are limited to a growth of 2.2 percent per year (option I) the proportion of cattle arriving by rail will decline from 42 percent in year 0 to 36 percent in year 20. If an adequate number of rail cars are furnished (option II), the percentage of imports to areas 14 and 15 hauled by rail will increase from 59 percent in year 0 to 64 percent in year 20. Under this policy, 643 rail cars will be required in year 20. This represents an increase of 5.7 percent per year in rail car numbers over what is now available. However, if a successful trypanosomiasis control program can be implemented (option III), the required number of rail cars for use in shipment to areas 14 and 15 can be reduced to 390 in year 20. To reach this number, rail car numbers would have to be increased only 3.1 percent per year. Under option III, 1,082,923 cattle are provided to areas 14 and 15 at an average price of Ƅ34 per head in year 20. For option I, the number of cattle imported to areas 14 and 15 in year 20 is 896,591 at a price of Ƅ37 per head. Therefore, in year 20, 20 percent more cattle arrive in areas 14 and 15 at a 9 percent lower price under option III relative to option I.

As shown in Table VI-17, under options I and III in year 20, approximately 50 percent of the cattle arriving in area 14 will be trekked while almost all of the cattle moving to area 15 will utilize the trek routes. Even assuming option II is implemented, 30 percent of area 14's imports will utilize the trek routes and 50 percent of the imports to area 15 will be trekked. Therefore, policies to improve trek routes will be important considerations in all investment plans for the beef distribution system.

Appendix Figures III-16 to III-19 show that areas 1, 2, 3, 4, 5, 8, 9, 11 and 13 actually retain fewer cattle for internal consumption through time. As transfer charges are lowered (especially option III) and demands increase rapidly in areas 14 and 15, more cattle are diverted from local markets and exported to the southern areas. This tends to increase local prices and hence decreases quantities demanded within these areas. This phenomenon occurs under all three options but to a greater extent for option III. Therefore, if interarea transfer charges are lowered significantly, many northern areas in Nigeria may face a declining number of market cattle for consumption within the area.

The estimated total receipts from beef sales generated under option III would be about ₦11,500,000 more than the total received by the beef industry under option I. The beef industry would gain an average of ₦575,000 per year in total receipts for 20 years from investments to control trypanosomiasis and furnish adequate numbers of rail cars. However, the increases in total receipts are not shared equally by all areas for all investment options. All areas had higher receipts under investment option III, after marketing charges were subtracted than if option I had been followed (see Table V-22). However, if an adequate number of rail cars had been furnished, but no disease control program implemented, (option II), areas 1 and 2 would have lower total net receipts in year 20 then would be received under option I. With an increase in rail cars, areas 4 and 5 shipped cattle to area 14 at the expense of cattle from areas 1 and 2.

Table VI-16 gives the average distribution cost per head for all the cattle moving in interarea trade under all investment options. In year 20, the average cost per head for options I, II and III is ₦10.5, ₦10.7 and ₦8.7 respectively. The cost per head under option III is approximately 15 percent less than for either option I or II.

Because of the rapid increase in population of the southern areas in Nigeria, demand for beef in these locations will probably expand more rapidly than in other areas. Therefore, the limited funds available for investment in beef distribution should be allocated to programs that are concerned with movement of beef from the northern excess supply areas to the southern excess demand locations. It appears that furnishing more rail cars through time along with a trypanosomiasis control program and better provision of feed and water on treks and rail cars are potentially productive investments for improving the distribution of these cattle to the southern areas. As previously stated, the investments made by Nigeria in their transportation sector will influence the kinds of investments that will need to be made in beef distribution. It is apparent that improvements in shrinkage losses and transit times are necessary for rail hauling, truck hauling and meat shipment if higher quality cattle are going to be furnished to southern consumers at prices that they can pay.

<u>Other Uses of the Model</u>

The model framework was developed so that it would be sufficiently flexible to help evaluate the consequences of several changes that might occur and investment plans that might be envisioned. This section will discuss possible uses of the model that were not explicitly considered in this study.

Future investments in the transportation sector of Nigeria will probably have an affect on the beef transportation system. The present Nigerian development plan places heavy emphasis on investment in road construction and improvement. If these investments are made, the competitive position of truck shipment of cattle may change. The

TRNSCST component can be utilized to calculate the changes in the cost of hauling cattle by truck resulting from these investments. If road mileage between areas change, the new mileages can be entered in the road mileage array given in Table III-2. Improved road conditions would probably change the freight charge levied by truck owners. This parameter, appearing in equation 21 in Chapter III, could be adjusted accordingly. The increased speed of transit by truck could be reflected by adjusting the parameters in equation 24 in Chapter III. Investments in providing more feed and water to animals traveling by truck could be analyzed by changing the independent values of the shrinkage function shown in Figure 7.

If investments were made in extending rail lines or improving the speed of rail services, similar changes could be made in the parameters of the equations calculating rail costs. If mileages were affected, the entries in the rail mileage matrix should be adjusted (see Table III-6) along with the turnaround times in Table III-7. Investments that might be made to decrease shrinkage losses on rail hauling could be reflected by adjusting the parameters in the shrinkage function given in Figure 7.

An explanation of how investments in trypanosomiasis control for trekking cattle could be included are given in Chapter III since this was a policy that was considered in this study.

Once these new costs of distribution have been calculated by the TRNSCST component, they could be processed through the whole model structure through time as described at the beginning of this chapter.

The transhipment linear program component discussed in Chapter IV can help evaluate a number of important issues. This component is

constructed so the optimum location, output level and number of modern abattoirs can be determined given the demand for "cold" meat and the unit costs of operation at various levels of output. The explanation of this procedure is given in Logan and King {24,p.145}. As more markets for "cold" meat develop in Nigeria, the optimum location of the abattoirs and shipment routes and methods can be ascertained. This could be done by adding extra equations for the location of the "cold" meat demand and adding extra activities for the shipment of the processed meat to these locations in the same way as was done for the "cold" meat demand in areas 14 and 15 (see Table IV-1).

The effects of location specific investments in certain trek, rail or truck routes on the configuration of transporation methods could be evaluated by adjusting the costs along these specific routes (derived from TRNSCST) in the objective function. These kinds of investments may have to be implemented if funds are inadequate for investments along all routes.

The linear program component was constructed so that the method of shipment utilized for a group of cattle could be changed at locations between the point of origin and destination. For example, it is possible in this component for cattle going from Maiduguri to Ibadan to be trekked to Zaria and railed on to Ibadan. This feature allows one to investigate the pattern of transportation that might result if only portions of a route were improved for some method of shipment.

The spatial equilibrium component could be used to evaluate changes in conditions or policies affecting the supply and demand for beef. As more information about beef demand becomes available, the parameters in the demand equation should be improved. If it becomes apparent that there are basic differences in tastes or customs among areas relating to beef consumptions, the demand curves in the areas could be adjusted accordingly. Differences in the price and availabilities of close substitutes for beef in the areas could be reflected in the demand functions. The effects of uneven interarea per capita income growth could be reflected by varying the extent the demand curves are shifted through time within the areas.

Another potentially valuable use of this model would result in combining it with the simulation model of Nigerian beef production discussed briefly at the end of Chapter II. This simulation model determines the quantity of cattle supplied through time as a function of available nutrition and policies aimed at improving the environment faced by the Nigerian cattle producers. By integrating these two models, the interactions of policies aimed at either production or distribution of beef could be evaluated. For example, the production model can estimate the shifts in location of beef production from changes in available grazing land and range deterioration. This shifting of beef production has important consequences on the distribution system requirements. On the other hand, the investments in transportation facilities in beef would affect the incentive for producing higher quality animals and the investments that might be made to support this incentive. These are just two examples of the potential usefulness that an integration of these two models might have.

Another important aspect of the supply of beef in Nigeria is the importation of cattle from Niger, Chad and the Cameroons. Changes in these import supplies could be reflected in adjusting the supply functions of the areas bordering these countries.

In general, this model framework can assist in evaluating many changes in conditions and investments that might occur through time. However, to insure proper adjustments are made, the user must be familiar with the assumptions and techniques used in the framework as well as the procedures involved in integrating the three components. Additionally to be of use in helping to solve real problems, the user should be closely coordinated with the policymakers involved in making decisions relating to beef distribution.

Major Research Needs

One useful result of the process of building and specifying an integrated model of beef distribution in Nigeria is that it facilitates the identification of areas that need further research. This section provides a description of research problems that are important to understanding the beef distribution system and how it might be improved. Unfortunately, most of these problems do not fall neatly into any one academic discipline but rather require insights from several. Additionally, proper identification of problems and research priorities will require coordination with public and private institutions involved with the beef industry in Nigeria. Therefore, successful research studies will require cooperation among different disciplines and between decision makers and researchers.

More information is needed on the costs of the alternative methods of shipment. This is true of all the methods considered in this study. It would be useful to observe several actual treks on various routes during alternating seasons so that better estimates could be obtained on shrinkage, salvage, and death losses as well as availability and expenditures on supplementary feed and water. Weighings at intermediate points along the routes would give valuable information about the relationship between trek days and weight loss. It would be useful to record slaughter weights so that the relationship between live weight loss and actual tissue shrinkage could be obtained. This would involve slaughtering a control group at the point of departure. It would be important that the type of cattle and trek procedures be as representative of actual trek conditions as possible.

The same kind of research is needed to accurately specify the results of treating trek cattle for trypanosomiasis. The administrative and operating costs of a trypanosomiasis program should also be specified so that benefits and costs can be compared.

For rail hauling, information is badly needed on live weight shrinkage of cattle as a function of days in transit. The relationship between this live weight shrinkage and actual tissue loss for varying transit times is crucial. Is the shrinkage a loss of fill or actual tissue reduction? The effects on live weight and tissue shrinkage of feed and water provision on rail cars is also important. Perhaps tissue loss could be restored efficiently by feeding programs at the destinations market. These same types of questions need to be investigated for truck shipment as well.

Much more research is needed on processing and transporting meat from the north to the south. The unit costs of slaughter and processing meat at the abattoirs for varying levels of output would be useful. With this kind of information, the model component described in Chapter IV could determine the optimum location and level of output for the abattoirs processing meat for shipment to the south as well as the least cost transportation configuration. The experience of the firms now processing and shipping "cold" meat should be carefully reviewed in terms of the capital and operating costs involved in operating this kind of activity. Methods developed by Logan and King provides a useful framework for this type of study {24}.

Projects need to be instituted to identify consumer preferences toward consumption of both "hot" and "cold" meat. Is the lack of demand for "cold" meat a result of a lack of retail outlets available to the average Nigerian consumer? Would he consume "cold" meat if it were available at prices comparable with the traditionally processed meat? Why does he differentiate between the two? These and similar questions should be answered before any large investments are made in processing and shipping cold meat for consumption by people other than relatively wealthy foreigners and Nigerians.

Additional study needs to be done on the factors that affect the demand for beef. Improved estimates of price and income elasticities should be obtained. Identification of substitutes for meat along with the effect that changes in their prices and quantities available have on meat consumption is important. Since Nigeria is composed of many diverse cultures, demand studies in various areas would be useful.

One of the most important areas that needs further study relates to the supply of market cattle. The Fulani herdsmen are often characterized as economically irrational managers seeking status and wealth by accumulating cattle. What kind of supply response might be expected as prices for cattle increase in the future? This question is very complex as it relates to production conditions and decision processes of Fulani herdsmen. The total agricultural system of northern Nigeria is involved in this matter. Since the majority of market cattle are produced on residual land not yet cultivated, the increase in crop land area is a crucial variable in determining the amount of land available for grazing and hence the total herd size. Estimation of supply response must also consider the costs of producing the cattle. The acquisition price of an additional acre of grazing land is probably very low for the individual Fulani. However, it must be considerably higher for the whole set of beef producers. Under present property right rules, the individual beef producer has very little incentive to conserve the capital inherent in the grazing lands. The acquisition price for additional grazing land is very low and the salvage value is zero. Therefore, the deterioration of this capital embodied in the grazing areas from over grazing is considerable and must be an important variable in determining long term supply response. The relationship between transportation methods available and the age and quality of cattle is also involved. If the rigors of transporting an animal 800 miles in Nigeria were substantially reduced, would younger, higher quality cattle be marketed? Improved transportation methods must be developed if large numbers of higher quality cattle are to be available to the large number of consumers in the southern areas at prices they are willing to pay.

It is apparent from this discussion that many of the parameters and relationships used in this study are inaccurately known. Therefore, the results are not to be taken as highly accurate and final.

However, the attempt at gathering available information and "guesstimates" into an integrated model helps to provide a starting point for assisting decision-makers to develop wise policies in relation to the beef distribution system in Nigeria. The model cannot accurately predict the consequences in the future of alternative policies. But, policy decisions are being made and funds are being invested. If the model can provide a framework for organizing the best information available in a systematic way, and provide a vehicle for cooperation of researchers and policymakers, it can make a valuable contribution to improving the performance of the beef distribution system in Nigeria.

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APPENDICES

APPENDIX I

SURVEY ON COSTS OF HAULING CATTLE BY TRUCK

Since little was known about costs of transporting cattle by truck in Nigeria, a survey was implemented to fill this data gap. This survey was a cooperative effort by Dr. S. O. Olayide, Department of Agricultural Economics, University of Ibadan; Dr. Dupe Olatunbosun, Nigerian Institute of Social and Economic Research, University of Ibadan; and Earl Kellogg, Department of Agricultural Economics, Michigan State University. The information was gathered in June 1969 outside Ibadan, Nigeria on the main highway from the northern section of the country. A total of 30 different truck drivers were interviewed while they stopped at the military check point outside Ibadan. The questionnaire used on the survey is given in Appendix Table I-1.

The results of the survey are summarized in Appendix Table I-2. On the average, it takes 3.5 days to travel between both Kano and Katsina to Lagos (a 720 mile trip). The number of cattle hauled on the 5 ton trucks was about 13. The average for the 15 ton trucks was about 23 cattle. The average freight charge per animal on the 5 ton lorries was approximately ₤9 per animal on the Katsina-Kano to Lagos trips. The average freight charges on the 15 ton lorries was a little cheaper being about ₤8.5 per animal. Of the 27 drivers that answered, 15 indicated that the cattle they were hauling exhibited severe road stress. None of the drivers said that they stopped to feed or water the cattle on the 3 day trips. Twenty-five of the twenty-seven drivers that answered, indicated the cattle they were hauling were owned by northern cattle dealers and were to be delivered to these dealers' selling agents in the south.

Appendix Table I-1: Survey Questionaire For Truck Hauling Costs

NIGERIAN INSTITUTE OF SOCIAL AND ECONOMIC RESEARCH,
UNIVERSITY OF IBADAN.
and
DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION,
UNIVERSITY OF IBADAN.
and
DEPARTMENT OF AGRICULTURAL ECONOMICS
MICHIGAN STATE UNIVERSITY, U.S.A.

Economics of Cattle Movement

Questionnaire on Truck Movement

A. General Information

1. Plate No. of Vehicle ____________________
2. Size of Lorry (5, 15-ton, etc.) ____________________
3. Day of Interview ____________________
4. Time of Interview ____________________
5. Driving experience of driver (yrs.) ____________________
6. Number of cattle in lorry (count) ____________________

B. Specific Questions

1. Where did the journey start from? ____________________
2. On what date did it start? ____________________
3. At what time of the day? ____________________
4. How many cattle were then loaded? ____________________
5. Were there any pick-ups en-route (Yes/No)? ____________________
6. If YES, how many? (i)__________ where__________

   (ii)__________ where__________

   (iii)__________ where__________

   (iv)__________ where__________

7. Were there any off-loading en-route (Yes/No)? ________________

8. If Yes, how many? (i) ____________ where ____________________

(ii) ____________ where ____________________

(iii) ____________ where ____________________

(iv) ____________ where ____________________

9. How long has the trip taken now? ______________________________

10. What is your destination? ____________________________________

11. How long do you think it will take to get there from here? ____

12. Normally how long has the journey taken you on previous occasions? ____

C. Livestock Condition

1. Did you have any difficulties with the animals en-route (Yes/No) ______________________________________

2. If Yes, what form? (i) Sickness __________________

(ii) Heat ______________________

(iii) Road Stress ________________

(iv) Water ______________________

(v) Feed _______________________

(vi) Others _____________________

3. How many stops were made as a result of these and where?

(i) ______________________ where ________________________

(ii) ______________________ where ________________________

(iii) ______________________ where ________________________

(iv) ______________________ where ________________________

(v) ______________________ where ________________________

4. How long was the delay in performing the services of?

(i) Feeding (a)________________ where________________

(b)________________ where________________

(c)________________ where________________

(d)________________ where________________

(ii) Watering (a)________________ where________________

(b)________________ where________________

(c)________________ where________________

(d)________________ where________________

5. How many animals die enroute?________________________________

6. What do you think the conditions of the remaining stock are now?

(i) Excellent ________________

(ii) Good ________________

(iii) Fair ________________

(iv) Bad ________________

(v) Very Poor ________________

D. Cost of Transportation

1. Who owns the cattle? (i) Dealer____________________________

(ii) Agent____________________________

(iii) Association____________________________

2. To whom do you deliver? (i) Agent in cattle market______________

(ii) Association____________________________

(iii) Dealers in cattle market____________

(iv) Private Butchers____________________

3. Is the lorry on hire (Yes/No)________________________________

4. If so what is normal charge________________________________

5. If not what are your needs for the journey?

(i) gasoline____________________gallons @______________m.p.g.

(ii) engine oil__________________gallons

(iii) daily stipend of driver__________________________________

(iv) daily stipend of driver's apprentice_____________________

6. How do you base your charges on cattle movement

(i) ₦ _______________________per load.

(ii) ₦ _______________________per head of cattle.

(iii) ₦ _______________________load excluding petrol and other expenses.

Appendix Table I-2: Results of Survey on Hauling Cattle by Truck

Size of Truck (In Tons)	Route	Time of Trip (In Days)	Number of Cattle on Truck	Total Cost per Truck (£)	Cost Per Animal (£)	Road Stress Indicated?
5	Kano to Lagos	3.5	10	90	9	Yes
"	" " "	3.5	10	80	8	No
"	" " "	3.5	14	110	8	No
"	" " "	3.5	14	150	10.7	No
"	" " "	3.5	14	150	10.7	No
"	" " "	3.5	12	108	9	No
"	" " "	3.5	12	108	9	Yes
"	" " "	3.5	14	126	9	Yes
"	" " "	3.5	14	126	9	No
"	Katsina to Lagos	3.5	12	126	9	Yes
"	" " "	3.5	14	140	10	Yes
"	" " "	3.5	12	108	9	Yes
"	Kano to Ibadan	3.0	14	126	9	No
15	Kano to Lagos	3.5	22	198	9	No
"	" " "	3.5	24	216	9	Yes
"	" " "	3.5	24	180	7.5	Yes
"	" " "	3.5	22	198	9	Yes
"	" " "	3.5	24	198	9	No
"	" " "	3.5	24	198	9	Yes
"	Katsina to Lagos	3.5	22	175	8	Yes
"	" " "	3.5	16	120	8	Yes
"	" " "	3.5	25	175	7	Yes

Table I-2 continued--

Size of Truck (In Tons)	Route	Time of Trip (In Days)	Number of Cattle on Truck	Total Cost per Truck (£)	Cost Per Animal (£)	Road Stress Indicated?
15	Katsina to Lagos	3.5	24	200	8.3	Yes
"	" " "	3.5	24	180	7.5	No
"	" " "	3.5	22	198	9	Yes
"	" " "	3.5	22	198	9	No
"	Kano to Ibadan	3.0	22	176	8	N.A.
"	Zaria to Lagos	3.5	24	216	9	No
"	Ogbomosho to Lagos	1.0	22	110	5	No

APPENDIX II

COMPUTER PROGRAM FOR TRNSCST MODEL

The listing of the computer program written in fortran and fordyn is given in this appendix. The description of the variables is included in Chapter III. The array data was entered in data statements which do not appear here. These data are given in the tables in Chapter III.

FOR1.3A

```
      PROGRAM DIS COST
      DIMENSION TM(15,15),PA(15),PM(15),WM(15,15),WSF(15,15)
     1,SF(15,15),RC(15,15),RM(15,15),TFC(15,15),TDL(15,15),TS
     2C(15,15),TTDC(15,15),DF(15,15),CM(15,15),MC(15,15),SC(15,15),CS(15
     3,15),CI(15,15),TWDC(15,15),AC(15,15),RSC(15,5),TRDC(15,15),RTDL(1
     45,15),RTSC(15,15),RTTDC(15,15),RMC(15,15),SCR(15,15),RCS(15,15),RC
     5I(15,15),RTWDC(15,15),RRSC(15,15),RTRDC(15,15),VSF(15,15)
     6,TAT(15,15),CHYR(15,15),TDCP(15,15),RTDCP(15,15),RDCP(15,15),RRDCP
     7(15,15)
      DIMENSION VAL(12),DLR(15,15),RDLR(15,15)
      REAL MF,MC,LWS
      SMALL=0
      DIFF=.5
      KF=11
      CW=340.
      CLC=.77
      SDL=.0007
      SSP=.004
      PTFC=3.
      PDT=.02
      FM=24.
      TCT=72.
      PDF=.54
      PCM=18.
      MWD=13.
      CPD=15.
      OE=100.
      WA=700.
      PPS=.44
   15 RI=.1
      DO 11 M=1,2
      DO 8 I=2,15
      K=I-1
      DO 7 J=1,K
      TFC(I,J)=PTFC*TM(I,J)
      TDL(I,J)=PDT*PA(J)*.34*TM(I,J)
      RTDL(I,J)=PDT*PA(I)*.34*TM(I,J)
      DT=TM(I,J)/700.*3.5
      LWS=TABEXE(VAL,SMALL,DIFF,KF,DT)
      TSC(I,J)=LWS*CLC*PM(J)*CW + .5*(LWS*WA-LWS*CLC*CW)*PPS*PM(J)
      RTSC(I,J)=LWS*CLC*PM(I)*CW + .5*(LWS*WA-LWS*CLC*CW)*PPS*PM(I)
      TTDC(I,J)=(TFC(I,J)+TDL(I,J)+TSC(I,J)+TCT+FM)/240.
      RTTDC(I,J)=(TFC(I,J)+RTDL(I,J)+RTSC(I,J)+TCT+FM)/240.
      TDCP(I,J)=TTDC(I,J)*20.
      RTDCP(I,J)=RTTDC(I,J)*20.
      DF(I,J)=PDF*WM(I,J)
      CM(I,J)=(PCM*WM(I,J)/MWD)/CPD
      IF(M.EQ.1) GO TO 12
      IF(I.EQ.10.OR.I.EQ.12.OR.I.EQ.14.OR.I.EQ.15) GO TO 10
      IF(J.EQ.10.OR.J.EQ.12.OR.J.EQ.14.OR.J.EQ.15) GO TO 10
```

```
12 MC(I,J)=.333*SF(I,J)*PA(J)*240.
   RMC(I,J)=.333*SF(I,J)*PA(I)*240.
   SC(I,J)=SF(I,J)*(PA(J)-.333*PA(J))*240.
   SCR(I,J)=SF(I,J)*(PA(I)-.333*PA(I))*240.
   CS(I,J)=.024*WM(I,J)/100.*CLC*PM(J)*CW+.5*(.025*WM(I,J)/100.*WA-
  1.025*WM(I,J)/100.*CLC*CW)*PPS*PM(J)
   RCS(I,J)=.025*WM(I,J)/100.*CLC*PM(I)*CW+.5*(.025*WM(I,J)/100.*WA-
  1.025*WM(I,J)/100.*CLC*CW)*PPS*PM(I)
   GO TO 9
10 MC(I,J)=.5*.33*SF(I,J)*PA(J)*240.
   RMC(I,J)=.5*.33*SF(I,J)*PA(I))*240.
   SC(I,J)=.5*SF(I,J)*(PA(J)-.33*PA(J))*240.
   SCR(I,J)=.5*SF(I,J)*(PA(I)-.33*PA(I))*240.
   CS(I,J)=VSF(I,J)*CLC*CW*PM(J)+.5*(VSF(I,J)*WA-VSF(I,J)*CLC*CW)
  1*PPS*PM(J)+VF+VML*PM(J)
   RCS(I,J)=VSF(I,J)*CLC*CW*PM(I)+.5*(VSF(I,J)*WA-VSF(I,J)*CLC*CW)
  1*PPS*PM(I)+VF+VML*PM(I)
 9 CI(I,J)=((PA(J)*RI*240.)/365.)*((WM(I,J)/MWD)+4.)
   RCI(I,J)=((PA(I)*RI*240.)/365.)*((WM(I,J)/MWD)+4.)
   TWDC(I,J)=(DF(I,J)+CM(I,J)+FM+SC(I,J)+CS(I,J)+CI(I,J)+WSF(I,J)+
  1TCT+MC(I,J))/240.
   RTWDC(I,J)=(DF(I,J)+CM(I,J)+FM+SCR(I,J)+RCS(I,J)+RCI(I,J)+WSF(I,J)
  1+TCT+RMC(I,J))/240.
   AC(I,J)=.221*RM(I,J)
   DV=(TAT(I,J)-2.)/2.
   DR=AMAX1(1.,DV)
   LWS=TABEXE(VAL,SMALL,DIFF,KF,DR)
   RSC(I,J)=LWS*CLC*PM(J)*CW+.5*(LWS*WA-LWS*CLC*CW)*PPS*PM(J)
   RRSC(I,J)=LWS*CLC*PM(I)*CW+.5*(LWS*WA-LWS*CLC*CW)*PPS*PM(I)
   DLR(I,J)=SDL*DR/2.*PA(J)*240.+SSP*DR/2.*(PA(J)-.333*PA(J))*240.
   RDLR(I,J)=SDL*DR/2.*PA(I)*240.+SSP*DR/2.*(PA(I)-.333*PA(I))*240.
   TRDC(I,J)=(RC(I,J)+AC(I,J)+RSC(I,J)+DLR(I,J)+TCT+FM)/240.
   RTRDC(I,J)=(RC(I,J)+AC(I,J)+RRSC(I,J)+RDLR(I,J)+TCT+FM)/240.
   CHYR(I,J)=(300./TAT(I,J))*26.
   RDCP(I,J)=CHYR(I,J)*TRDC(I,J)
   RRDCP(I,J)=CHYR(I,J)+RTRDC(I,J)
13 FORMAT (5X 3(13,1X))
   PRINT 13, I,J,M
 6 FORMAT (2(10E13,3,/))
   PRINT 6,TFC(I,J),TDL(I,J),RTDL(I,J),TSC(I,J),RTSC(I,J),DF(I,J),
  1CM(I,J),MC(I,J),RMC(I,J),SC(I,J),SCR(I,J),CS(I,J),RCS(I,J),
  2CI(I,J),RCI(I,J),AC(I,J),RSC(I,J),RRSC(I,J),DLR(I,J),RDLR(I,J)
20 FORMAT (5X 6E13,3)
   PRINT 20,TTDC(I,J),RTTDC(I,J),TWDC(I,J),RTWDC(I,J),TRDC(I,J),
  1RTRDC(I,J)
17 FORMAT (5E13.3)
   PRINT 17,CHYR(I,J),TDCP(I,J),RTDCP(I,J),RDCP(I,J),RRDCP(I,J)
 7 CONTINUE
 8 CONTINUE
11 CONTINUE
   END
```

```
FUNCTION TABEXE(VAL,SMALL,DIFF,KF,DUMMY)
DIMENSION VAL (I)
DUM=DUMMY-SMALL
N=MIN0(MAX1(1.0+DUM/DIFF,1.0),KF)
TABEXE=(VAL(N+1)-VAL(N))*(DUM-FLOAT(N-1)*DIFF)/DIFF+VAL(N)
RETURN
END
```

APPENDIX III

FIGURES SHOWING RESULTS OF THE SPATIAL EQUILIBRIUM MODEL

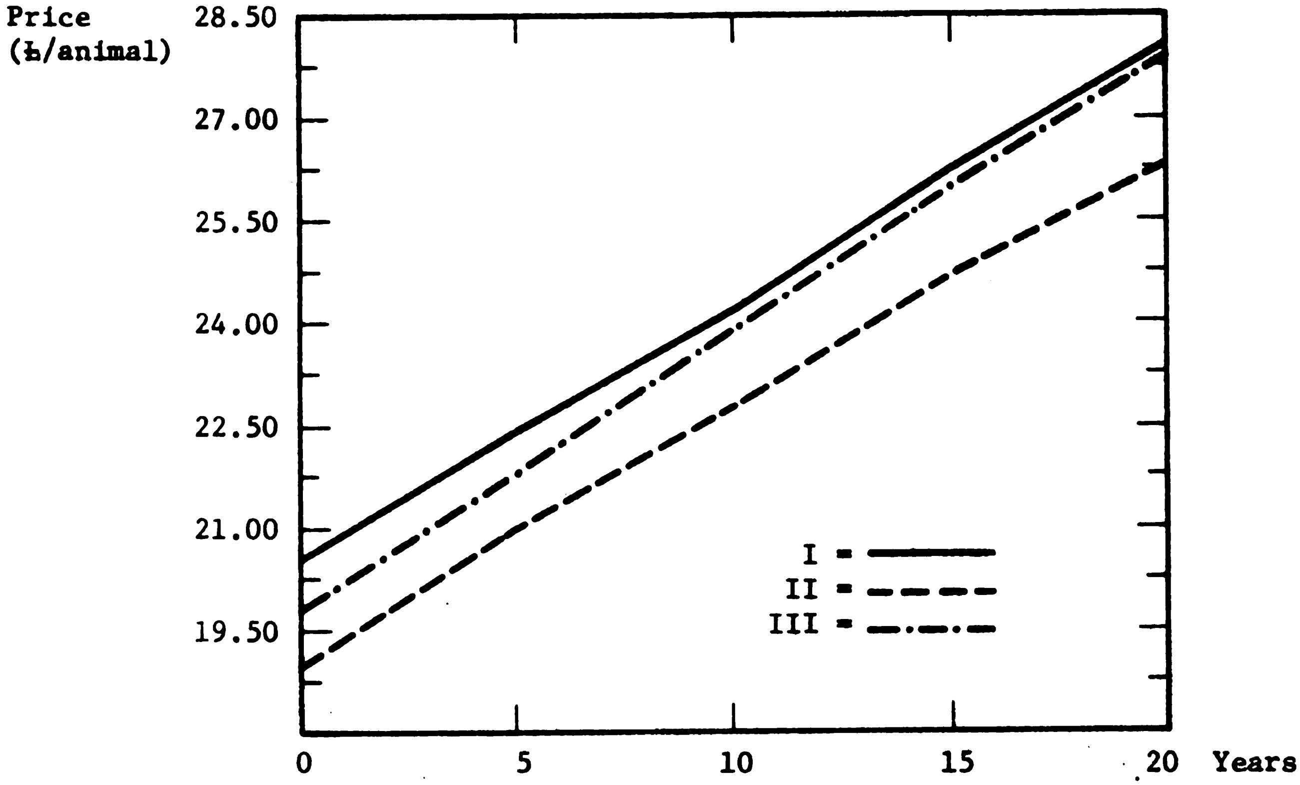
The figures contained in this appendix show the prices, quantities demanded and supplied, and interarea flows of beef through time in many of the 15 areas in Nigeria for three investment options in beef transportation. The results appear in table form in Chapter V.

The three transportation investment options are as follows:

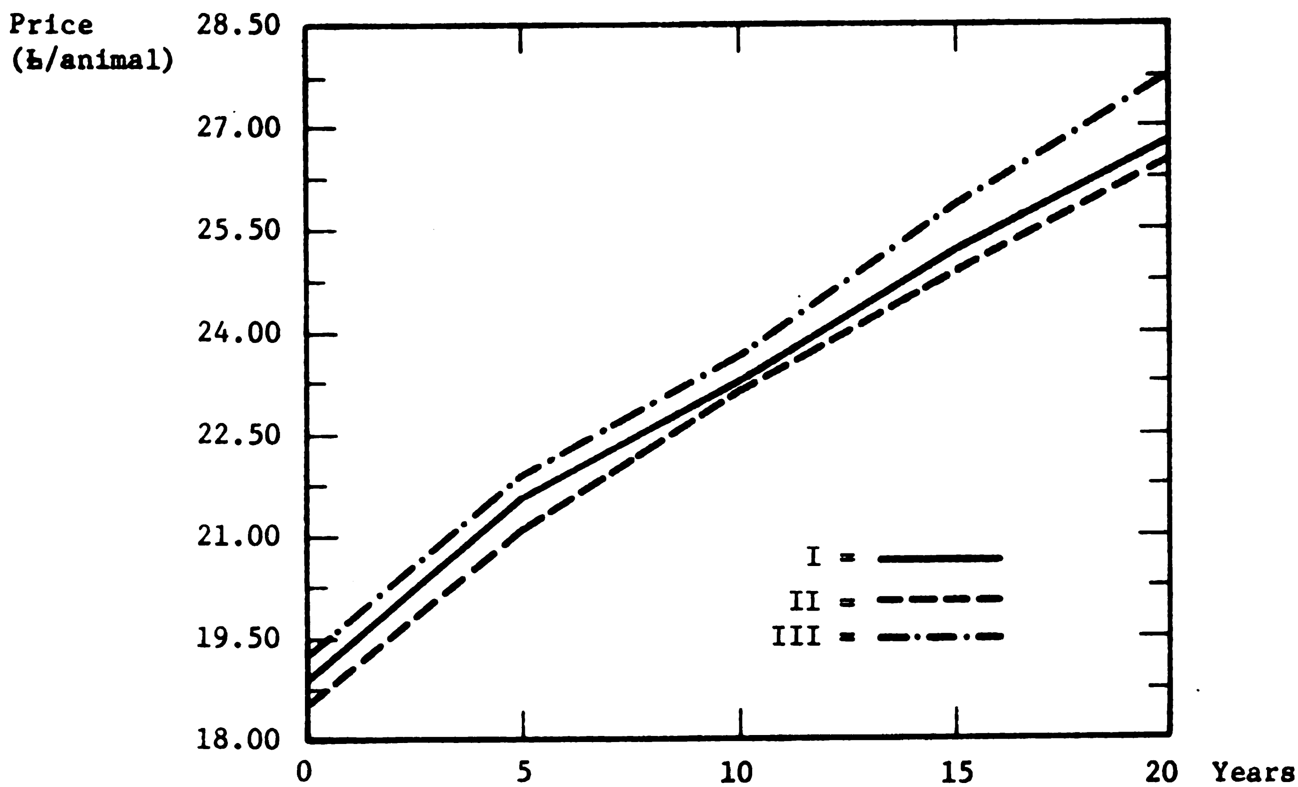
I - a policy that closely parallels the present one in Nigeria of providing fewer rail cars than can be effectively utilized and having no program to control trypanosomiasis.

II - a policy that furnishes as many cars as are needed but no investments in trypanosomiasis control.

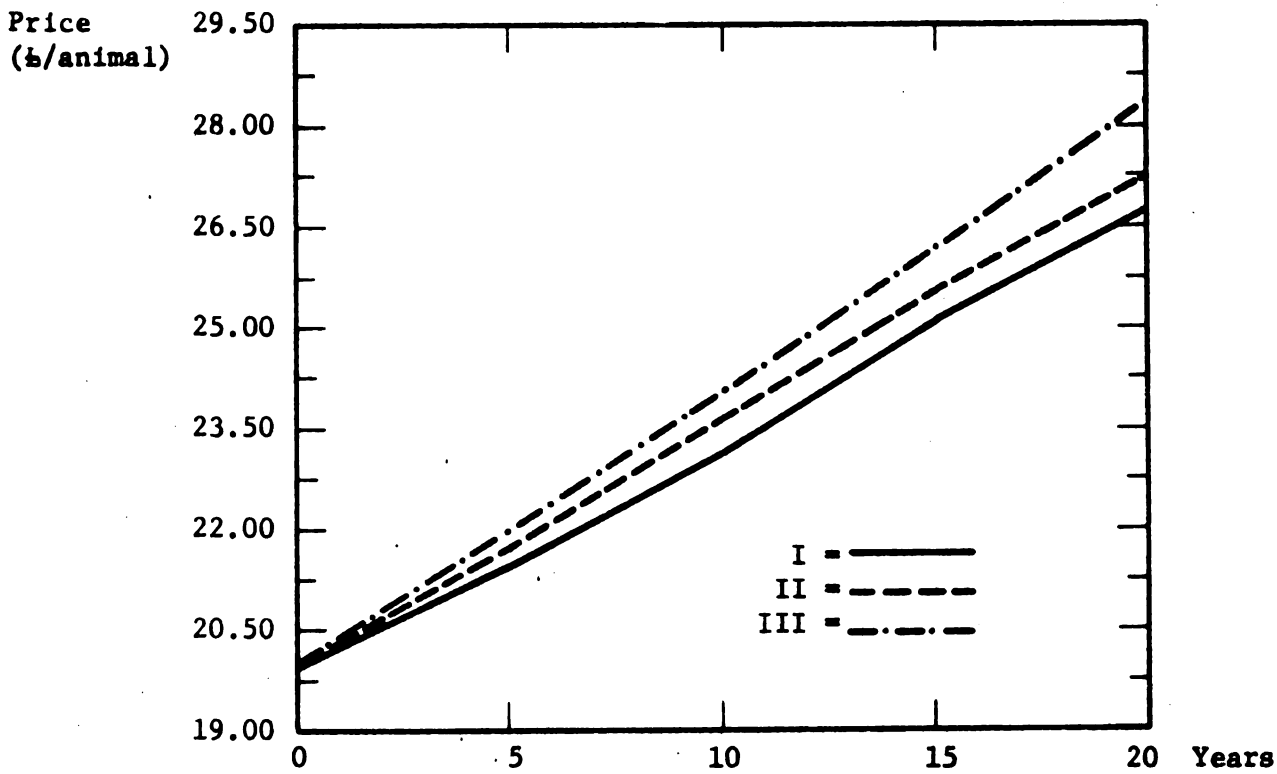
III - a policy that furnishes an adequate number of rail cars with a program to control trypanosomiasis along the trek routes.



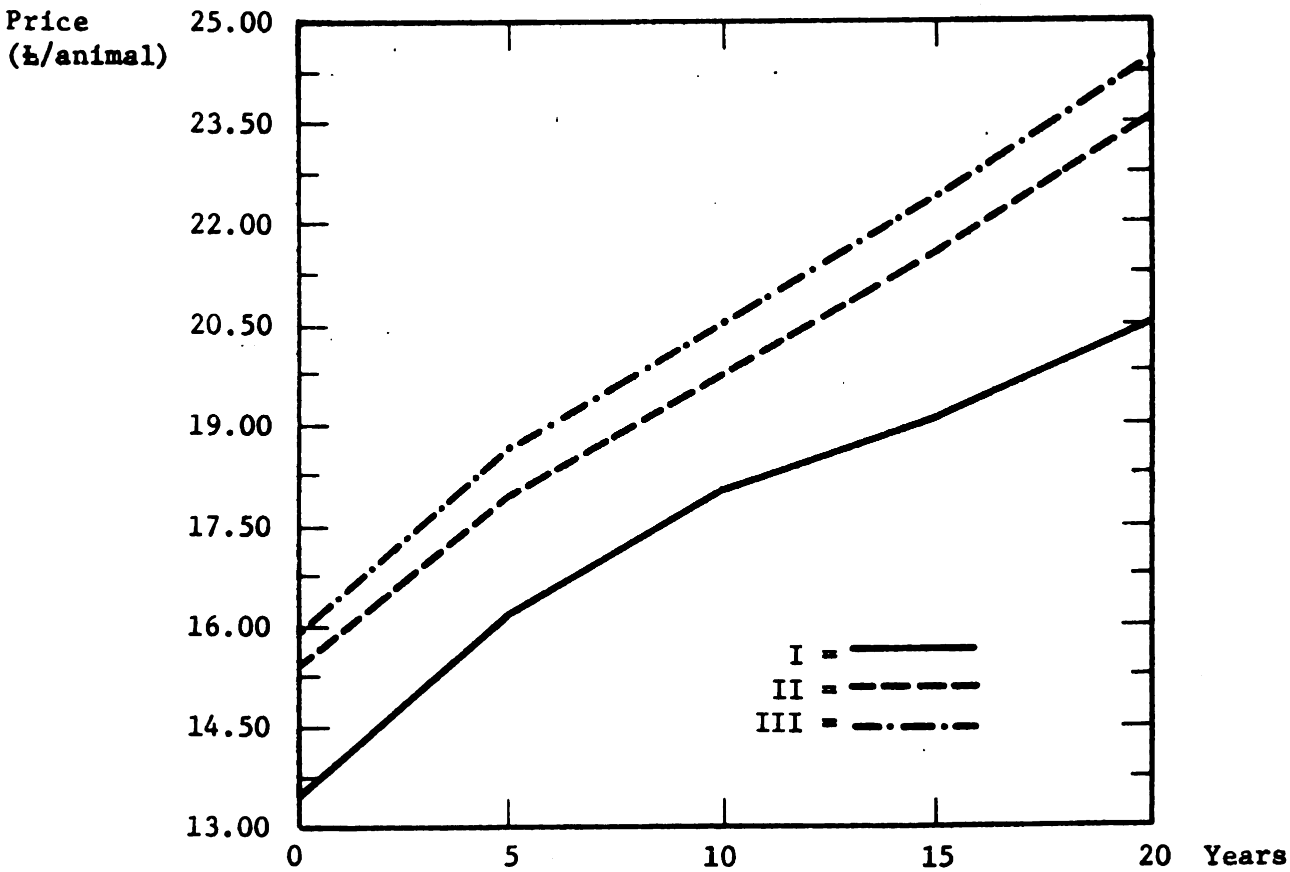
Appendix Figure III-1: Equilibrium Prices in Area 1 Through Time for Three Options



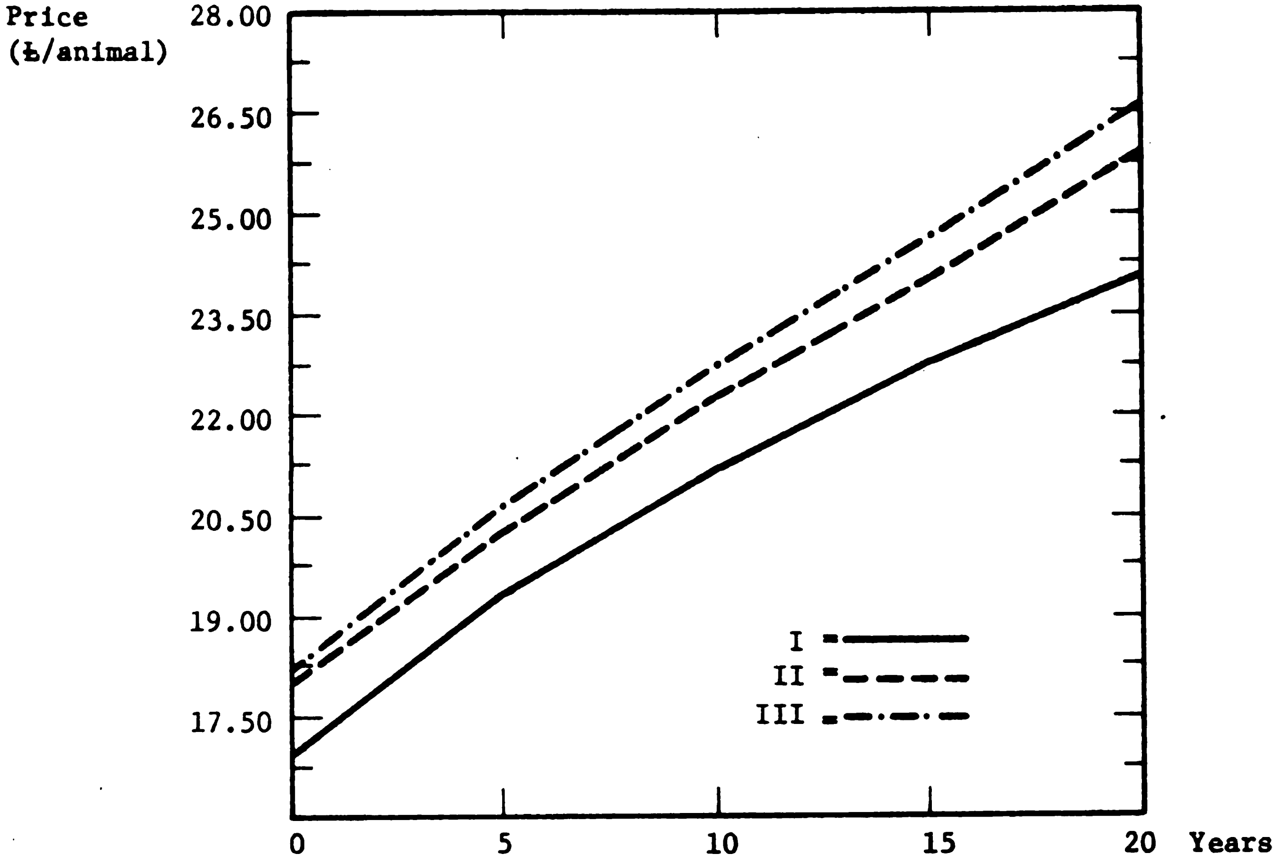
Appendix Figure III-2: Equilibrium Prices in Area 2 Through Time for Three Options



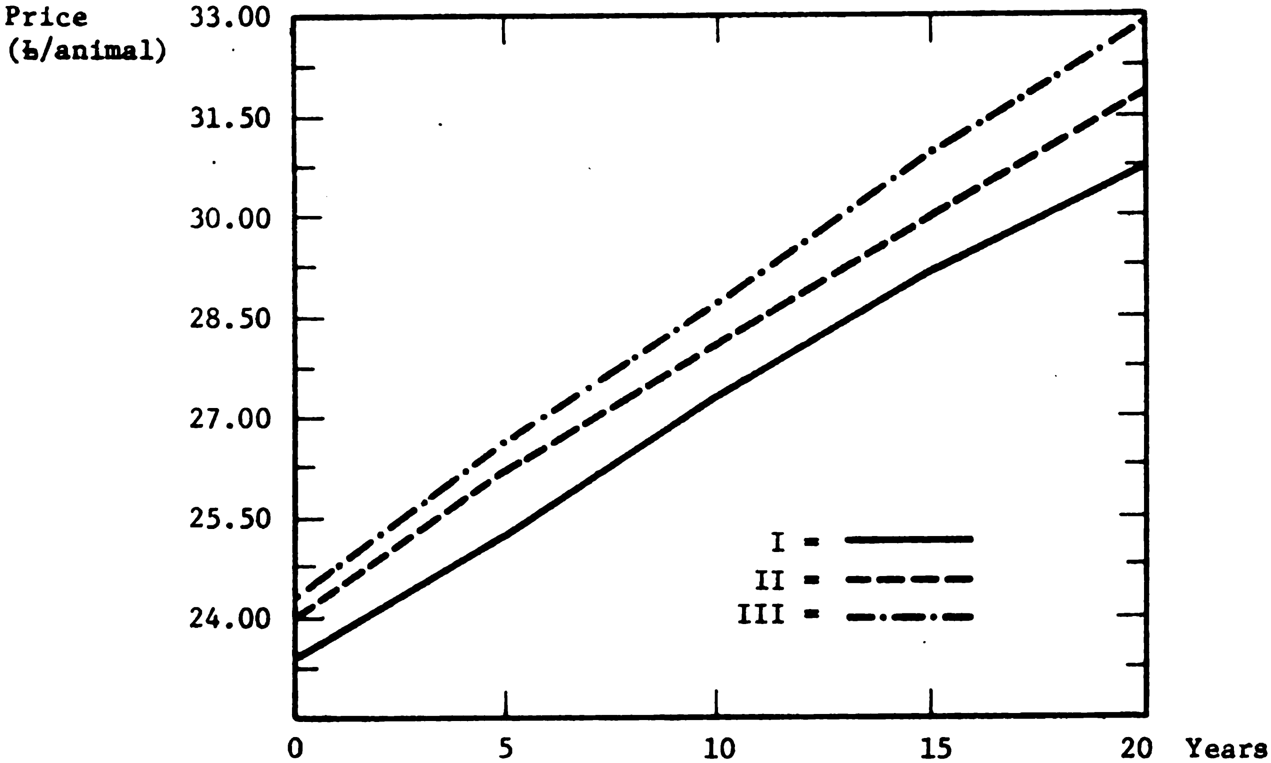
Appendix Figure III-3: Equilibrium Prices in Area 3 Through Time for Three Options



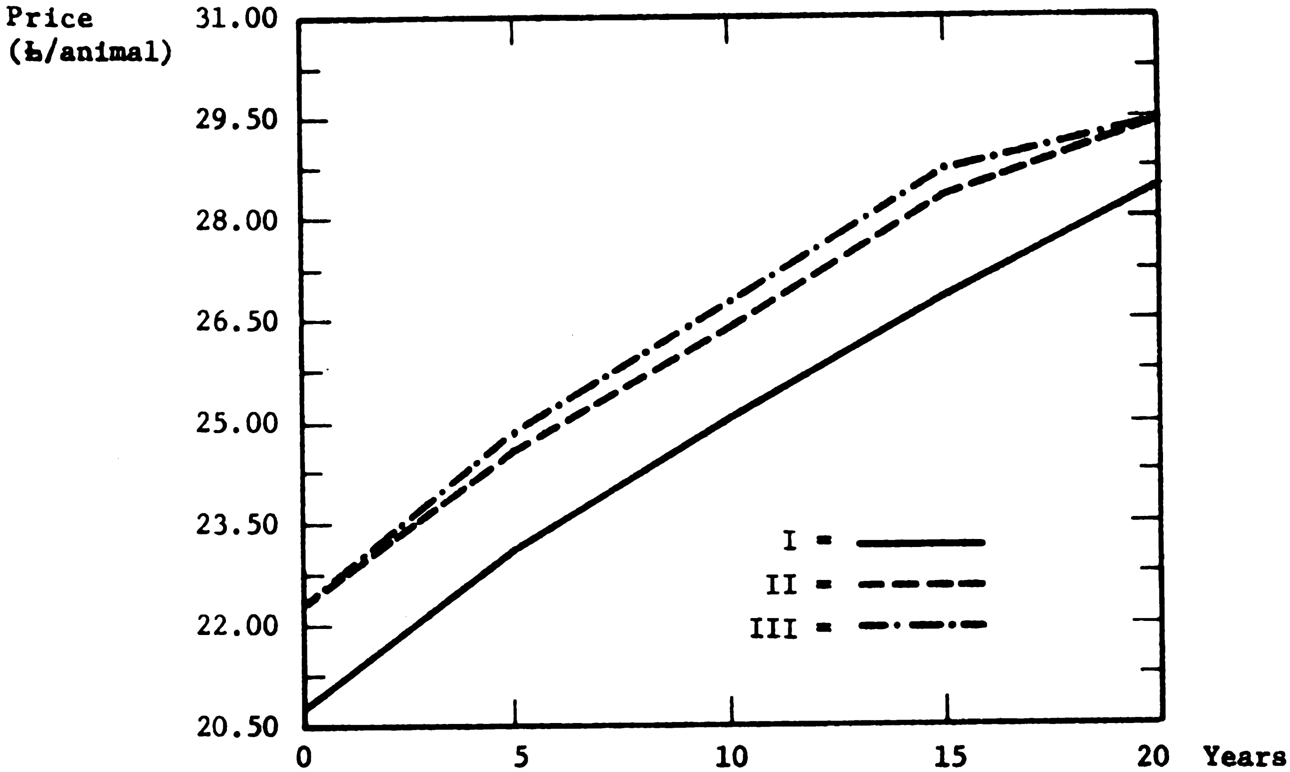
Appendix Figure III-4: Equilibrium Prices in Area 4 Through Time for Three Options



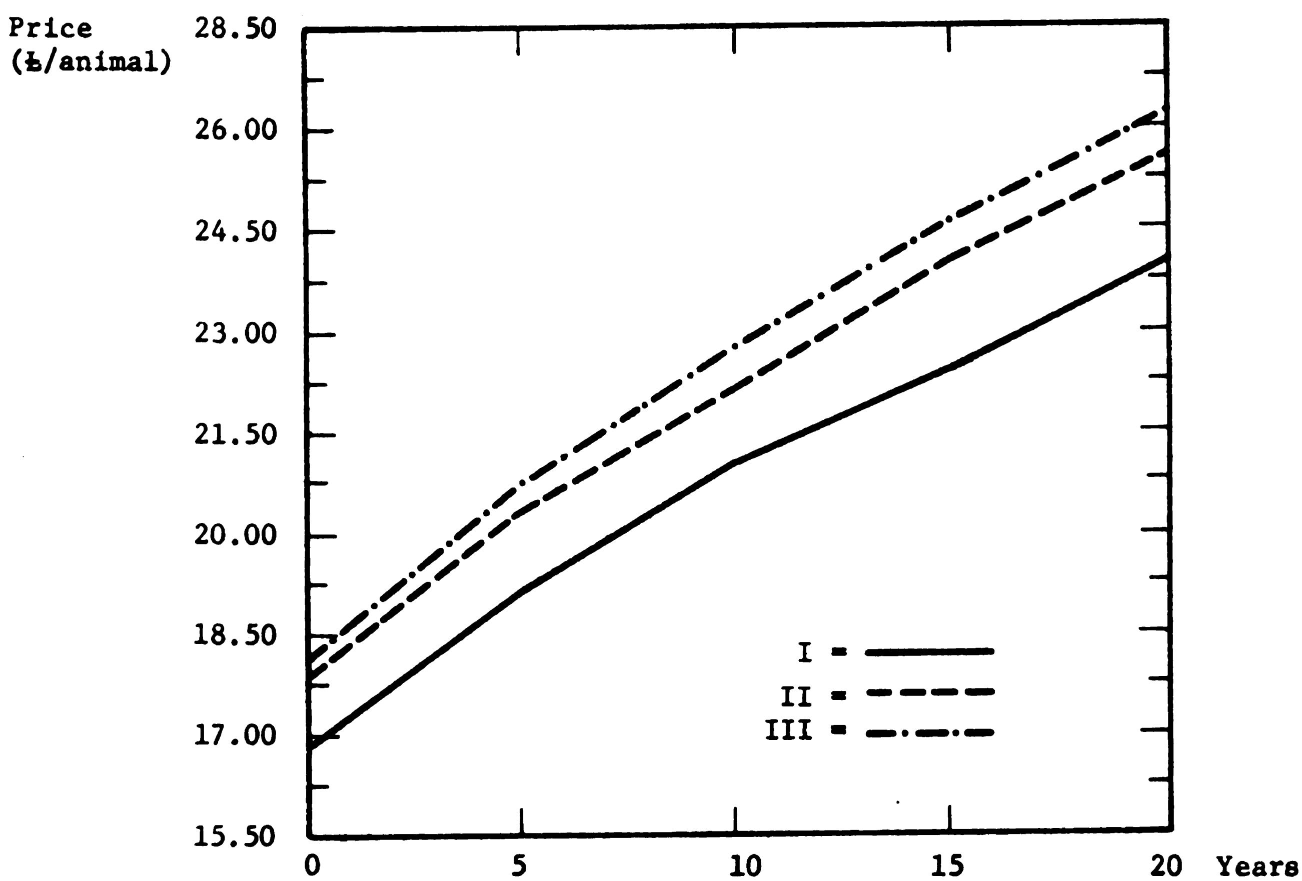
Appendix Figure III-5: Equilibrium Prices in Area 5 Through Time for Three Options



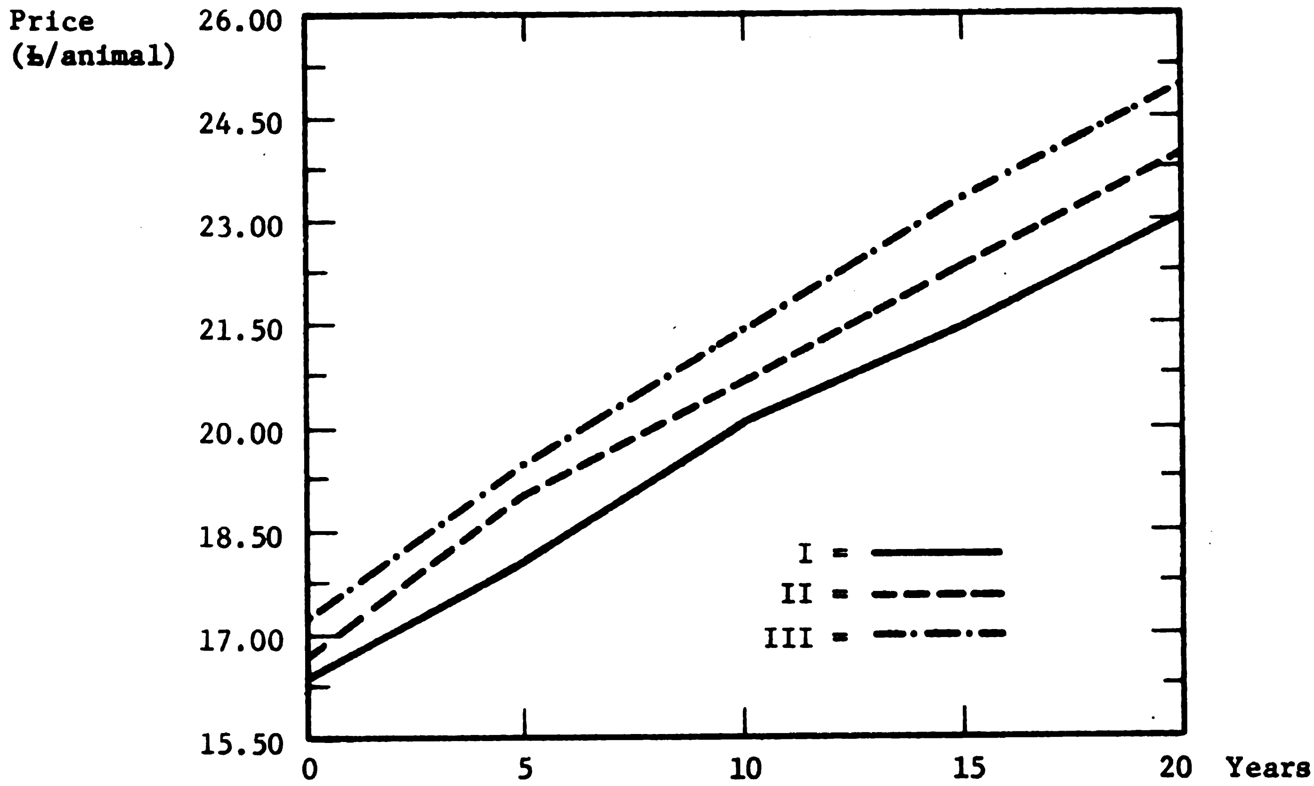
Appendix Figure III-6: Equilibrium Prices in Area 6 Through Time for Three Options



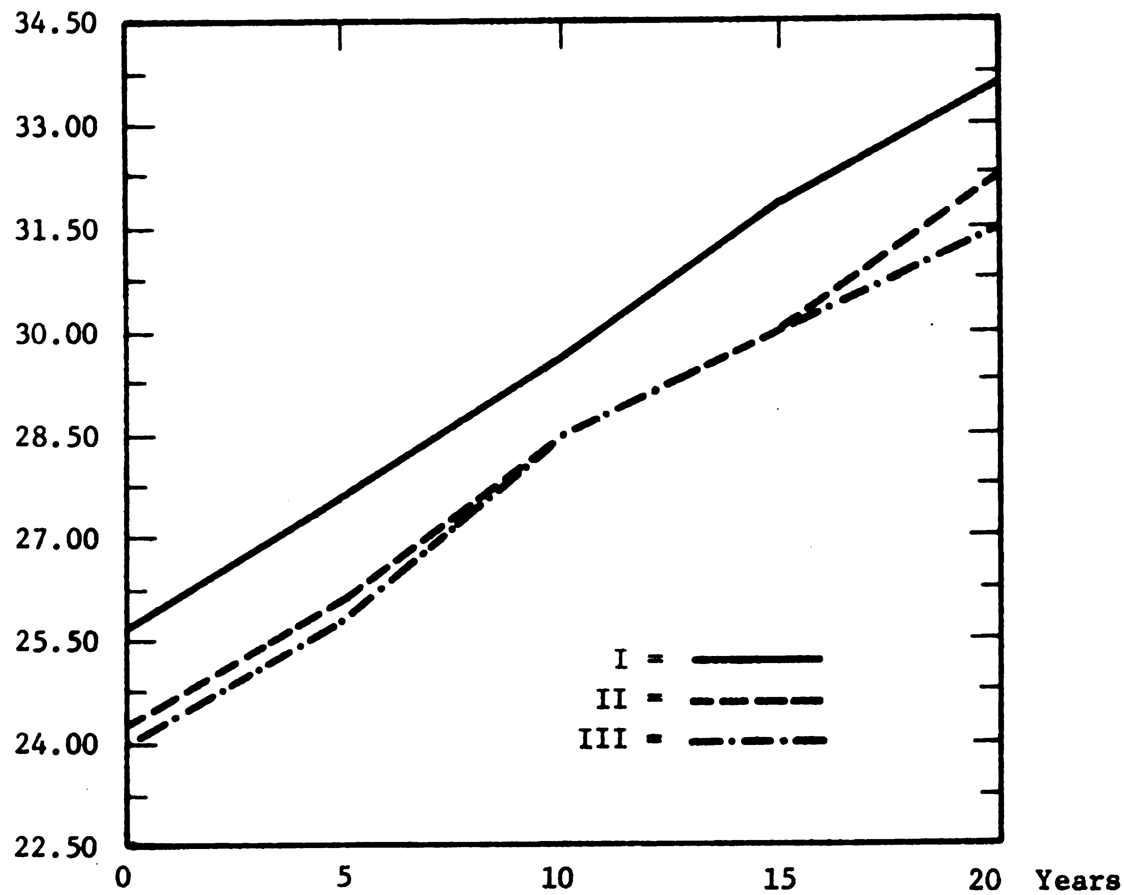
Appendix Figure III-7: Equilibrium Prices in Area 7 Through Time for Three Options



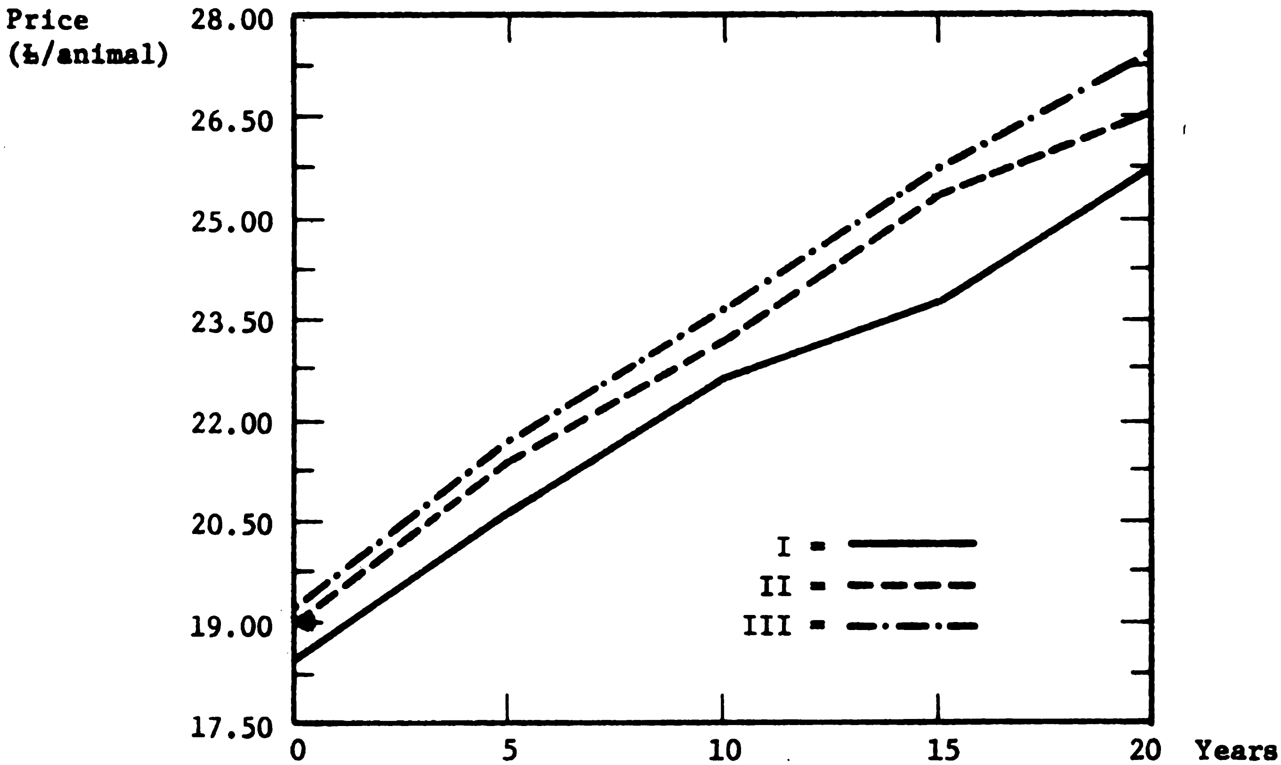
Appendix Figure III-8: Equilibrium Prices in Area 8 Through Time for Three Options



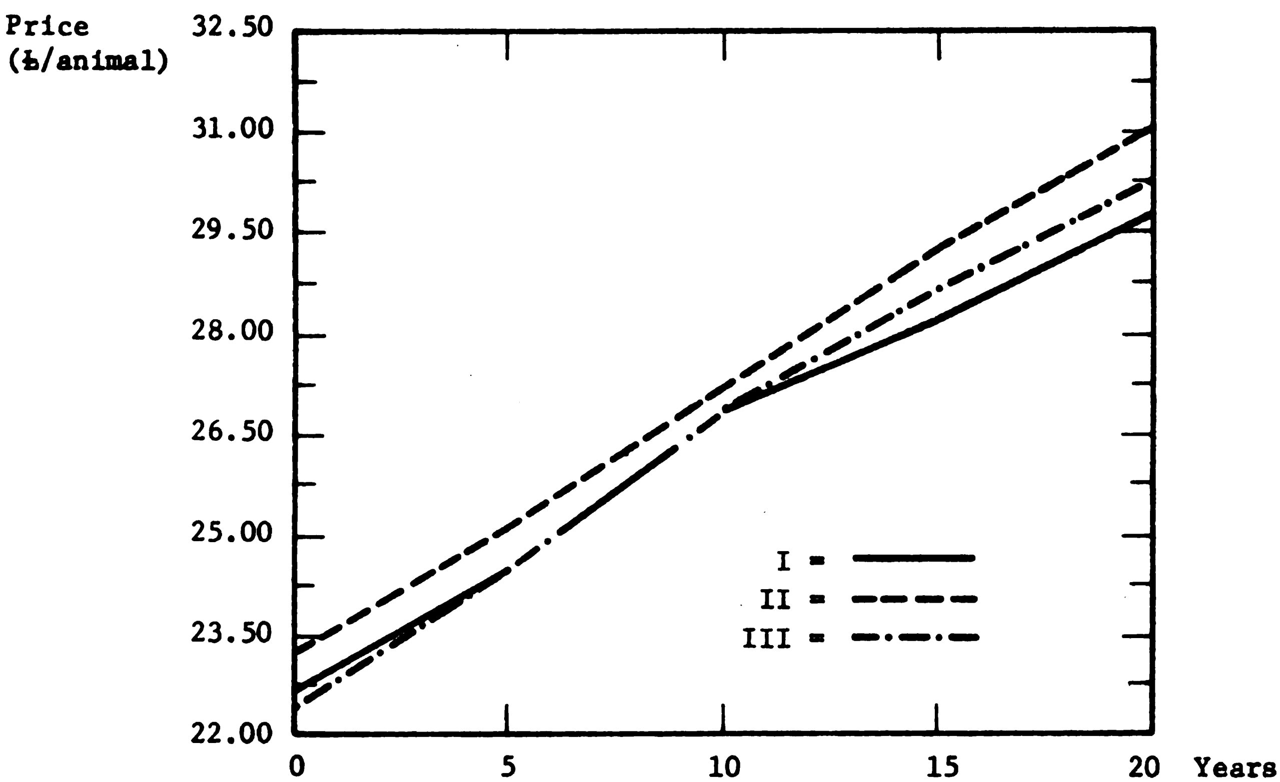
Appendix Figure III-9: Equilibrium Prices in Area 9 Through Time for Three Options



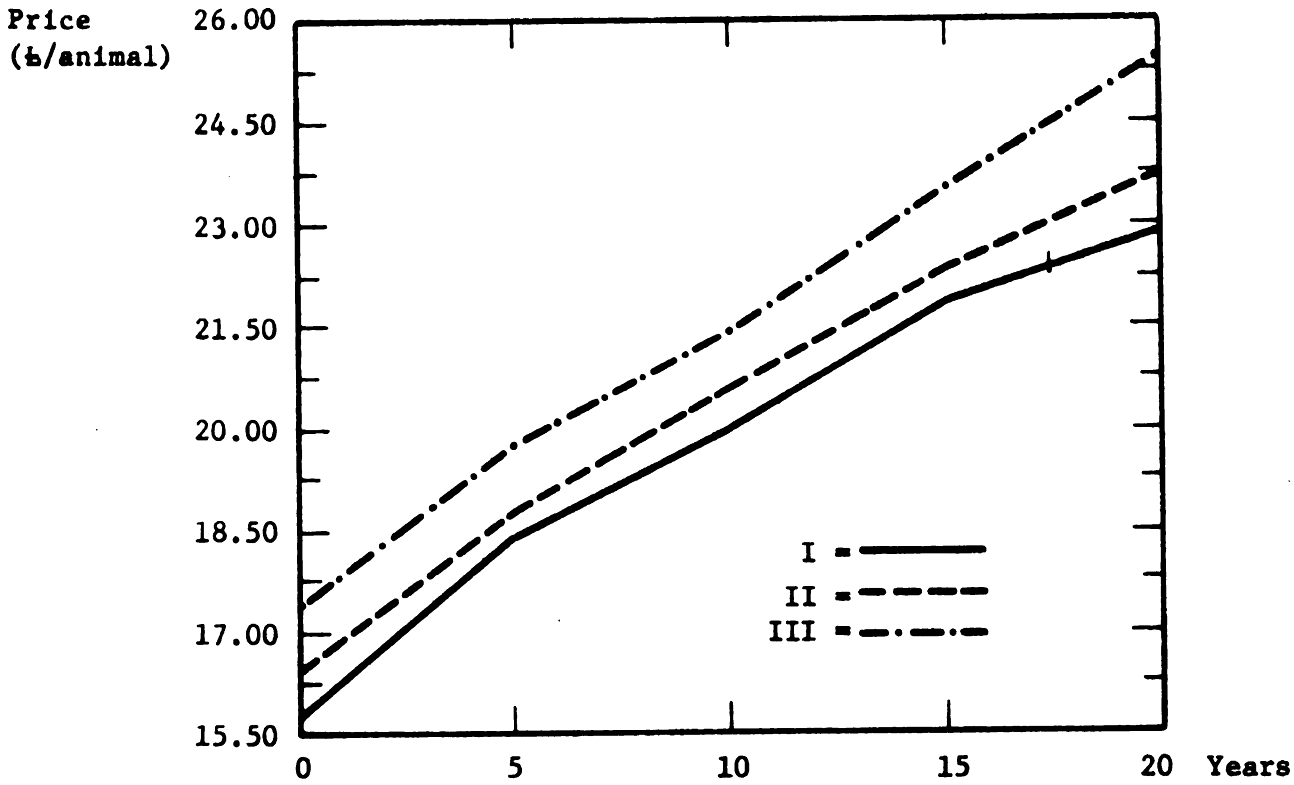
Appendix Figure III-10: Equilibrium Prices in Area 10 Through Time for Three Options



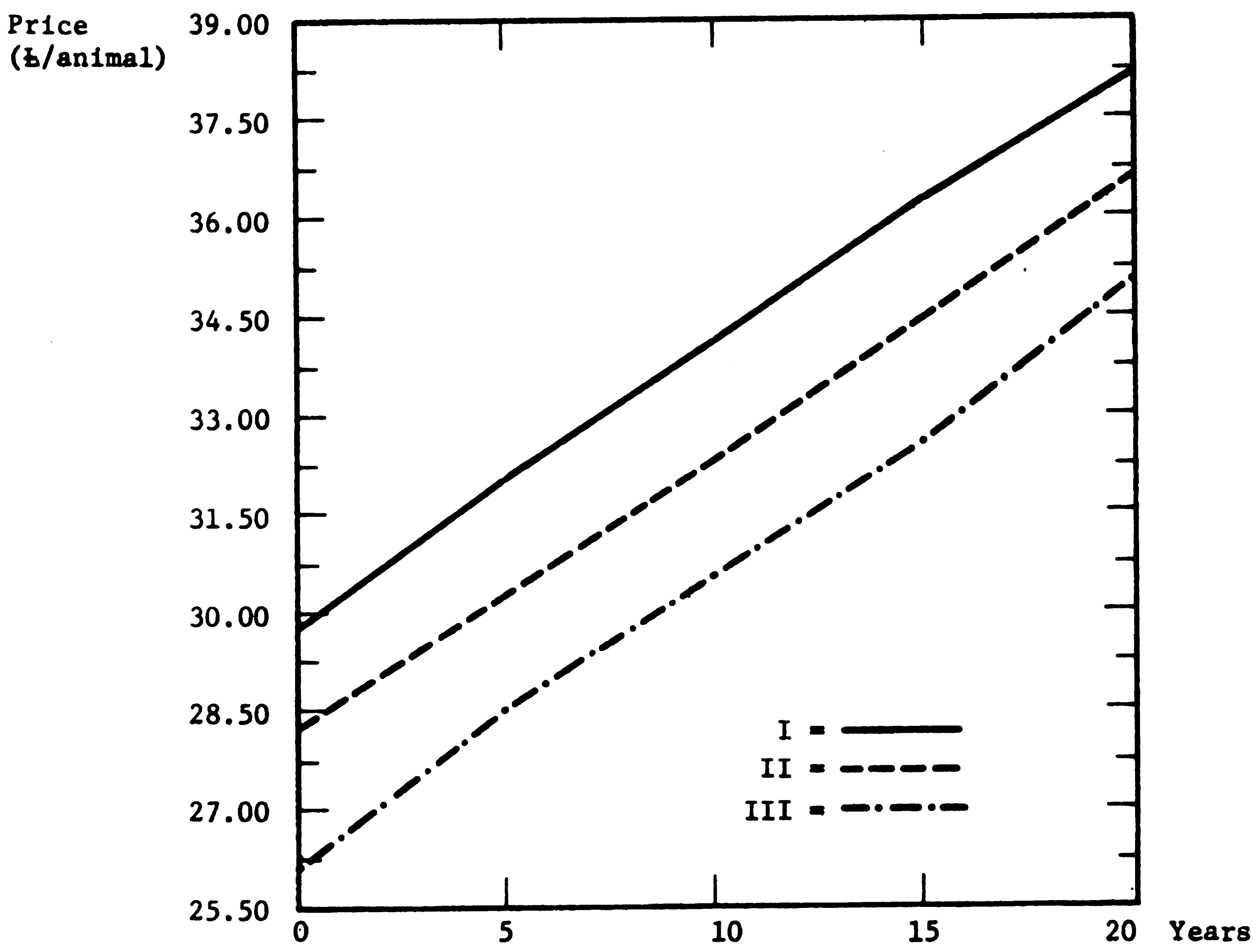
Appendix Figure III-11: Equilibrium Prices in Area 11 Through Time for Three Options



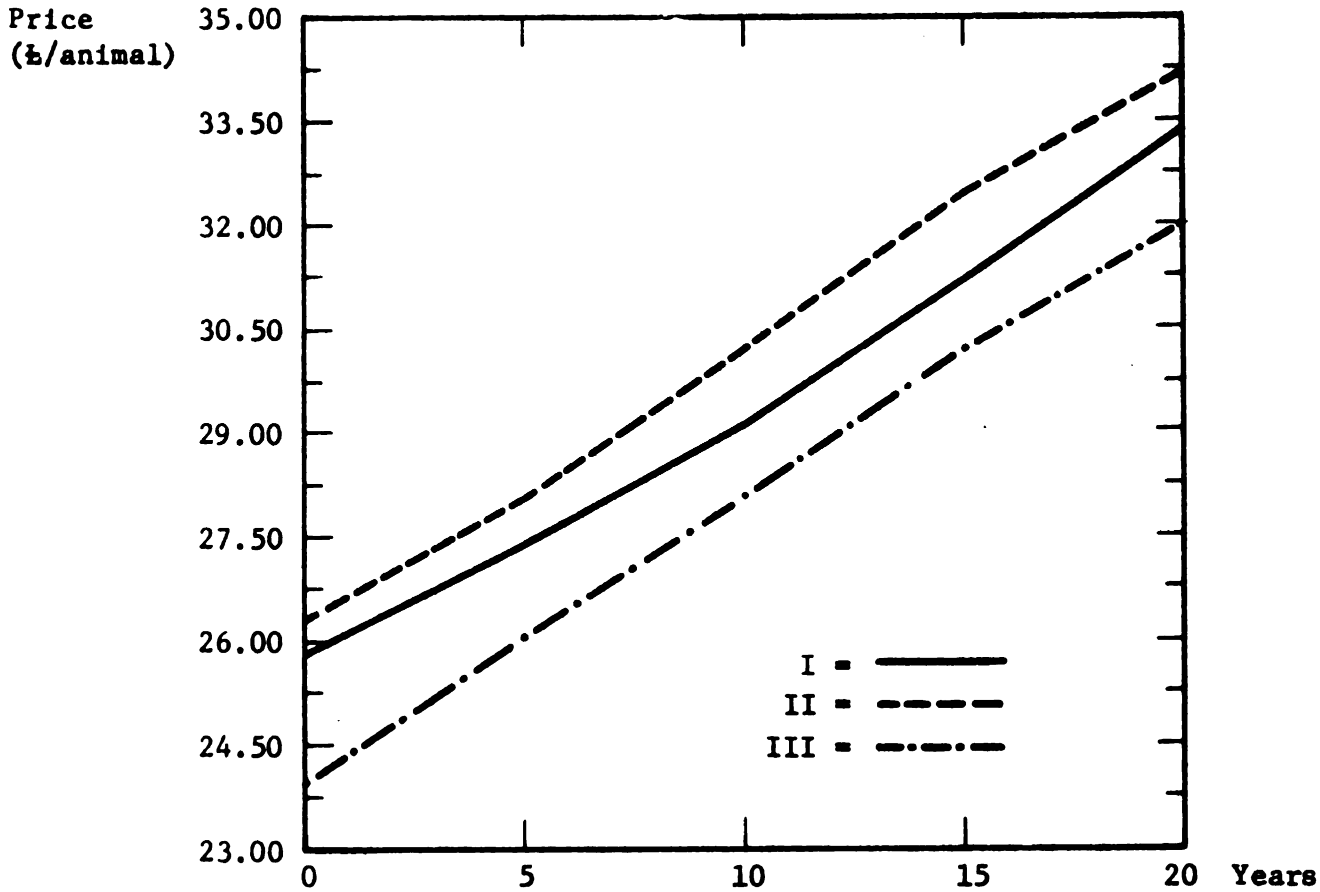
Appendix Figure III-12: Equilibrium Prices in Area 12 Through Time for Three Options



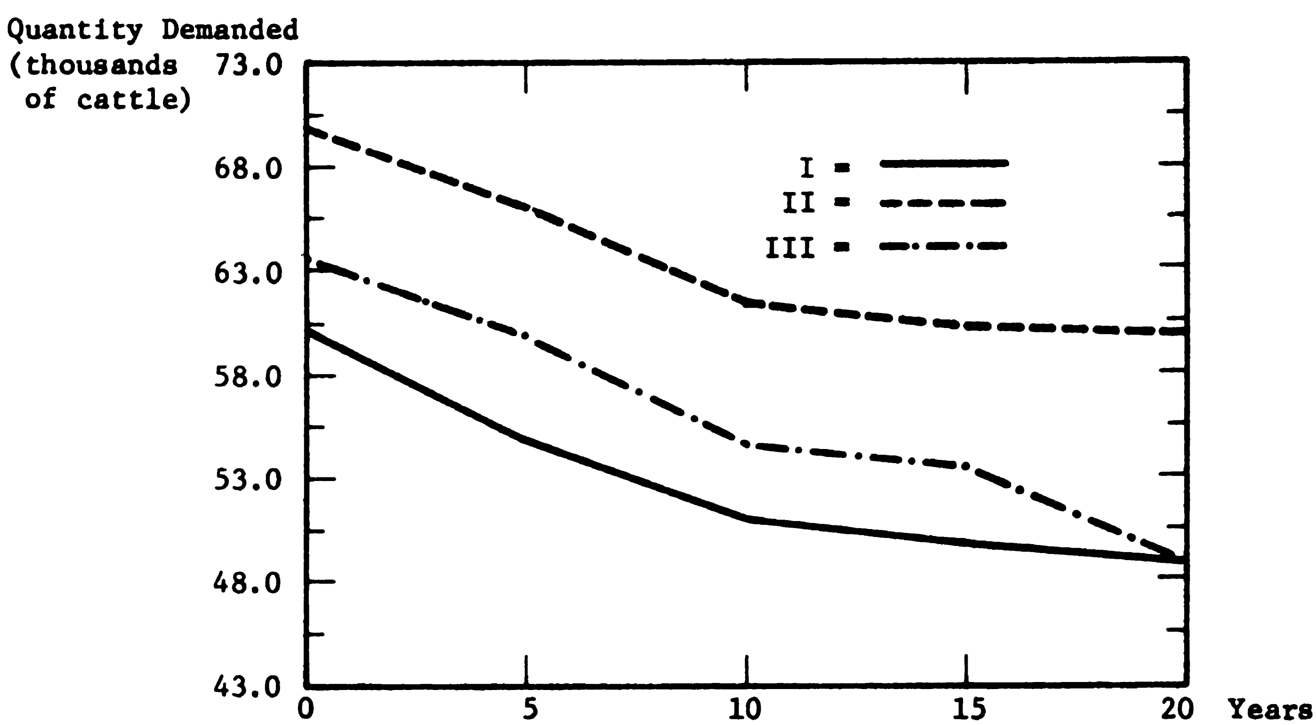
Appendix Figure III-13: Equilibrium Prices in Area 13 Through Time for Three Options



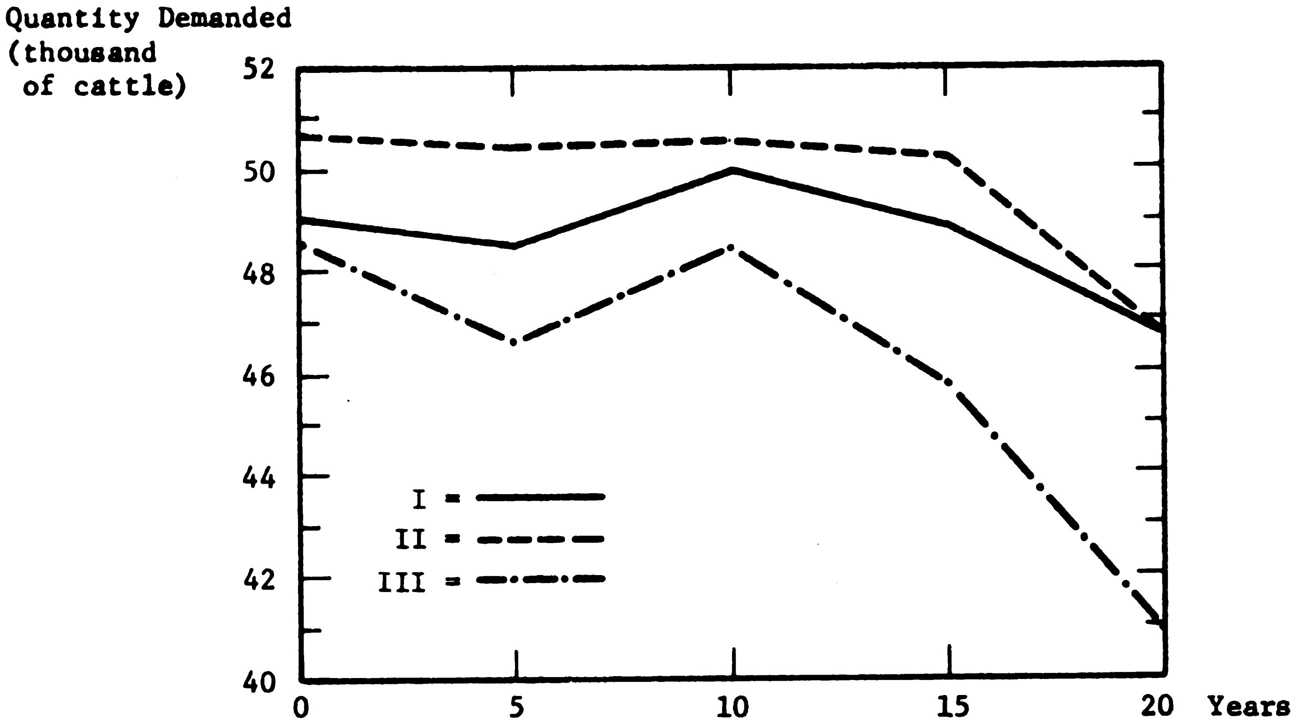
Appendix Figure III-14: Equilibrium Prices in Area 14 Through Time for Three Options



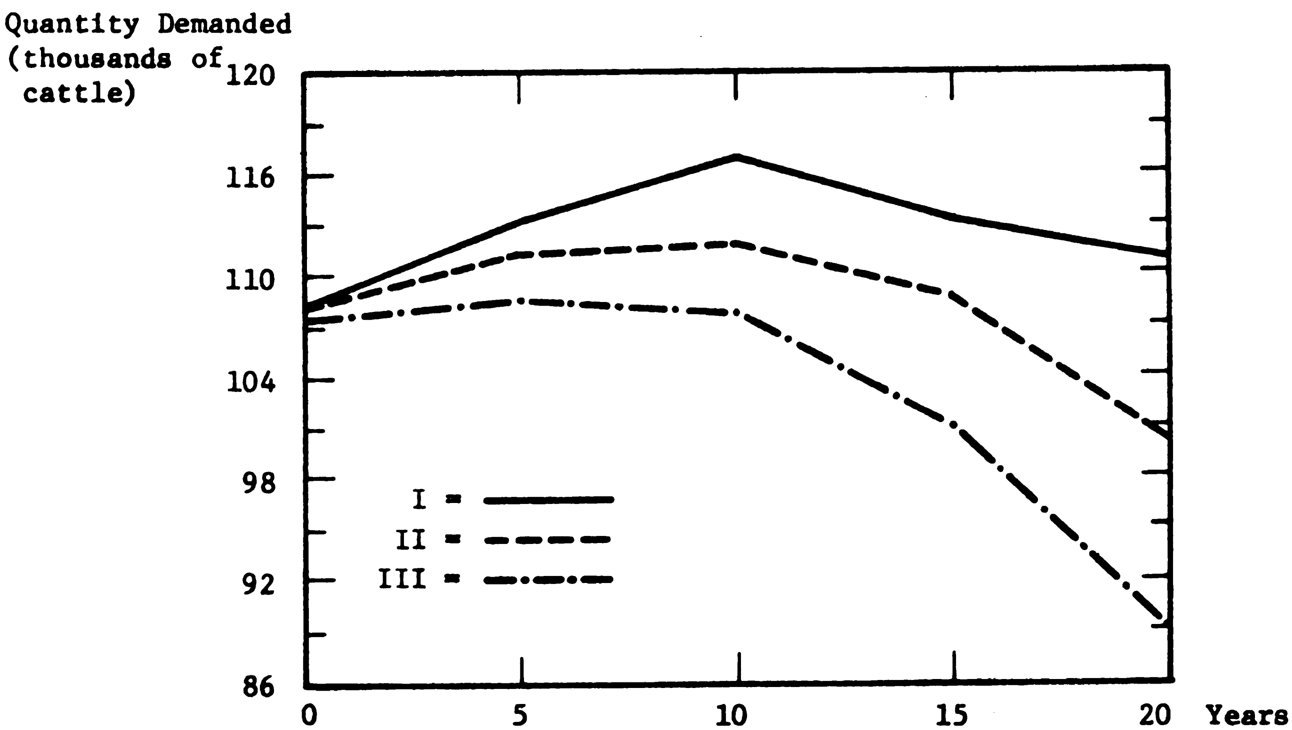
Appendix Figure III-15: Equilibrium Prices in Area 15 Through Time for Three Options



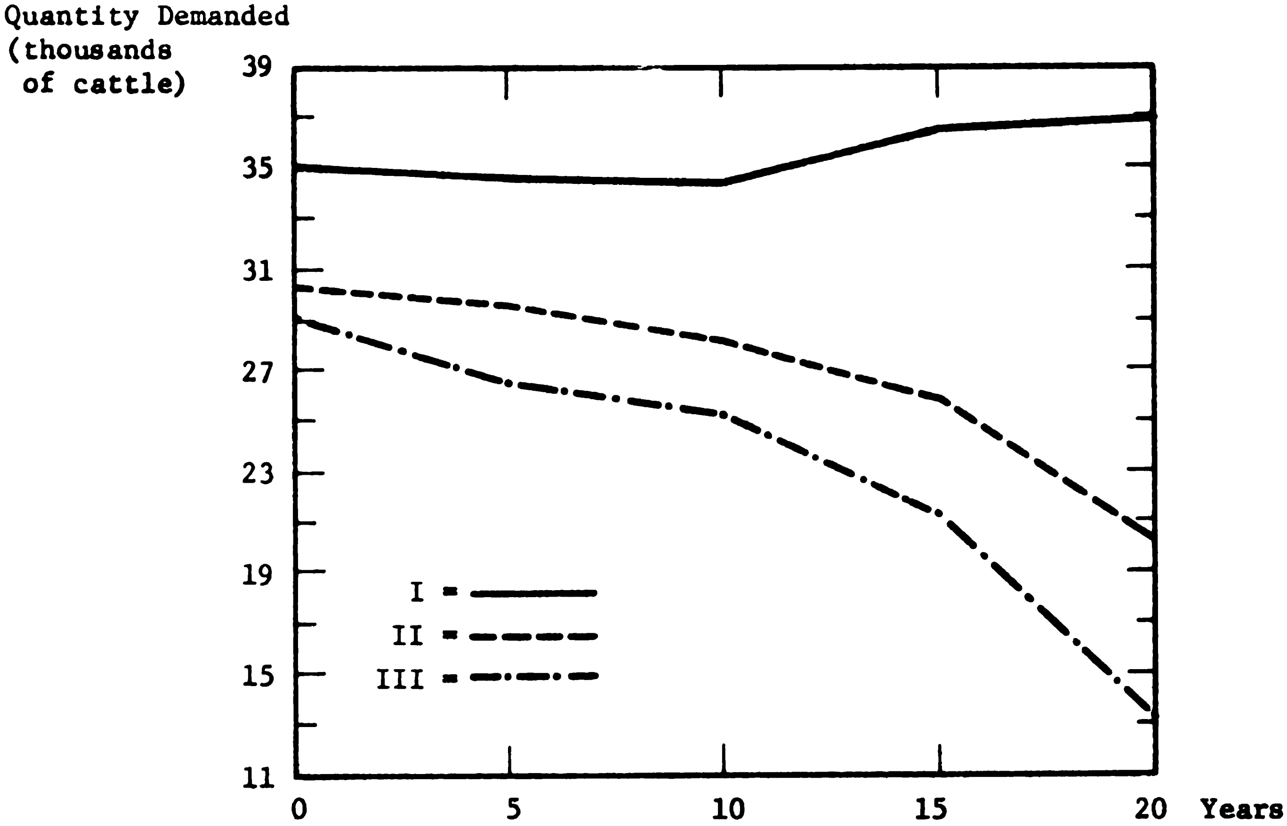
Appendix Figure III-16: Equilibrium Quantity Demanded in Area 1 Through Time Under Three Options



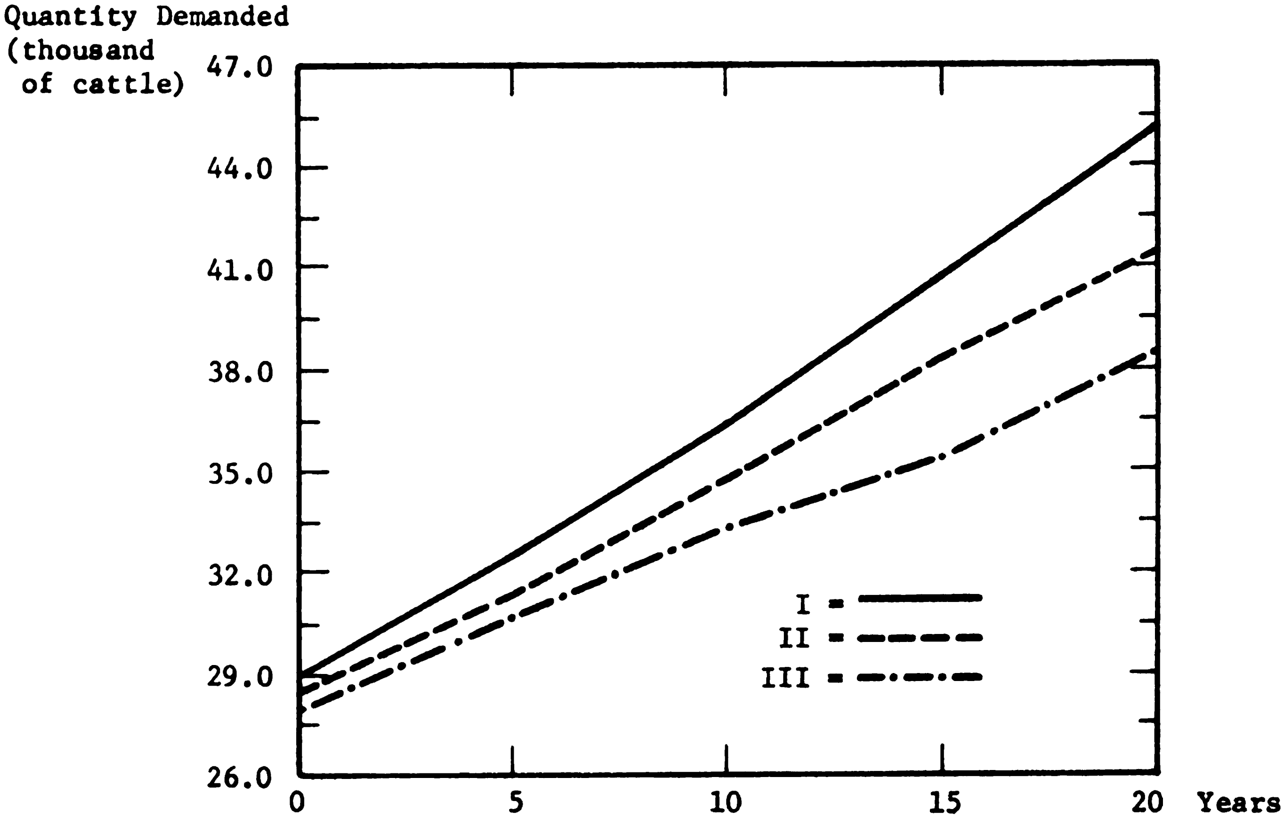
Appendix Figure III-17: Equilibrium Quantity Demanded in Area 2 Through Time Under Three Options



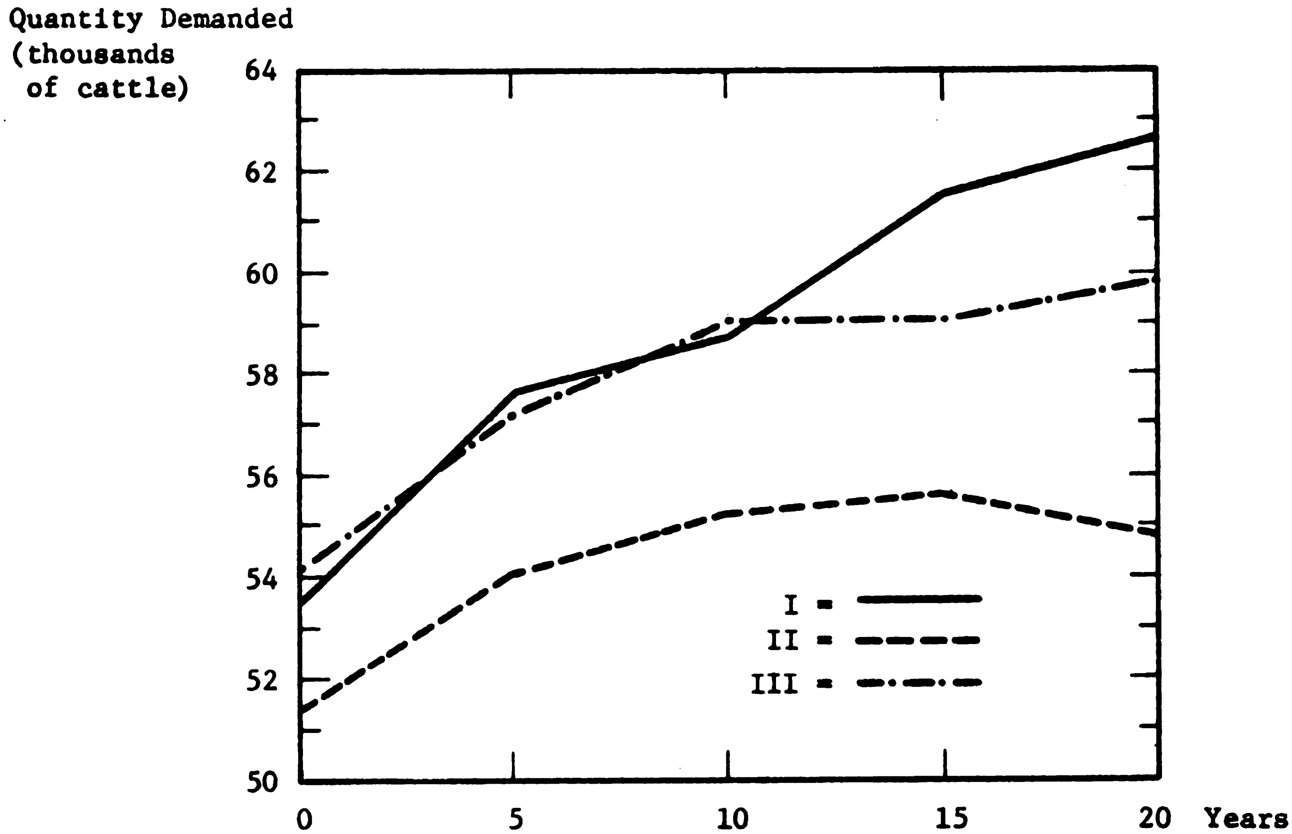
Appendix Figure III-18: Equilibrium Quantity Demanded in Area 3 Through Time Under Three Options



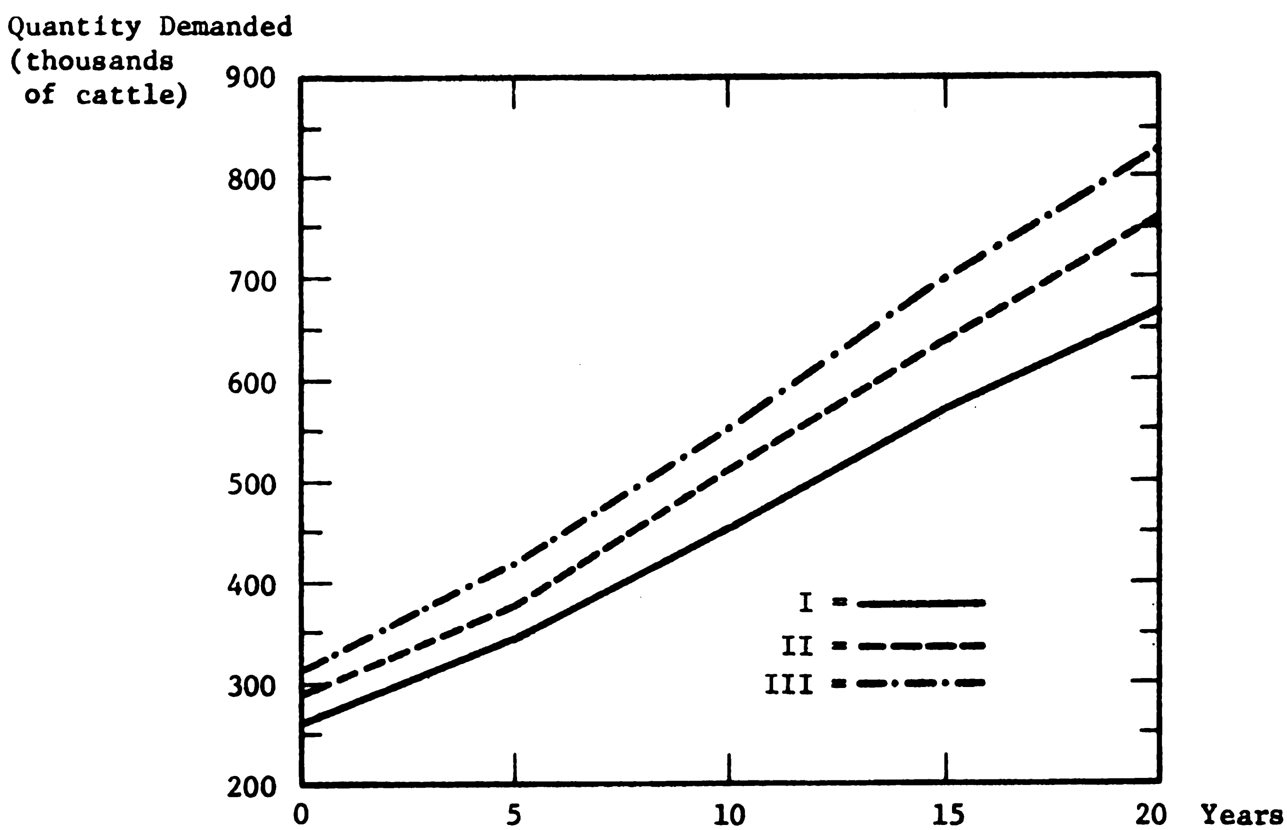
Appendix Figure III-19: Equilibrium Quantity Demanded in Area 4 Through Time Under Three Options



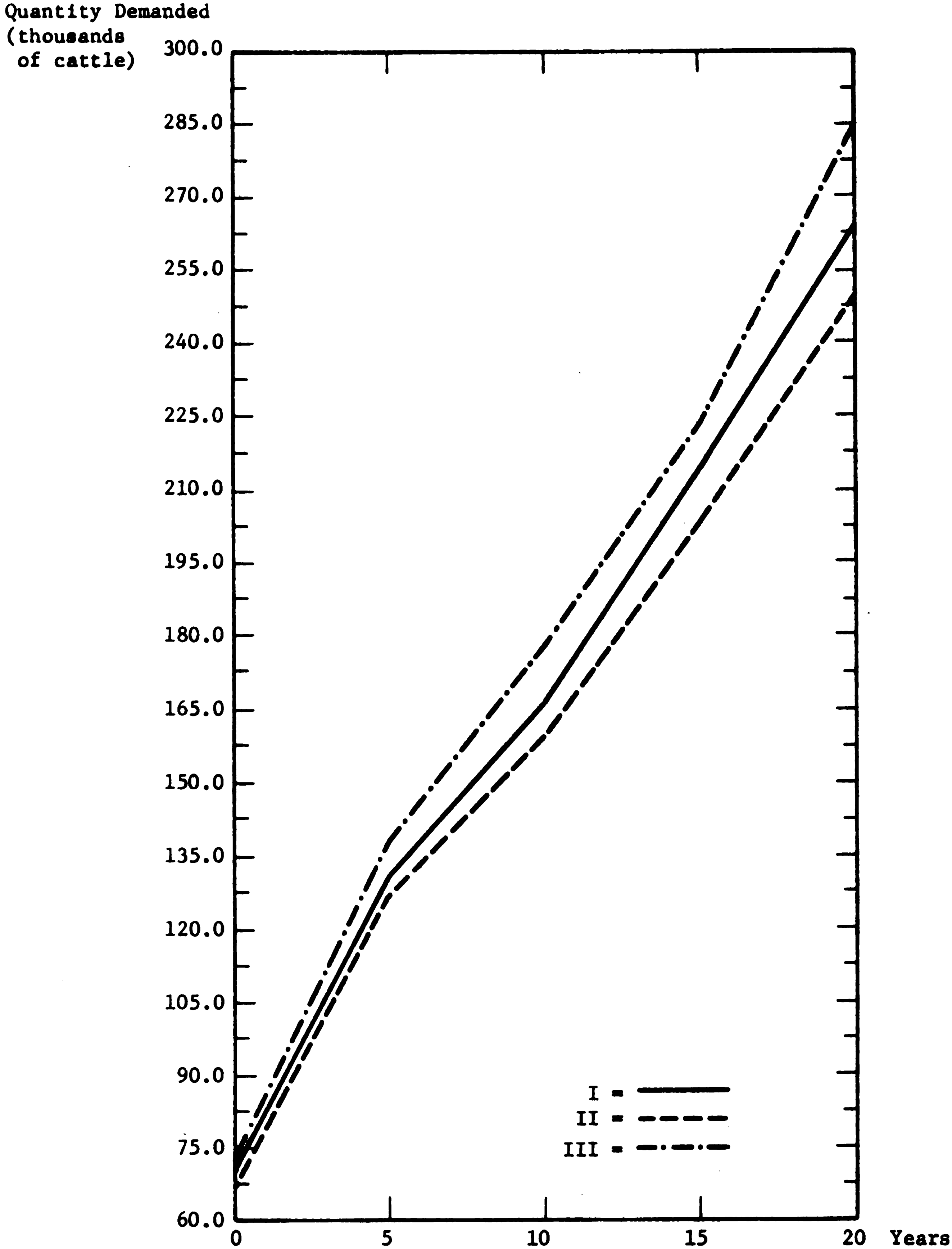
Appendix Figure III-20: Equilibrium Quantity Demanded in Area 6 Through Time Under Three Options



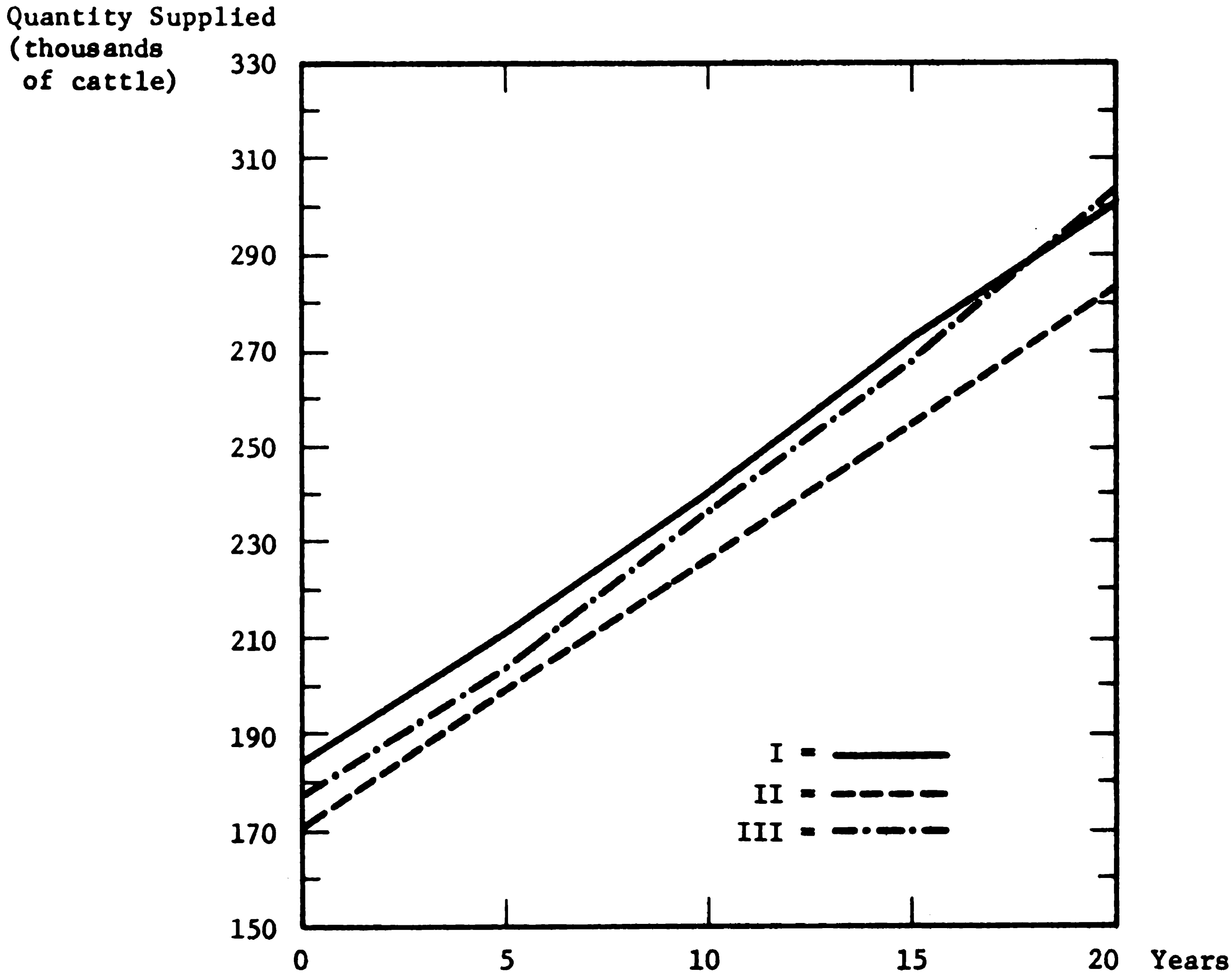
Appendix Figure III-21: Equilibrium Quantity Demanded in Area 12 Through Time Under Three Options



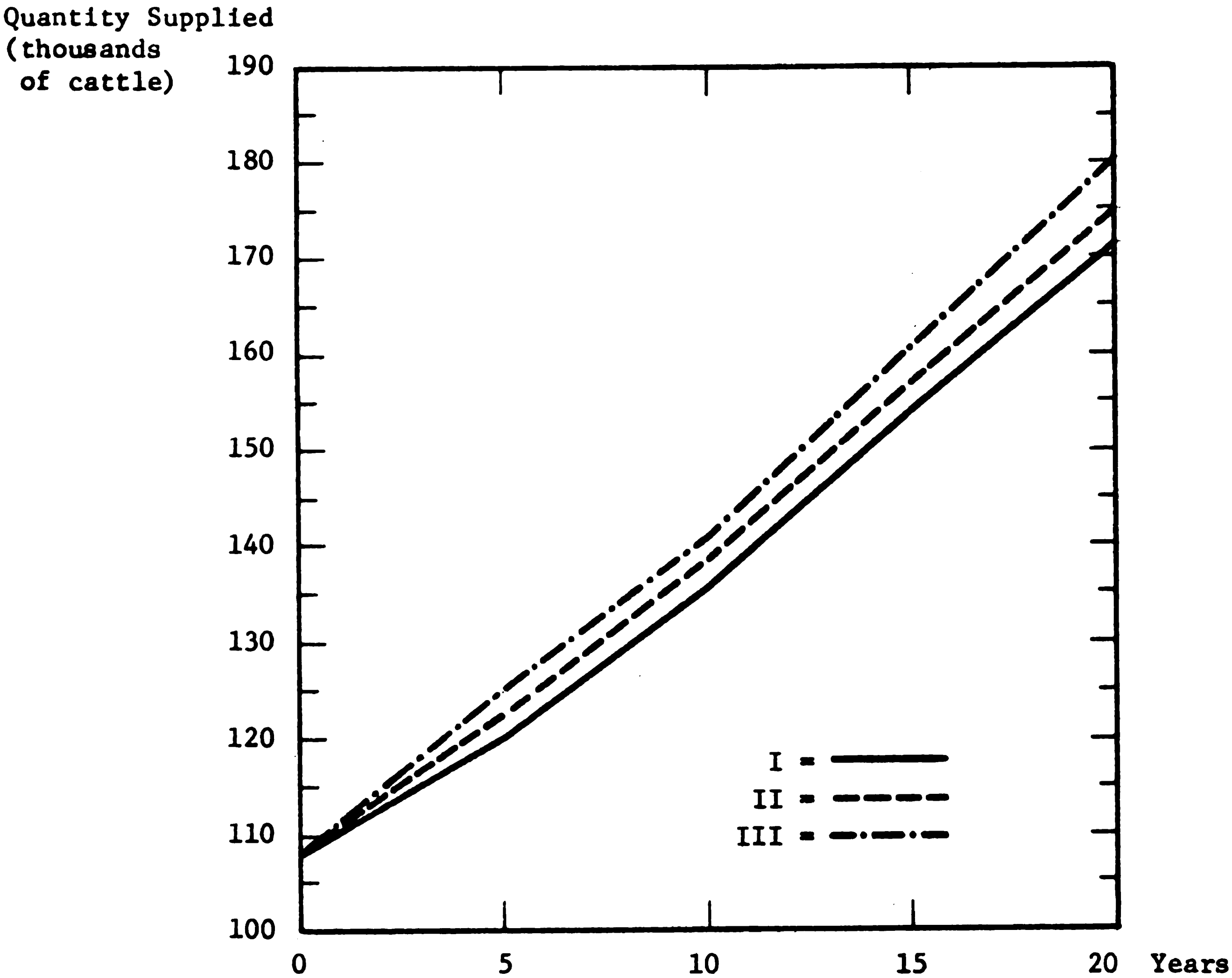
Appendix Figure III-22: Equilibrium Quantity Demanded in Area 14 Through Time Under Three Options



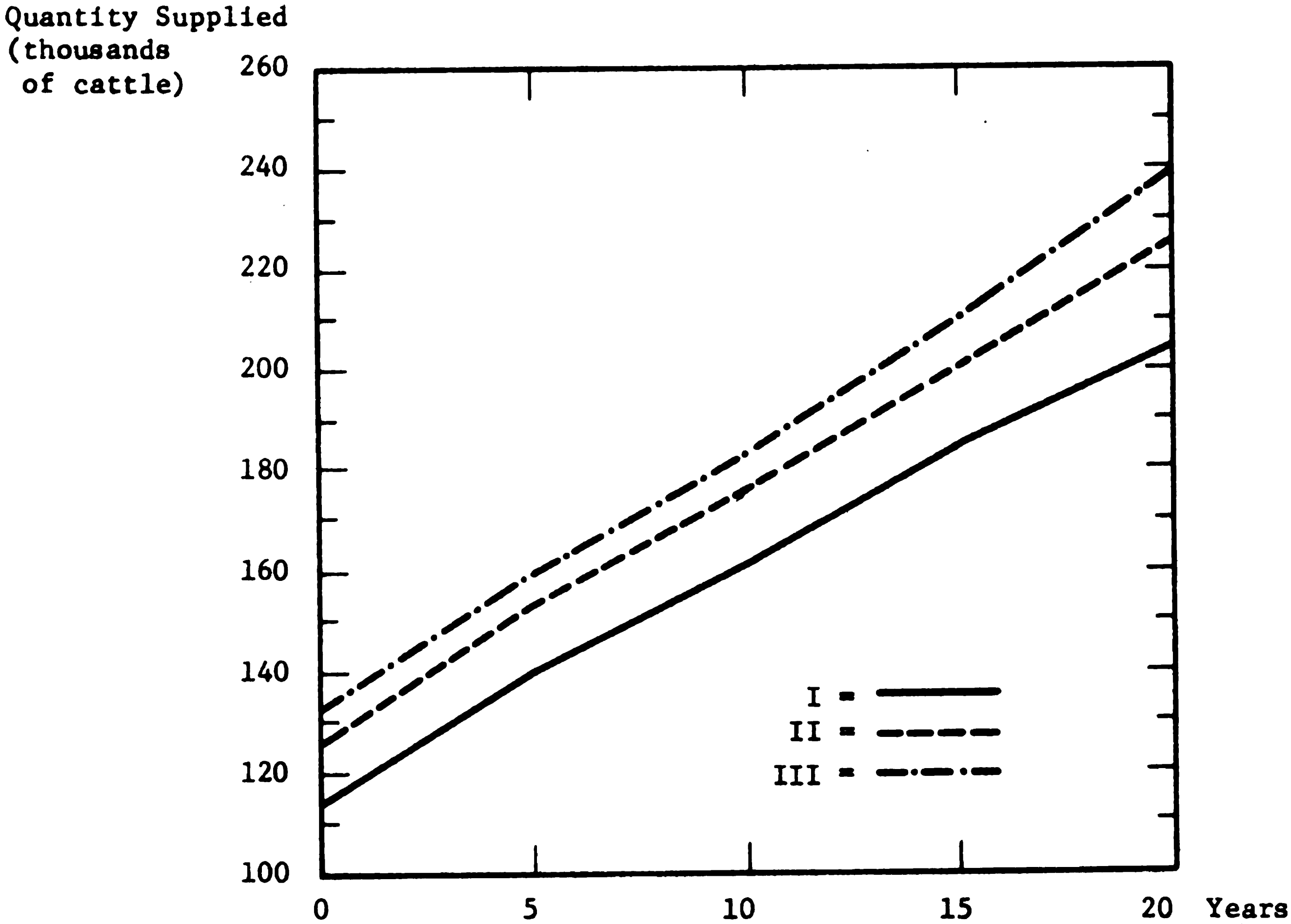
Appendix Figure III-23: Equilibrium Quantity Demanded in Area 15 Through Time Under Three Options



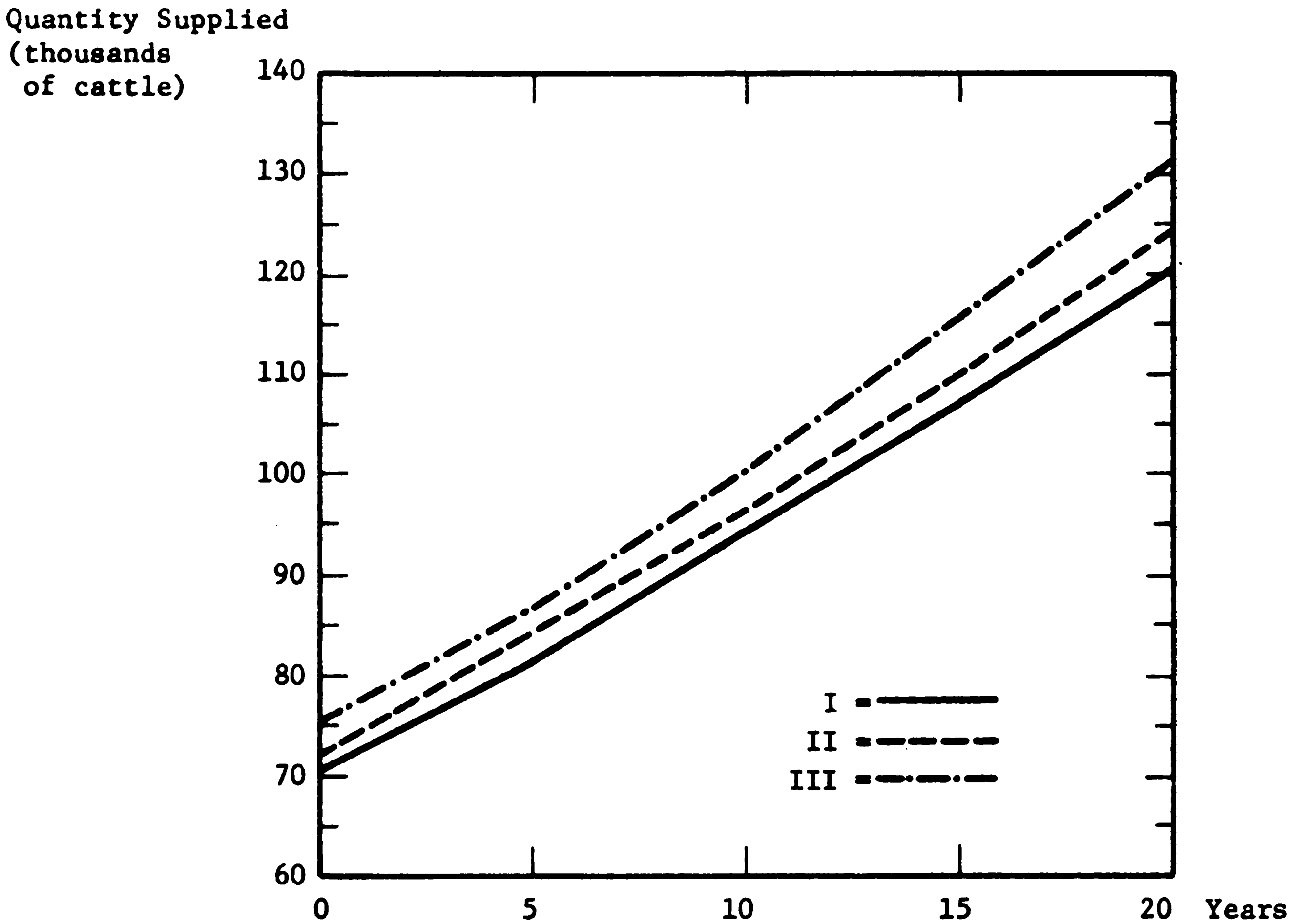
Appendix Figure III-24: Equilibrium Quantity Supplied in Area 1 Through Time Under Three Options



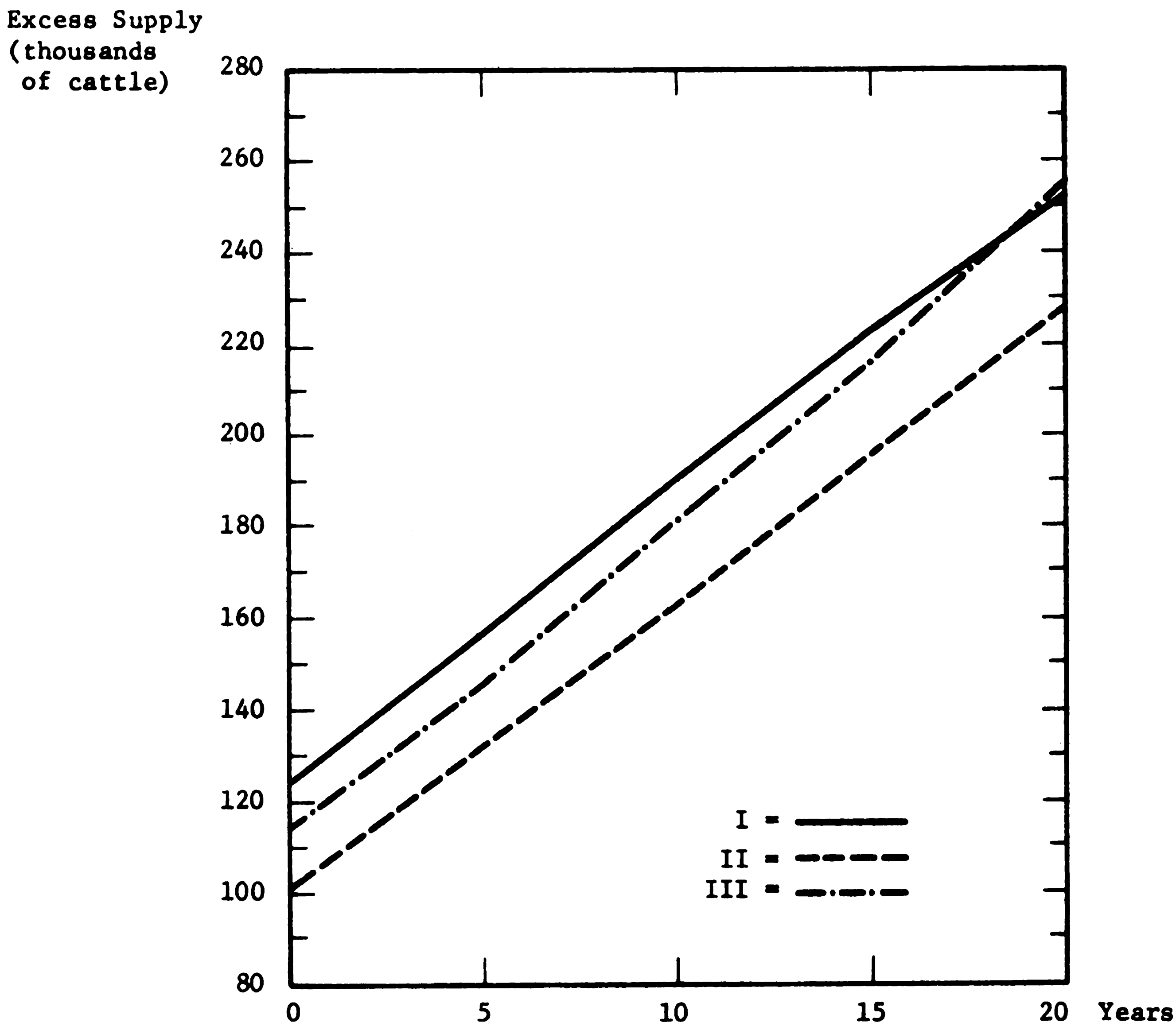
Appendix Figure III-25: Equilibrium Quantity Supplied in Area 3 Through Time Under Three Options



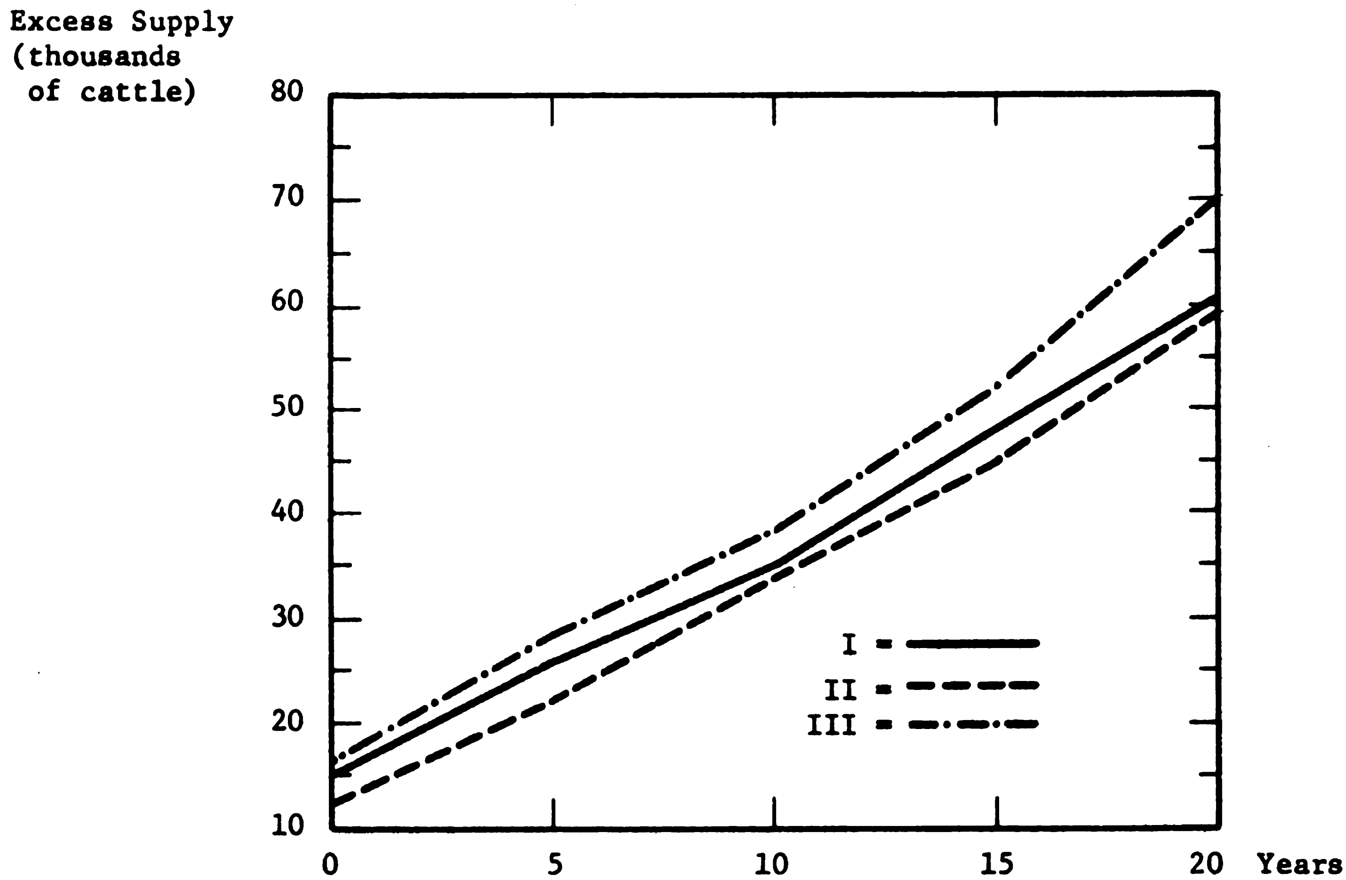
Appendix Figure III-26: Equilibrium Quantity Supplied in Area 4 Through Time Under Three Options



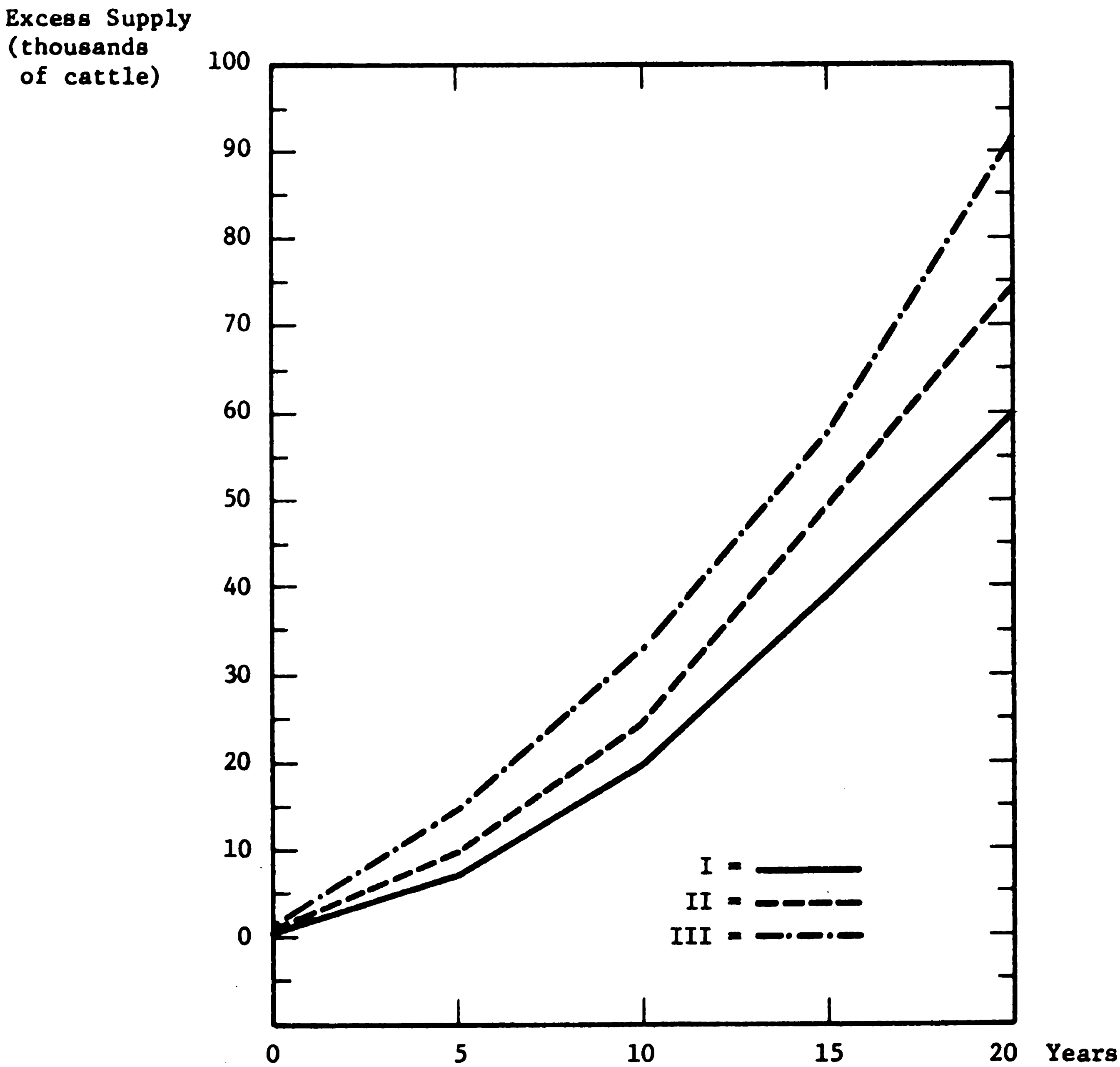
Appendix Figure III-27: Equilibrium Quantity Supplied in Area 9 Through Time Under Three Options



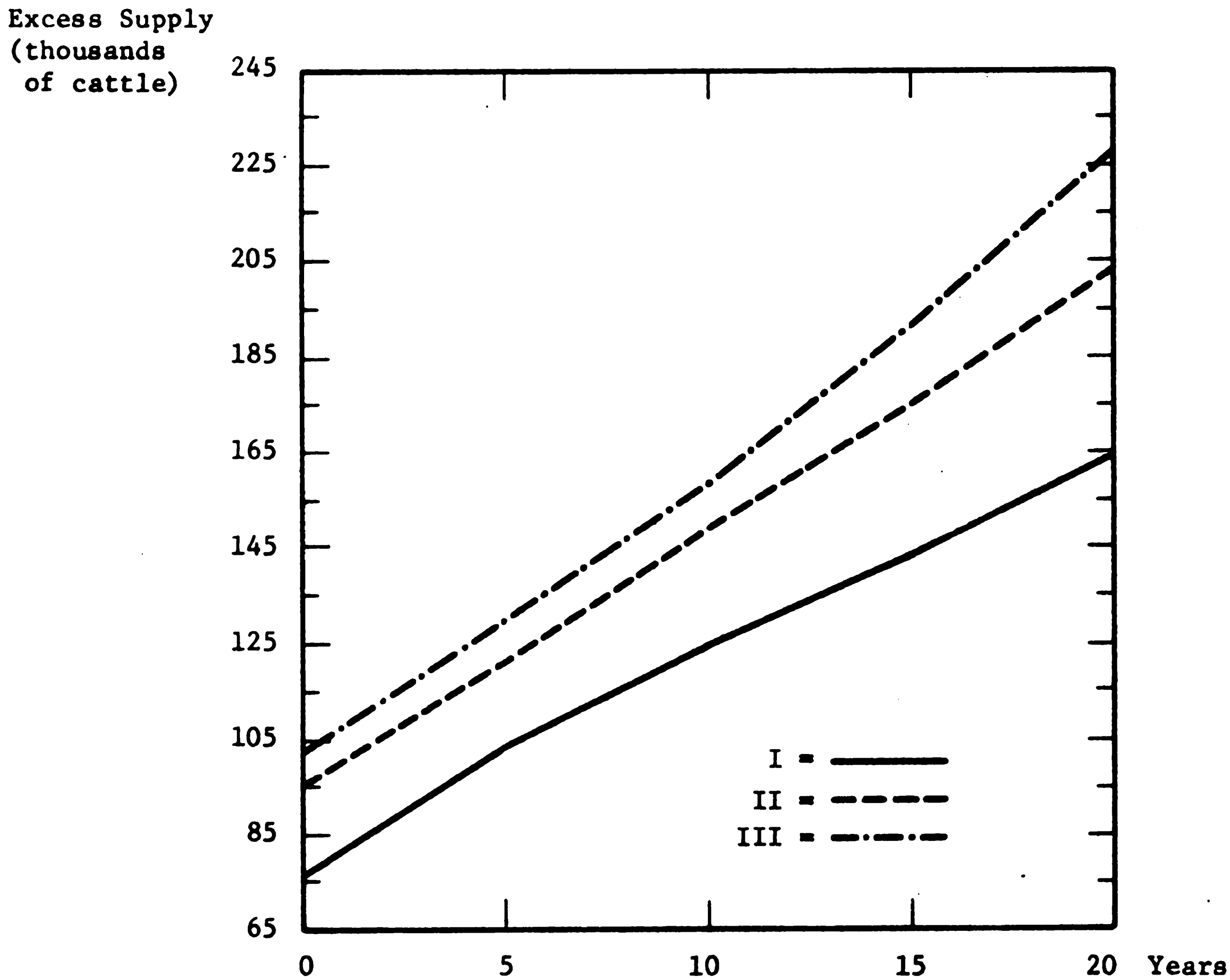
Appendix Figure III-28: Excess Supply in Area 1 Through Time Under Three Options



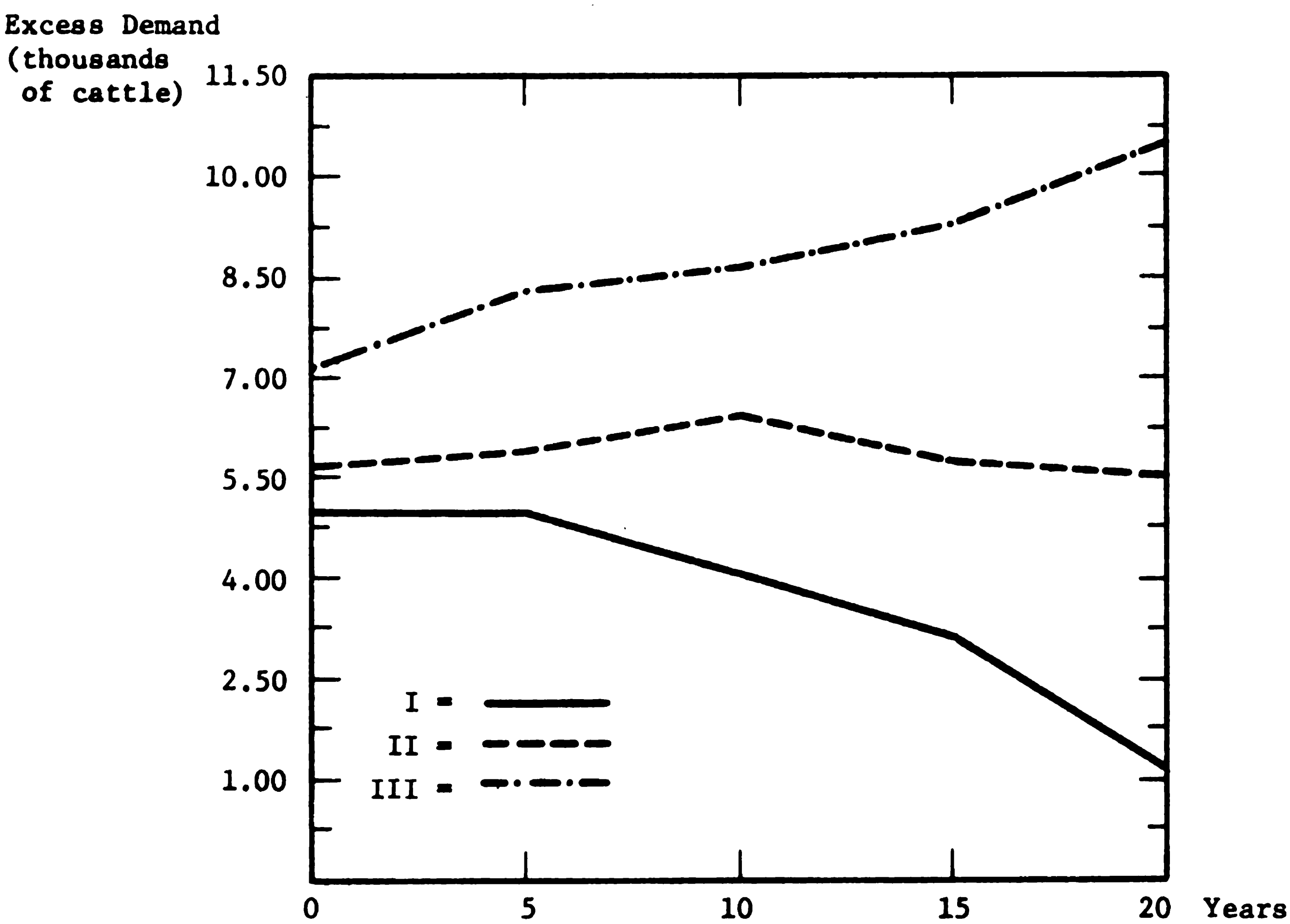
Appendix Figure III-29: Excess Supply in Area 2 Through Time Under Three Options



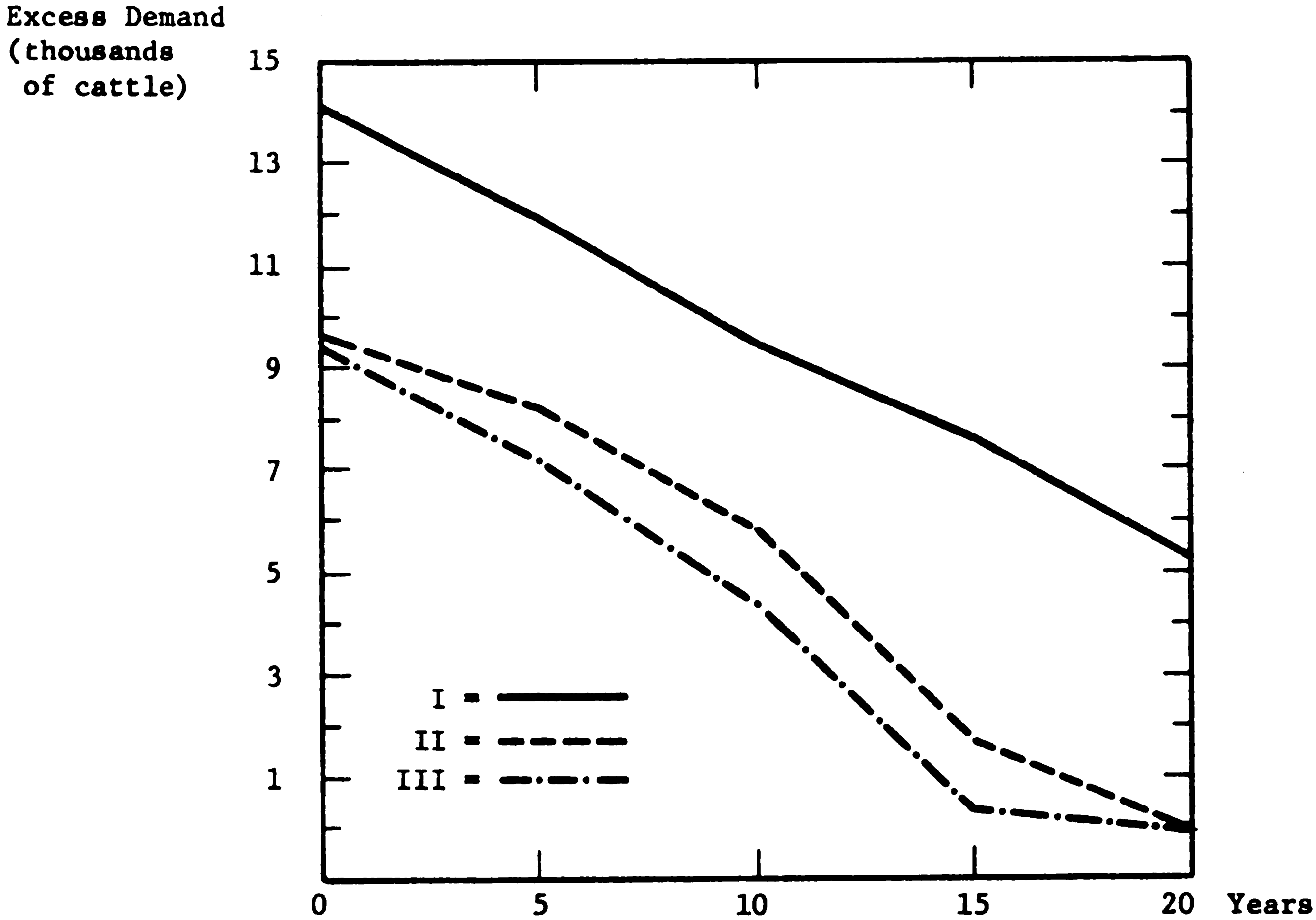
Appendix Figure III-30: Excess Supply in Area 3 Through Time Under Three Options



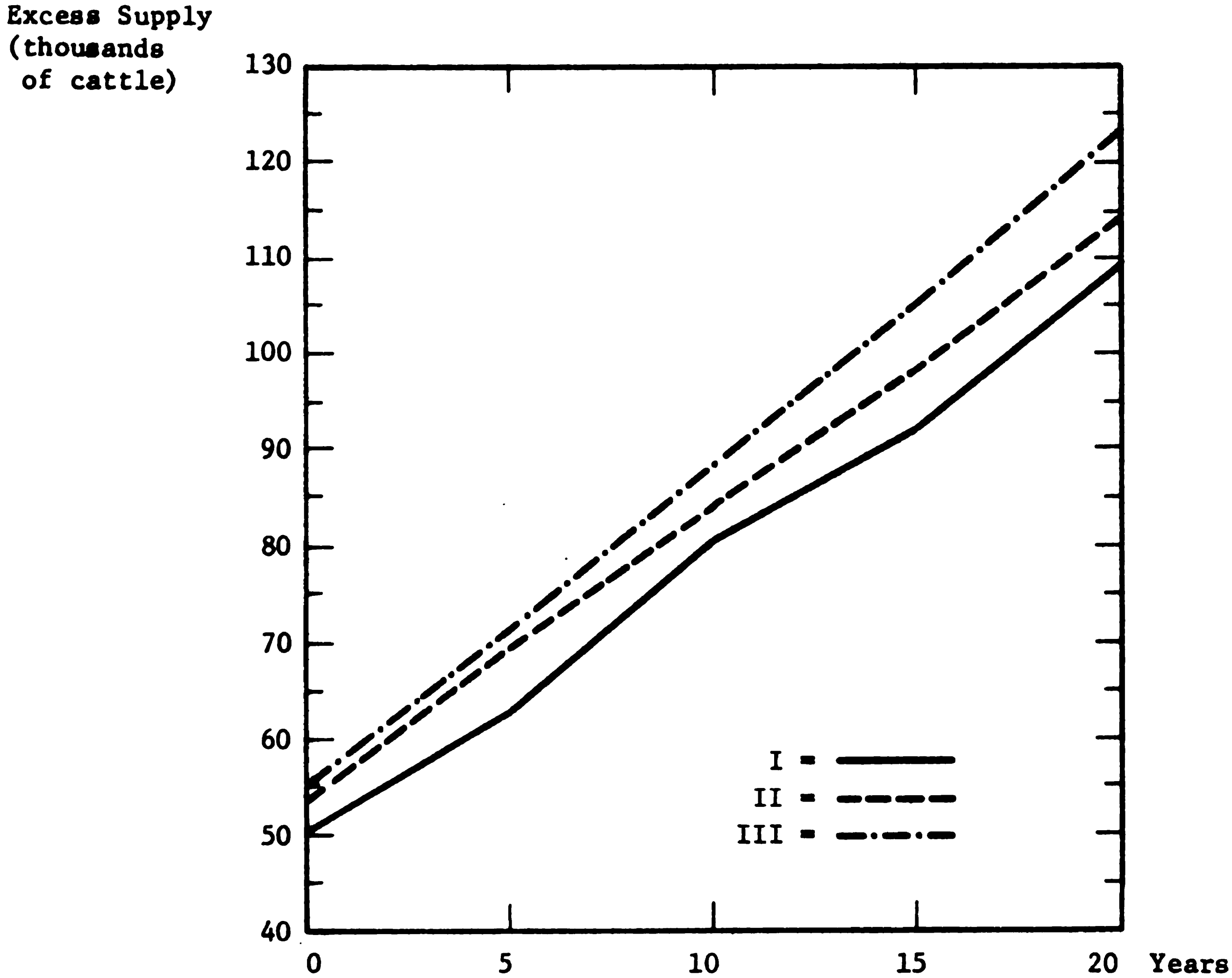
Appendix Figure III-31: Excess Supply in Area 4 Through Time Under Three Options



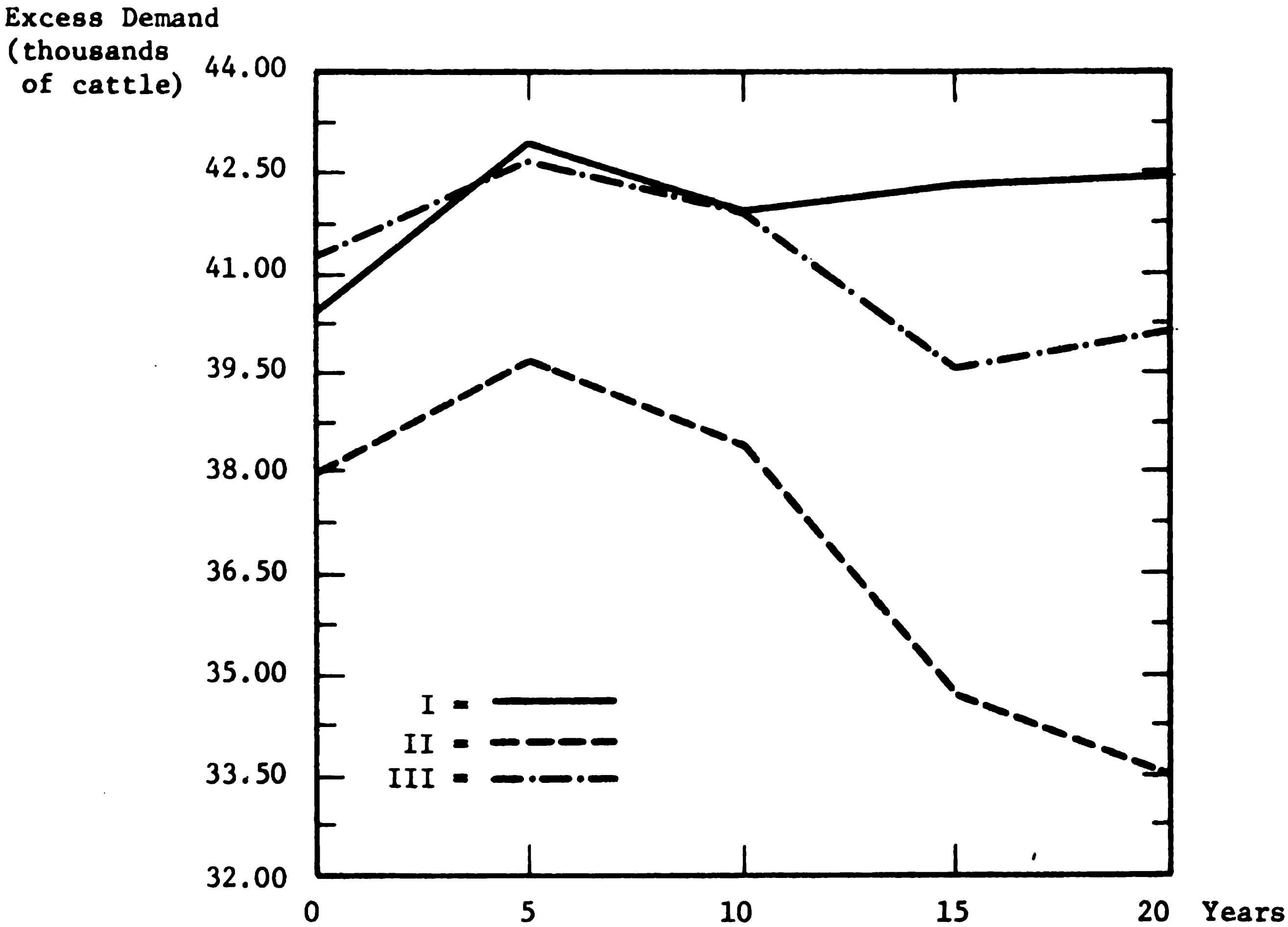
Appendix Figure III-32: Excess Demand in Area 6 Through Time Under Three Options



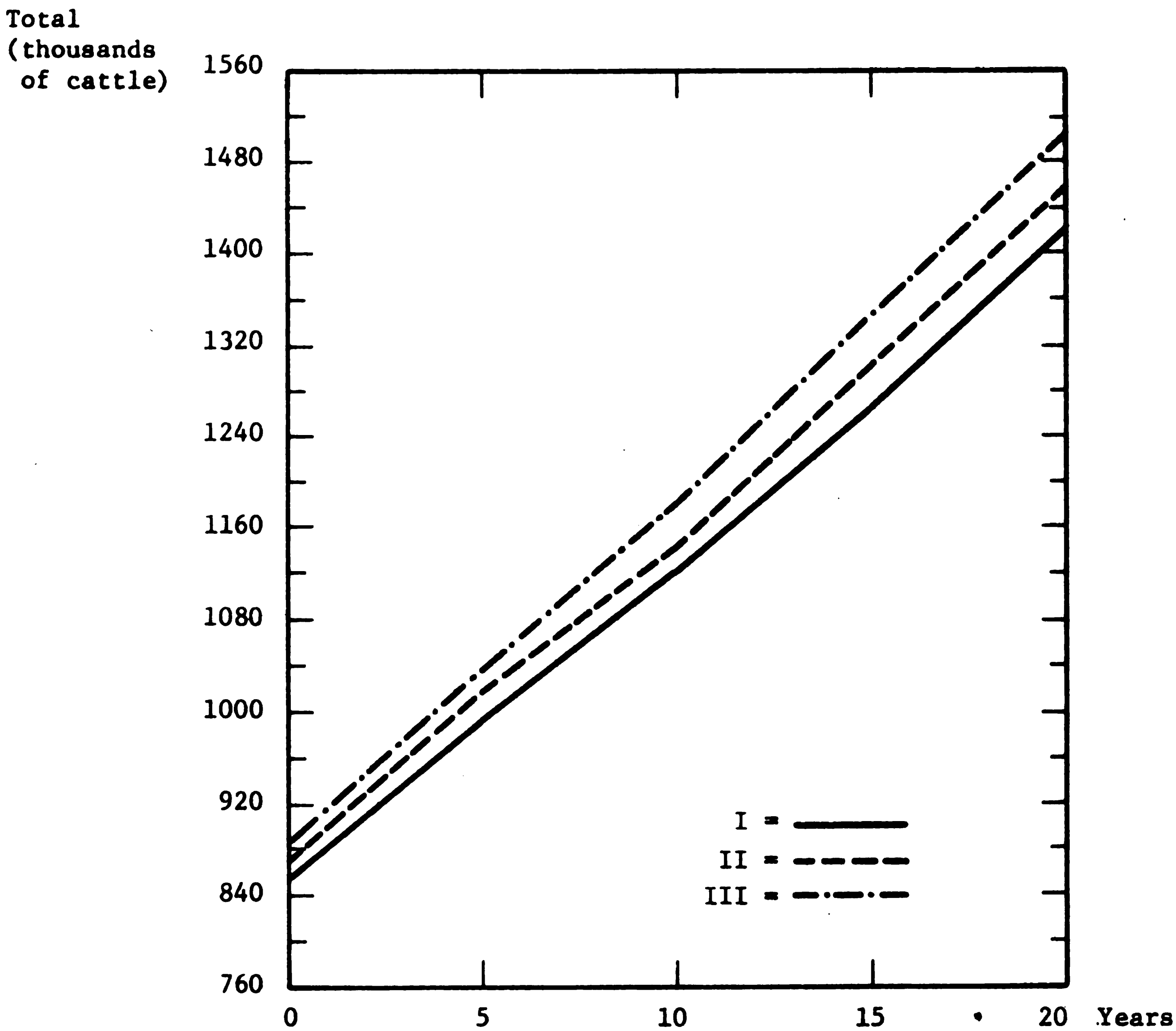
Appendix Figure III-33: Excess Demand in Area 7 Through Time Under Three Options



Appendix Figure III-34: Excess Supply in Area 9 Through Time Under Three Options



Appendix Figure III-35: Excess Demand in Area 12 Through Time Under Three Options



Appendix Figure III-36: Total Supply and Demand of Nigeria Through Time Under Three Options

APPENDIX IV

SPATIAL PRICE EQUILIBRIUM MODEL FORMULATION AND SOLUTION

The purpose of this appendix is to specify the spatial market economic problem in a manner that may be solved by mathematical programming to derive the optimum prices, quantities and interarea flows. The solution of this problem will then be shown to satisfy the spatial equilibrium market conditions specified in Chapter V. These conditions are repeated here to facilitate understanding this appendix.

Spatial Market Equilibrium Conditions

An economic state is said to be in a stable price equilibrium if the following conditions are met: {19}

(1) Market Equilibrium

No excess demand and excess supply conditions:

(a) $$\bar{y}_i - \sum_j \bar{x}_{ji} \leq 0 \quad .$$ over all i
$$\bar{\rho}_i \, (\bar{y}_i - \sum_j \bar{x}_{ji}) = 0 \quad .$$

where:

$\bar{y}_i$ = optimum consumption in area i.

$\bar{x}_{ji}$ = optimum interarea flow from area j to area i.

$\bar{\rho}_i$ = equilibrium market demand price in area i.

i,j = 1,2 ... N = number of areas in the entity being considered.

(b) $$\bar{x}_i - \sum_j \bar{x}_{ij} \geq 0$$
$$\bar{\rho}^i \, (\bar{x}_i - \sum_j x_{ij}) = 0$$ over all i's.

where:

$\bar{x}_i$ = optimum supply in area i

$\bar{\rho}^i$ = equilibrium market supply price in area i

(2) Area Consumer Equilibrium

$$\bar{\rho}_i - \bar{P}_i \geq 0$$

and

$$\bar{y}_i(\bar{\rho}_i - \bar{P}_i) = 0 \text{ for all i.}$$

where:

$\bar{P}_i$ = the maximum price the community is willing to pay for the consumption of the quantity of the commodity, $\bar{y}_i$.

(3) Area Producer Equilibrium

$$\bar{\rho}^i - \bar{P}^i \leq 0$$

and

$$\bar{x}_i(\bar{\rho}^i - \bar{P}^i) = 0 \text{ for all i}$$

where:

$\bar{P}^i$ = the minimum price at which the producer in the area are willing to supply $\bar{x}_i$.

(4) Locational Price Equilibrium

$$\bar{\rho}_j - \bar{\rho}^i - t_{ij} \leq 0$$

and

$$x_{ij}(\bar{\rho}_j - \bar{\rho}^i - t_{ij}) = 0 \text{ for all i and j}$$

where:

t_{ij} = transfer charge for the commodity to flow between area i and area j.

Problem Specification

Assume that both the demand function and supply function are given for the i^{th} region as:

$$P_i = \lambda_i - \omega_i y_i \text{ - demand}$$

$$p^i = \gamma_i + \eta_i x_i \text{ - supply}$$

for all i

Now, construct the following area quasi-welfare function for area i

$$W_i = \int_{\hat{y}_i}^{y_i} (\lambda_i - \omega_i y_i) dy_i - \int_{\hat{x}_i}^{x_i} (\gamma_i + \eta_i x_i) dx_i$$

$$= K_i + \lambda_i y_i - 1/2\, \omega y_i^2 - \gamma_i x_i - 1/2\, \eta_i x_i^2$$

where $\hat{y}_i$ and $\hat{x}_i$ are the pre-trade equilibrium quantities and K_i is a constant.

The total quasi-welfare function for the economy overall n areas is assumed to be additive and is given as:

$$W(y,x) \equiv \sum_{i=1}^{n} W_i(y_i,x_i) = \sum_{i=1}^{n} (K_i + \lambda_i y_i - 1/2\, \omega_i y_i^2 - \gamma_i x_i - 1/2\, \eta_i x_i^2)$$

in matrix form

$$W(y,x) = K + \lambda' Y - \lambda' X - 1/2\, Y' \Omega Y - 1/2\, X' HX$$

where,

$$K = \sum_i K_i$$

$$\lambda = (\lambda_1 \lambda_2 \ \ldots\ldots \ \lambda_n)'; \quad Y = (y_1 y_2 \ \ldots\ldots \ y_n)'$$

$$\gamma = (\gamma_1 \gamma_2 \ \ldots\ldots \ \gamma_n)'; \quad X = (x_1 x_2 \ \ldots\ldots \ x_n)'$$

$$\Omega = \begin{bmatrix} \omega_1 & & & \\ & \omega_2 & & \\ & & \ddots & \\ & & & \omega_n \end{bmatrix} \quad \text{and} \quad H = \begin{bmatrix} 1 & & & \\ & 2 & & \\ & & \ddots & \\ & & & n \end{bmatrix}$$

The total transportation cost for all possible flows can be written as

$$\Sigma_i \ \Sigma_j \ t_{ij} \ x_{ij} \equiv T'X$$

where $T = (t_{11} \ldots t_{1n} \ldots t_{n.} \ldots t_{nn})'$

and $X = (x_{11} \ldots x_{1n} \ldots x_{n1} \ldots x_{nn})'$

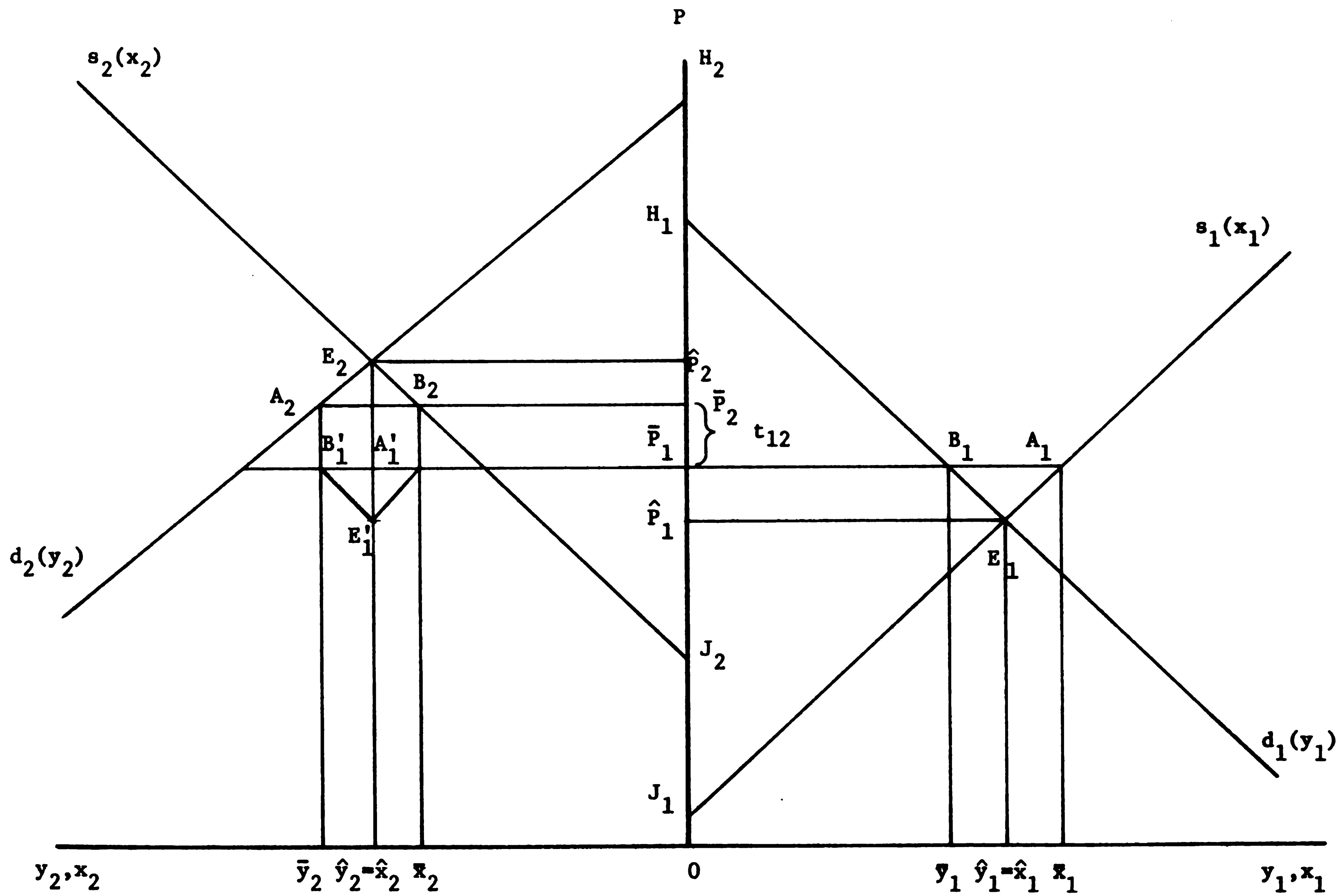
Since these costs are determined exogenously, they are considered a negative benefit or welfare for the society. Therefore, the net quasi-welfare function is:

$$NW(y,x,X) = K + \lambda'y - \gamma'x - 1/2y'\Omega y - 1/2x'Hx - T'X$$

Diagrammatic Illustration of the Quasi-Net Welfare Function

Figure IV-1 illustrates the two area example of the problem. In this case,

$$NW(x,y,X) = \int_{\hat{y}_1}^{\bar{y}_1} (\lambda_1 - \omega_i y_1)\,dy_1 - \int_{\hat{x}_1}^{\bar{x}_1} (\gamma_1 + \eta_1 x_1)\,dx_1$$



Notation

x_1, x_2 = supply quantities in area 1 and 2 respectively
y_1, y_2 = demand quantities in area 1 and 2 respectively
$s_1(x_1), s_2(x_2)$ = supply functions in area 1 and 2 respectively
$d_1(y_1), d_2(y_2)$ = demand functions in area 1 and 2 respectively

$\hat{y}_1, \hat{x}_1, \hat{y}_2, \hat{x}_2$ = pre-trade equilibrium quantities
$\bar{y}_1, \bar{x}_1, \bar{y}_2, \bar{x}_2$ = post-trade equilibrium quantities
$\hat{P}_1, \hat{P}_2$ = pre-trade equilibrium prices
$\bar{P}_1, \bar{P}_2$ = post-trade equilibrium prices
t_{12} = transfer charges between area 1 and 2

Appendix Figure IV-1: Two-Region Equilibrium Trade

$$+ \int_{\hat{y}_2}^{\bar{y}_2} (\lambda_2-\omega_2 y_2)\,dy_2 - \int_{\hat{x}_2}^{\bar{x}_2} (\gamma_2+\eta_2 x_2)\,dx_2$$

$$- t_{12}(\bar{x}_1-\bar{y}_1)$$

The integral $\int_{\hat{y}_1}^{\bar{y}_1} (\lambda_1-\omega_1 Y_1)\,dy_1$ represents area $-B_1Y_1\hat{Y}_1E_1$ or

equivalently $-B_1'\bar{y}_2\hat{y}_2E_1'$

$\int_{\hat{x}_1}^{\bar{x}_1} (\gamma_1+\eta_1 x_1)\,dx_1$ represents area $E_1\hat{x}_1\bar{x}_1A_1$ or equivalently area

$E_1'\hat{x}_2\bar{x}_2A_1'$

$\int_{\hat{y}_2}^{\bar{y}_2} (\lambda_2-\omega_2 y_2)\,dy_2$ is area $E_2A_2\bar{y}_2\hat{y}_2$

$\int_{\hat{x}_2}^{\bar{x}_2} (\gamma_2+\eta_2 x_2)\,dx_2$ is area $-E_2\hat{x}_2\bar{x}_2B_2$

$t_{12}(\bar{x}_1-\bar{y}_1)$ is area $A_2B_2B_1'A_1'$

Careful geometry will show the quasi-net welfare function is area $E_2A_2B_2+B_1'A_1'E_1'$. When spatial price equilibrium is reached, this area will be maximized.

Constraints

For each area, the quantity actually consumed is assumed to be less than or equal to the quantity shipped into the area from all other areas. Thus,

$$y_i \le \sum_{j=1}^{n} x_{ji}$$

for all i and j

Additionally, the actual supply quantity, x_i, is assumed to be greater than or equal to the effective supply to all regions. Thus,

$$x_i \ge \sum_{j=1}^{n} x_{ij} \text{ for all } i \text{ and } j$$

These constraints may be written compactly in the following matrix form.

$$GX \begin{bmatrix} y \\ \\ -x \end{bmatrix} \text{ and } y \ge 0,\ x \ge 0,\ X \ge 0$$

where

$$G = \begin{bmatrix} 1 & & & 1 & & & \cdots & 1 & & \\ & 1 & & & 1 & & \cdots & & 1 & \\ & & \ddots & & & \ddots & & & & \ddots \\ & & 1 & & & 1 & & & & 1 \\ -1 & -1 & \cdots & -1 & & & & & & \\ & & & -1 & -1 & \cdots & -1 & & & \\ & & & & & & \ddots & & & \\ & & & & & & & -1 & -1 \cdots & -1 \end{bmatrix}$$

$(2n \times n^2)$

$$X = \begin{bmatrix} x_{11} x_{12} \cdots x_{1n}, x_{21} x_{22} \cdots x_{2n} \cdots x_{n1}, x_{n2} \cdots x_{nn} \end{bmatrix}'$$

$(n^2 \times 1)$

$$\begin{bmatrix} y \\ \\ -x \end{bmatrix} = (y_1, y_2 \ldots y_n, x_1, x_2 \ldots x_n)'$$

The first row of the constraint inequality is

$$x_{11} + x_{21} + \ldots + x_{n1} \geq y_1$$

The $(n+1)^{\underline{st}}$ row of the constraint inequality is

$$-x_{11} - x_{12} \ldots -x_{1n} \geq -x_1$$

Therefore, the two constraining conditions are correctly specified in

$$GX \begin{bmatrix} y \\ \\ -x \end{bmatrix} .$$

Optimality Conditions

In order to derive the necessary conditions for the maximum of the objective function subject to the constraints, the following Lagrangean is formed:

$$\phi(y_1 x_1 X_1 \rho) = K + \lambda' y - \gamma' x - 1/2\ y'\ \Omega y - 1/2\ x' H x - T' X + \rho(GX - \begin{bmatrix} y \\ \\ -x \end{bmatrix}$$

where

$$\rho \equiv (\rho_1 \rho_2 \ldots \rho_n,\ \rho^1 \rho^2 \ldots \rho^n)$$

$$(2n\ X\ 1)$$

Following Kuhn-Tucker, the necessary conditions for this saddle value problem are as follows:

$$\text{(a)} \quad \frac{\partial\bar{\phi}}{\partial y} = \lambda - \Omega y - \bar{\rho}_y \leq 0 \text{ and } \left(\frac{\partial\bar{\phi}}{\partial y}\right)' \bar{y} = 0$$

$$\text{(b)} \quad \frac{\partial\bar{\phi}}{\partial x} = -\gamma' - Hx + \bar{\rho}_x \leq 0 \text{ and } \left(\frac{\partial\bar{\phi}}{\partial y}\right)' \bar{x} = 0$$

$$\text{(c)} \quad \frac{\partial\bar{\phi}}{\partial X} = -T' + G'\bar{\rho} \leq 0 \text{ and } \left(\frac{\partial\bar{\phi}}{\partial X}\right) \bar{X} = 0$$

$$\text{(d)} \quad \frac{\partial\bar{\phi}}{\partial \rho} = G\,\bar{X} - \begin{bmatrix} \bar{y} \\ \\ -\bar{x} \end{bmatrix} \geq 0 \text{ and } \left(\frac{\partial\bar{\phi}}{\partial \rho}\right) \bar{\rho} = 0$$

Component wise, the above expressions are:

$$\text{(a)} \quad \frac{\partial\bar{\phi}}{\partial y_i} = \lambda_i - \omega_i y_i - \bar{\rho}_i \leq 0 \text{ and } \frac{\partial\bar{\phi}}{\partial y_i}\,\bar{y}_i = 0 \text{ for all } i$$

$$\text{(b)} \quad \frac{\partial\bar{\phi}}{\partial x_i} = \bar{\rho}^i - (\gamma_i + \eta_i x_i) \leq 0 \text{ and } \frac{\partial\bar{\phi}}{\partial x_i}\,\bar{x}_i = 0 \text{ for all } i$$

$$\text{(c)} \quad \frac{\partial\bar{\phi}}{\partial x_{ij}} = \bar{\rho}_j - \bar{\rho}^i - t_{ij} \leq 0 \text{ and } \frac{\partial\bar{\phi}}{\partial x_{ij}}\,\bar{x}_{ij} = 0 \text{ for all } i \text{ and } j$$

$$\text{(d)} \quad \begin{aligned} &\frac{\partial\bar{\phi}}{\partial \rho_i} = \sum_{j=1}^{n} x_{ji} - \bar{y}_i \geq 0 \text{ and } \frac{\partial\bar{\phi}}{\partial \rho_i}\,\bar{\rho}^i = 0 \text{ for all } i \\ &\frac{\partial\bar{\phi}}{\partial \rho^i} = -\sum_{j=1}^{n} \bar{x}_{ij} + \bar{x}_i \geq 0 \text{ and } \frac{\partial\phi}{\partial \rho^i}\,\bar{\rho}^i = 0 \text{ for all } i \end{aligned}$$

These optimality conditions fulfill the equilibrium spatial market conditions previously specified as explained below.

Condition (a) may be rewritten as:

$$P_i = \lambda_i - \omega_i\bar{y}_i \leq \bar{\rho}_i$$

and

$$\bar{y}_i(\bar{\rho}_i - \bar{P}_i) = 0 \qquad \text{for all } i$$

This is equivalent to (2) the consumer equilibrium condition which states that at the optimum, (i) when consumption in the i^{th} area is positive, then the area demand price P_i, is equal to the market demand price, $\bar{\rho}_i$, and (ii) when $\bar{y}_i = 0$, the market demand price $\bar{\rho}_i$, must be greater than or equal to the area demand price, P_i.

Condition (b) may be written as:

$$P^i = \gamma_i + \eta_i - \bar{x}_i \geq \bar{\rho}^i$$

and

$$\bar{x}^i\ (\bar{\rho}^i - \bar{P}^i) = 0$$

This corresponds to condition (3) and may be interpreted as follows: At the optimum, (i) when the supply is positive in the i^{th} region, then the market supply price, $\bar{\rho}^i$, is equal to the area supply price, P^i and (ii) if $\bar{x}_i = 0$, the market supply price, $\bar{\rho}^i$, must be smaller than or equal to the regional supply price.

Condition (c) is:

$$\bar{\rho}^i + t_{ij} = \bar{\rho}_j$$

and $\qquad$ for all i and j

$$\bar{x}_{ij}(\bar{\rho}_j - \bar{\rho}^i - t_{ij}) = 0$$

This is equivalent to condition (4). It may be interpreted as: When the optimum flow is positive, $\bar{x}_{ij} > 0$, the difference between the market supply and demand price is equal to the transportation rate, and

(ii) if $\bar{x}_{ij} = 0$, the difference is less than or equal to the transportation cost.

Finally, condition (d) relates the excess demand and supply possibilities and is equivalent to condition 1 (a) and (b).

$$\sum_{j=1}^{n} \bar{x}_{ji} \geq \bar{y}_i$$

and

$$\bar{\rho}_i \left(\sum_{j=1}^{n} x_{ji} - \bar{y}_i \right) = 0.$$

When the optimal market demand price, $\bar{\rho}_i$, is positive, the optimal consumption quantity, $\bar{y}_i$, is exactly met by inshipments from all areas, $\sum_j \bar{x}_{ji}$. If $\bar{\rho}_i$ is zero, there may be excess inshipment or zero inshipment over the optimal consumption.

$$\sum_{j=1}^{n} x_{ij} \leq \bar{x}_i$$

and

$$\bar{\rho}^i \, (\bar{x}_i - \sum_{j=1}^{n} x_{ij}) = 0$$

When the optimal market price, $\bar{\rho}^i$, is positive, the total supply quantity, $\bar{x}_i$, is exactly met by the out shipments to all areas including itself. If $\bar{\rho}^i$ is zero, the total production in the area exceeds or just meets the total of self supply and outshipments from the area. Therefore, it is shown that that result of maximizing the objective function previously stated fulfills the conditions laid down for spatial price equilibrium.