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The comparative advantage of the Michigan beef industry's feedlot sector

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THE COMPARATIVE ADVANTAGE OF THE MICHIGAN BEEF INDUSTRY'S FEEDLOT SECTOR

By

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ABSTRACT

THE COMPARATIVE ADVANTAGE OF THE MICHIGAN BEEF INDUSTRY'S FEEDLOT SECTOR

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The comparative position of the Michigan fed cattle industry is determined. The comparison of net returns to raising fed cattle on farm produced feeds to those earned on a similar land base growing a corn-soybean-wheat rotation is used to determine the value added by feeding crops grown to fed cattle as part of the farm operation. This comparison showed that fed cattle production in Michigan, practiced under most production and marketing strategies, can add value to farm raised crops. Comparing net returns to fed beef cattle production in Michigan with those in Kansas provides insight into the future locational evolution of fed cattle production in the U.S. Under most production and marketing strategies considered, net return to fed cattle production in Michigan was found to be higher than in Kansas. Therefore, if the U.S. fed cattle industry is in equilibrium, the Michigan industry has strong potential for growth. Although, depending on the opportunity cost of capital invested in feedlots in the Central and Southern Plains, the U.S. industry may not be in equilibrium and the profitability of feeding cattle in Michigan may diminish as feeder cattle prices are bid up and fed cattle prices are bid down. If this is the case, as is hypothesized by observing the rapidly growing fed cattle industry in the Central and Southern Plains states, the industry will continue to shift to this region. As a precursor to determining comparative advantage, net return to Michigan fed cattle production for different size farms and under various production and marketing strategies including varying purchase and sale weights of cattle, seasonal versus year round marketing, and the feeding of different diets is determined. Net returns to fed beef production in Michigan were found to be highly dependent on production and, particularly marketing, strategies employed on the farm

although positive net returns were found under all strategies and for each size feedlot. The net return to feeding calves was, in general, higher than that for feeding yearlings. Net return was higher when calves and yearlings were purchased at lighter weights and when yearlings were sold at a heavier weight. More concentrated diets, in general, resulted in higher net returns than less concentrated diets. Net return was higher with seasonal versus year round marketing for feedlots with 1200 head or more capacity. Favorable seasonal price trends under seasonal marketing outweighed higher production costs resulting from the lower annual level of capacity utilization. Economies of size were nearly exhausted by the 3000 head capacity feedlot size.

Dedicated to the men and women of the Michigan beef cattle industry

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TABLE OF CONTENTS

CHAPTER 3 METHODS

CHAPTER 6 REGIONAL COMPARATIVE ADVANTAGE IN THE FED BEEF CATTLE INDUSTRY

CHAPTER 7 SUMMARY AND CONCLUSIONS

APPENDICES

LIST OF TABLES

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 5

LIST OF FIGURES

CHAPTER 1

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

GLOSSARY

400 OT	400 head capacity feedlot feeding one group of 400 cattle annually.
400 CM	400 head capacity feedlot marketing cattle year round and operating at 80% capacity.
1200 OT	1200 head capacity feedlot feeding one group of 1200 cattle annually.
1200 CM	1200 head capacity feedlot marketing cattle year round and operating at 80% capacity.
3000 OT	3000 head capacity feedlot feeding one group of 3000 cattle annually.
3000 CM	3000 head capacity feedlot marketing cattle year round and operating at 80% capacity.
6000 OT	6000 head capacity feedlot feeding one group of 6000 cattle annually.
6000 CM	6000 head capacity feedlot marketing cattle year round and operating at 80% capacity.
C1	Calf diet 1. The starter, grower, and finisher diets are 45, 57, and 71 percent concentrate on a dry matter basis, respectively. Corn as a percent of diet is equivalent to that of Y4.
C2	Calf diet 2. The starter and finisher diets are 8 and 71 percent concentrate on a dry matter basis, respectively. The starter ration has no corn. The diet has no grower ration.
C3	Calf diet 3. The starter, grower, and finisher diets are 71, 81, and 89 percent concentrate on a dry matter basis, respectively. C3 is the most concentrated diet.
Diet	Describes the feeds fed to an animal during each of three stages in the feedlot; starter, grower, and finisher.
Ration	Described by the relative proportions of corn, corn silage, soybean meal, urea, limestone, potassium chloride, and white salt as a percent of the total mixed ration. Each diet is comprised of the starter, grower, and finisher rations.
SYRL	Short yearling; a yearling purchased at 600 lb.
Y1	Yearling diet 1. The starter, grower, and finisher rations are 63, 69, and 89 percent concentrate on a dry matter basis, respectively. Y1 is the most concentrated yearling diet.

Y2 Yearling diet 2. The starter, grower, and finisher rations are 25, 36, and 60 percent concentrate on a dry matter basis, respectively. Y2 is the least concentrated yearling diet and represents the average diet fed to steer yearlings by Michigan producers marketing more than 500 head of cattle annually.

Y3 Yearling diet 3. The starter, grower, and finisher rations are 25, 55, and 83 percent concentrate on a dry matter basis, respectively.

Y4 Yearling diet 4. The starter, grower, and finisher diets are 46, 59, and 74 percent concentrate on a dry matter basis, respectively.

YRL Yearling; a yearling purchased at 750 lb.

CHAPTER 1 INTRODUCTION

NATIONAL BEEF CATTLE INDUSTRY

Measured by value of total sales, the beef industry is the largest segment of the U.S. livestock sector. In 1991, sale of cattle and calves was 30.5 billion dollars and accounted for 16 percent of total cash receipts from all U.S. farms (U.S.D.A., 1992). Beef has historically been an important component of the U.S. diet. U.S. per capita consumption of beef increased rapidly from 1950 to the mid 1970's, peaked in 1976, and has since declined (Figure 1.1). The rapid industry growth prior to 1976 was fueled by increasing demand and decreased production costs. Real production costs fell as a result of technological advances in the production and marketing of beef. The subsequent decline in per capita beef consumption is attributed to decreased demand as consumers have become increasingly concerned about the effect of dietary consumption on health and to the inability of the industry to match the large production and distribution efficiency gains of the pork and, particularly, the poultry industries. More recent evidence indicates that the rate of decline in per capita beef consumption has slowed in recent years and, perhaps, stabilized (Ferris, 1992).

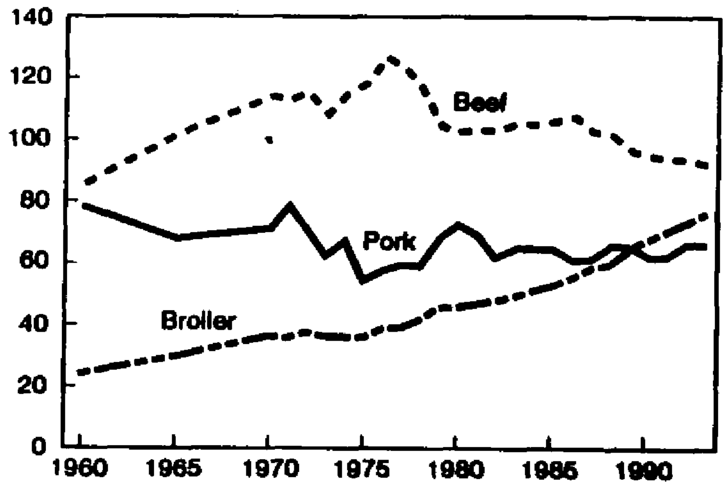

Figure 1.1 U.S. per capita beef consumption

As demand stabilizes, there has been a renewed interest in changes in the location and structure of the industry[1] [2]. Two such changes which have occurred in the beef cattle feedlot sector over the last three decades are the movement of cattle feeding to the Central and Southern Plains region and an increase in size and decrease in number of feedlots[3].

Since the mid 1950's, the location of fed cattle marketings has shifted from the Corn Belt to the Central and Southern Plains states (USDA, various years). While Texas, Oklahoma, Kansas, Nebraska, and Colorado increased their combined share of U.S. fed cattle marketed

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[1] Comprehensive reviews of the historic path of the U.S. beef cattle industry are presented in Krause (1991), McCoy and Sarhan (1988), and Riley and Heimstra (1982).

[2] A brief review of these changes and their underlying causes is provided in Chapter 2 as background information on the historical evolution of comparative advantage in fed beef production. It serves to provide context for the assessment of the present comparative advantage of the Michigan beef cattle industry's feedlot sector.

[3] A third structural change experienced by the U.S. beef cattle industry important, due to its potential to lower costs, increase revenue, and reduce risk for producers, is the trend towards vertical integration through ownership or contract.

from 30% in 1955 to 70% in 1989, that of the Corn Belt states dropped from 42% to 15% (Krause, 1991). In 1990, just 3 states (Nebraska, Texas, and Kansas) marketed 62% of all fed cattle from the 13 states included in the U.S.D.A Cattle on Feed report (Blach, 1991)[4]. The regional shift in fed cattle production is attributed to a combination of factors which lowered costs and increased revenues for producers in the Central and Southern Plains states relative to the Corn Belt states.

Most industry experts predict that cattle feeding will continue to shift to regions with a comparative advantage in feed efficiency due to a favorable climate and feed cost (National Cattlemen's Association, 1989). The current locational concentration of packers in the highest fed cattle production area of the country is further cited as evidence that feedlot concentration will not shift away from this area, if at all, for many years to come.

A second important structural change in the fed beef cattle industry occurring simultaneous to the locational shift is the increase in size and the reduction in number of cattle feeders. So concentrated has the industry become, that in 1990, 205 feed yards marketed 52% of all fed cattle in the thirteen major cattle feeding states. Out of 44,000 feedlots in these states, 1,634 feedlots marketed 85% of all fed cattle. The largest decline in feedlot number has been feedlots of less than 1000 head capacity, although the trend towards larger feedlots has varied by region.

[4] Arizona, California, Colorado, Idaho, Illinois, Iowa, Kansas, Minnesota, Nebraska, Oklahoma, South Dakota, Texas, and Washington are included in the Cattle on Feed Report.

The net result of these structural changes in the location, concentration, and size of feedlots in the U.S. is that Eastern Corn Belt states have lost ground relative to the Western Corn Belt and High Plains regions (Allen, 1984) (Figure 1.2). However, Michigan's share of cattle on feed in the Corn Belt and nationally has increased since 1980 (Figure 1.3, Figure 1.4). Beef cattle production is Michigan's fourth largest agriculture industry with approximately 800 cattle feeders marketing 300,000 fed cattle per year. Nationally, Michigan has moved from sixteenth position in 1980 to eleventh in 1992 in total beef production.

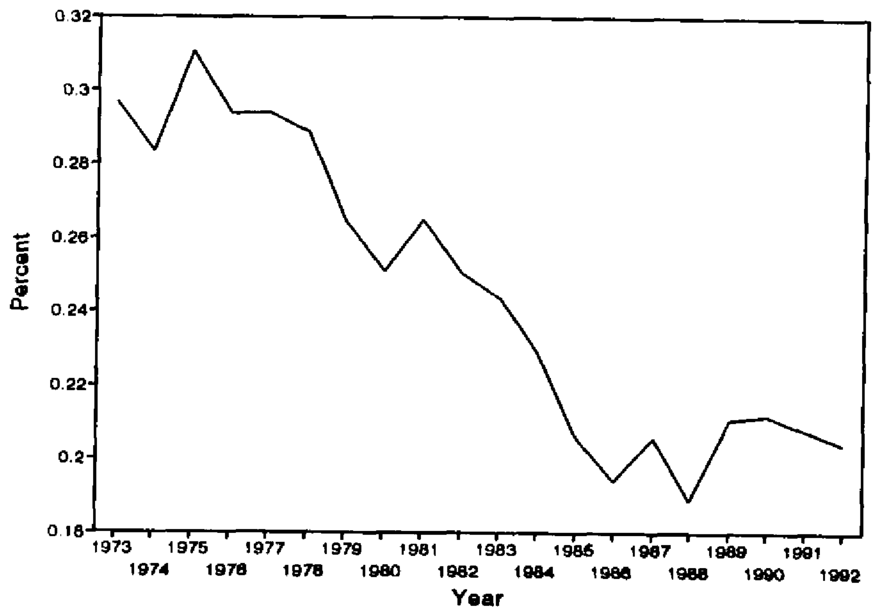

Figure 1.2 Cattle on feed: Corn Belt as a percent of the U.S. market

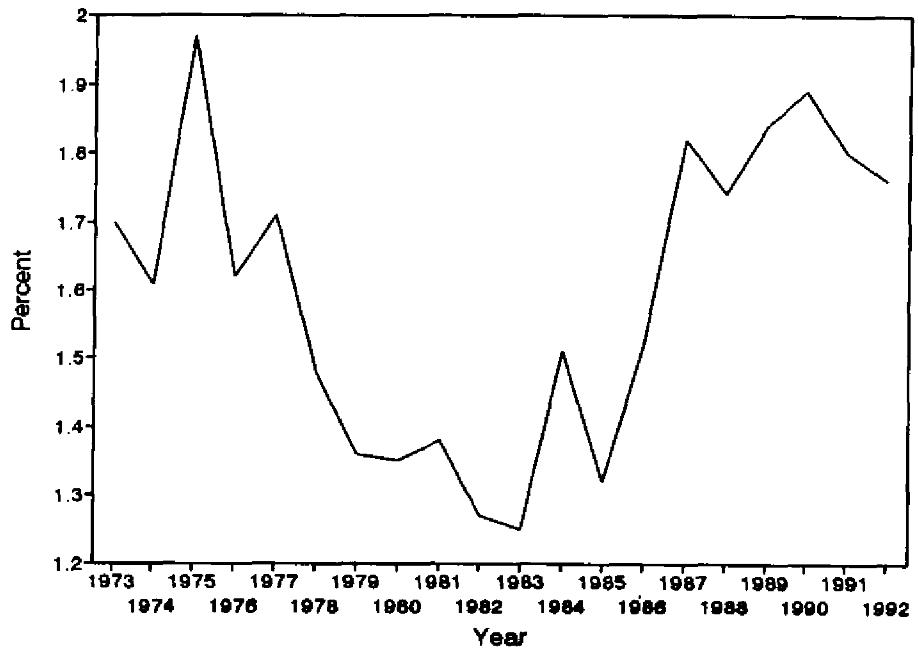

Figure 1.3 Cattle on feed: Michigan as a percent of the U.S. market

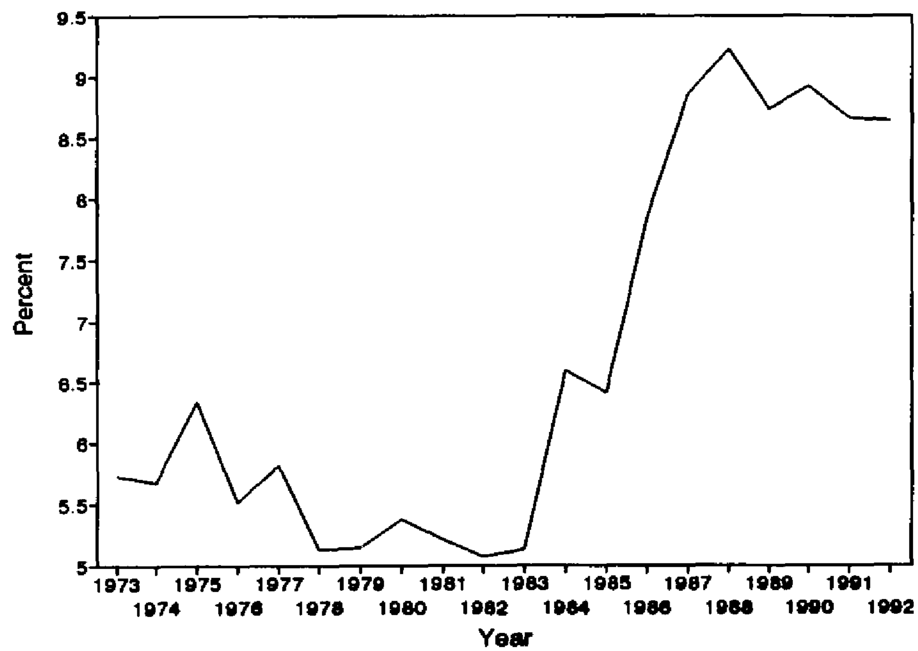

Figure 1.4 Cattle on feed: Michigan as a percent of the Corn Belt market

Although Michigan has lost market share relative to the Western Corn Belt and High Plains regions in both cattle feeding and slaughter, the increase in Michigan's share of both national and Corn Belt fed cattle marketings since 1980 indicates that it holds a comparative advantage over other Corn Belt states. While Illinois, Iowa, and Minnesota have lost market share, seemingly to more profitable opportunities in corn (Illinois and Iowa) and swine (Minnesota) production, industry leaders (Ritchie and Rust, 1992a) have projected that Michigan will continue to be in the top three cattle feeding states east of the Mississippi river[5].

PROBLEM STATEMENT AND OVERALL OBJECTIVE

Michigan is vying for a share in the mature, even declining, U.S. feedlot sector. The primary objective of this study is to determine the comparative situation of the Michigan fed beef cattle sector. Under the assumption that feeder and fed cattle prices are in equilibrium, the Michigan feedlot sector must be gaged relative to other viable agricultural industries in Michigan competing for available land, labor, and management. When the continuing shift of fed cattle production from the Corn Belt to the Central and Southern Plains is taken as evidence that feeder and fed cattle prices are not in equilibrium, Michigan's comparative advantage is gaged through comparison to fed cattle production in other regions. Satisfying this objective involves determining those conditions under which the Michigan feedlot industry's feedlot industry can compete.

[5] Participation of Michigan Livestock Exchange or an alternative credit provider will be particularly important.

SPECIFIC OBJECTIVES

Nine, more specific, objectives are addressed.

1. *Define and describe characteristics of Michigan cattle feeders.* The existing nature of the Michigan feedlot sector is described. Specific operational details are added using the 1989 Michigan feedlot survey (Ritchie, et al., 1992) and interviews with producers and other industry experts. Describing the characteristics of Michigan cattle feeders will involve estimating typical resource use relationships for producers with moderate to upper level management skills. Bioeconomic models depicting the feedlot and crop enterprises will be developed or updated to estimate input/output coefficients necessary to develop whole farm budgets for representative farms.

2. *Determine costs of producing fed beef cattle in Michigan for farms of different sizes under various production and marketing schemes.* Production costs will be estimated for farms of four sizes (400, 1200, 3000, and 6000 head capacity). Alternative marketing strategies will include seasonal versus year round marketing and alternative purchase and sale weights. Diets of varying energy content will be considered.

3. *Determine gross margins faced by Michigan cattle feeders.* Gross margins for Michigan producers buying cattle in the southeastern U.S. will be estimated. Transportation costs, commissions, shrink, and death loss will be subtracted from net revenue when calculating gross margins.

4. *Define the profitability of feeding cattle in Michigan for farms of different sizes and under varying production and marketing schemes as gross margin less production cost per head.*

5. *Determine the extent to which (dis)economies of size exist in Michigan fed cattle production.* A range of farm sizes is evaluated to identify the causes and estimate the magnitude of (dis)economies of size in Michigan fed cattle production.

6. *Determine the effect of different production and marketing strategies on net return to fed cattle production in Michigan.* The most and least profitable systems are identified.

7. *Calculate the economic return to cattle feeding in Michigan where: (1) economic profit is the accounting profit (net return to land and management) obtained from the feedlot enterprise less net return to the next most profitable alternative and (2) the next most profitable alternative is defined as a corn-soybean-wheat rotation on the same ground used to produce corn and corn silage for the feedlot enterprise.*

8. *Describe the costs and returns of feeding cattle in Kansas, a state with an expanding fed cattle industry, and compare returns to fed cattle production in Michigan with those in Kansas.* The ability of Michigan cattle producers to compete with producers in Kansas under current price levels will be determined. The ability of Michigan producers to bid feeder cattle in the southeastern United States away from Kansas feedlots will serve to indicate existing comparative advantage.

9. *Describe the situations under which cattle can viably be fed in Michigan and define the potential for expanding fed beef cattle production in Michigan.*

ORGANIZATION

The remaining chapters are organized as follows. Chapter 2 presents a review of literature, particularly that dealing with comparative advantage and of the presence of economies of size in the livestock industry. Sector level studies of cattle and hog feeding throughout the U.S. are considered. The major objectives of this review are to determine (1) factors which influence comparative advantage and economies of size within a region and between regions and (2) the affect of these factors under environments characterized by differing resource availability, competing agricultural and nonagricultural enterprises, climates, and government and other institutional influences. Chapter 3 describes and justifies the analytical model used to develop whole farm budgets, parameterize resource relationships, and determine net return to fed cattle production in Michigan. Components of the crop and animal enterprises are described. The results of the individual enterprise and whole farm analyzes are presented in Chapter 4. The presence of (dis)economies of size and the results of sensitivity analysis are also discussed. Sector considerations including alternative uses of farm resources are discussed in Chapter 5. A characterization and numerical descriptors of the fed cattle industry in Kansas (representative of a region gaining market share) and differences in net return to fed beef production between Michigan and Kansas are presented in Chapter 6. A summary of the objectives stated in Chapter 1, methodology by which these objectives are met, and resulting conclusions are presented in Chapter 7. Limitations of the analysis and directions for future research are also discussed in this chapter.

CHAPTER 2 LITERATURE REVIEW

Selected literature on comparative advantage and economies of size in the livestock industry is reviewed in this chapter. This material is relevant throughout much of this dissertation. Additional detailed research findings relevant to specific portions of this dissertation are found in later chapters, including whole farm model components (Chapter 3) and that relevant to the specific factors influencing comparative advantage in fed cattle production between regions (Chapter 6). This literature is presented in the section to which it relates in order to help the reader connect the methods used in this analysis to those used by past researchers addressing similar objectives.

The review begins with spatial equilibrium models, which have been widely used to understand and estimate comparative advantage between regions. A linear programming model is presented to illustrate the conceptual framework of spatial equilibrium as it applies to location of fed beef production. A review of the evolution of fed beef production (location and size) follows to provide background information on comparative advantage and economies of size in the fed beef cattle industry. Conclusions drawn from selected research then identify the current comparative advantage of different regions in fed cattle production. A discussion of the findings of selected research on the presence of economies of size completes the chapter. The discussion begins with a definition of economies of size, as it relates to fed beef production. Methods used to indicate its presence are discussed. Likely sources and the magnitude of economies of size in the fed beef sector are then identified. Finally, general conclusions from selected research addressing these issues are presented.

COMPARATIVE ADVANTAGE IN THE LIVESTOCK SECTOR, SPATIAL EQUILIBRIUM

Introduction

Production of agricultural commodities is geographically dispersed and is dependent upon the location of immobile resources (e.g. land, climate) and other raw materials, transportation costs associated with the movement of inputs to, and output of, the production process, and the location of demand (Sohn and Larson, 1984). Spatial equilibrium theory was developed by economists to consider the combined influence of these factors on the geographic location of production, prices, and product flows (Judge and Wallace, 1959). Spatial equilibrium models of the beef industry based on relative animal performance, costs of major production inputs, market location, and transportation have been developed in an attempt to predict the pattern of trade between regions and estimate regional differences in cattle feeding returns and the attractiveness of these returns to producers with several production options.

Enke (1951) developed a three region spatial equilibrium model. Using this model, the net price in each region, trade between regions, and net importers and net exporters could be estimated for a given commodity. Samuelson (1952), Fox (1952), and Judge and Wallace (1958) empirically tested this and other spatial equilibrium models. Samuelson demonstrated that linear programming could be used to solve a spatial equilibrium problem. Fox quantified a spatial equilibrium model of the livestock - feed economy to predict feed price differentials and consider the affect of changes in transportation cost between regions. Judge and Wallace developed and tested an operational spatial equilibrium model of the U.S. beef industry. A significant finding by Judge and Wallace was the inefficient locational matrix of slaughter plants. Some live cattle were exported from surplus regions to be slaughtered and reimported as beef. The southern and western movement of slaughter facilities over time, which we have seen, was predicted using these findings.

As transportation systems developed, the focus of spatial equilibrium models later turned to differences in feed costs between regions. Thor and Phillips (1961), King and Schrader (1962), and Williams and Dietrick (1966) suggested that differences in production costs associated with alternative feeding strategies were likely more important as factors in feedlot location than were differences in transportation costs (Hasbargen, 1967). Even with the focus solely on feed costs, coming up with meaningful results and conclusions often proved very challenging due to the large number of different quality feeds fed and the difficulty of pricing feeds such as corn silage (Hasbargen, 1967). In addition to feed cost, King and Schrader (1963) considered variations in feed conversion and non-feed cost, although it is now believed that cost and efficiency figures used in this study were erroneous. Linear programming was used to solve the model. Studies considering non-feed costs and, particularly, feed efficiency had been less common during this period. Hasbargen called for refinement in production cost specification within and between regions to improve spatial equilibrium models.

Spatial equilibrium models, the concept

In its most simplistic form, that is for a two region market and without consideration of transportation costs, trade between regions is shown in Figure 2.1.

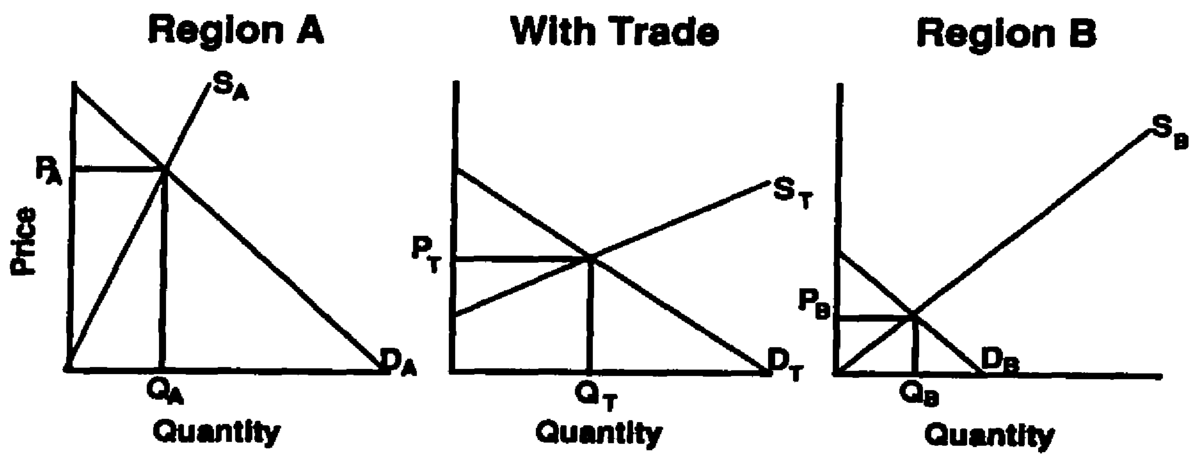

Figure 2.1 Trade between two regions

Supply and demand curves are shown for Region A and for Region B. The equilibrium price and quantity for each region in isolation is shown by the intersection of their respective supply and demand curves. Equilibrium price and quantity are shown as P_A and Q_A and P_B and Q_B for Region A and Region B, respectively. If the two regions are allowed to trade, D_T and S_T signify import demand of Region A and the export supply of Region B, respectively. The intersection of these curves determines the market price and quantity traded. In this model (assuming no transportation costs), P_T prevails in both regions and Q_T is exported from Region B and imported to Region A[6].

[6] In reality, regions are separated, but not isolated, by transportation costs. Incorporating transportation cost between regions would result in an equilibrium price differential between regions (P_A - P_B) equal or less than the transportation cost between the regions.

The usefulness of this model lies in the accuracy by which the supply and demand curves in, and transportation cost between, two regions can be estimated. Misspecification of supply and demand will decrease the explanatory power of a spatial equilibrium model. Sohn and Larson (1984) estimated demand and supply curves for beef. Demand was estimated as a function of population, per capita income, and urbanization. Supply was estimated as a function of total available energy in the region from concentrates, roughages, and pasture (reflecting resource endowment) and total energy available for competing sectors of the livestock industry from all natural resources in the region (to reflect opportunity cost of production). Figure 2.2 is a simplified depiction of the expected impact of each of these two factors on the position and slope of the supply curve when all resources are fully employed in their most profitable use.

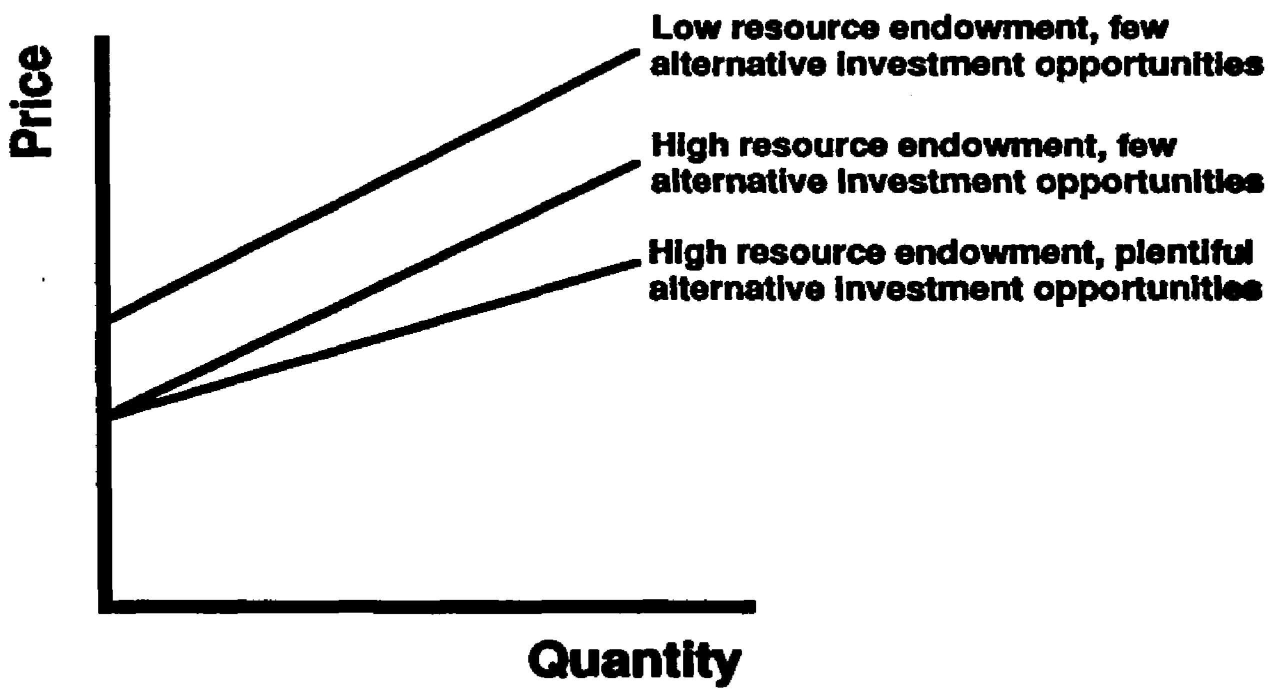

Figure 2.2 Supply curve for beef

Their model overestimated the beef production of states with large dairy cattle populations and in Illinois, a state which exports (rather than feeds) much of its feed grain. It underestimated fed beef production in some important feeding states. A regional surplus of fed beef was estimated and found for the Northern and Southern Plains states and the Corn Belt. These regions were found to have a comparative advantage in fed beef production.

Although this dissertation addresses similar questions to those considered by the research reviewed, spatial equilibrium analysis is not required. Michigan's share of the U.S. fed cattle industry is sufficiently small that even substantial growth in fed cattle production in the state would not significantly influence the price of feeder or fed cattle. The brief discussion of the theory behind, and factors considered in employing, spatial equilibrium analysis is, however, useful as a point of departure from which to consider the comparative position of the Michigan fed beef cattle sector.

Mathematical representation of spatial equilibrium models

Mathematical tools are necessarily used to numerically solve spatial equilibrium models. A spatial equilibrium problem can be written as a constrained optimization problem. In the case of the fed beef industry, the objective function is to minimize the total cost of producing beef for, and delivering beef products to, the end consumer. For illustrative purposes, total cost can be segmented into the cost of obtaining feeder cattle (feeder cattle cost plus transportation cost to the feedlot), feedlot production cost, and the marketing cost of fed beef (including transportation, slaughter, processing, and retailing costs). Linear programming is one tool which can be used to solve the spatial equilibrium model.

Consider the following example. Three regions of demand for beef, the Mid South Atlantic (MSA), the High Plains (HP), and the Eastern Corn Belt (ECB) regions, are specified. As is also true for production, transportation, and feeder cattle cost in this simplified example, demand is exogenous and independent of all other values. While a simplistic view of the balance of the industry, it emphasizes Michigan's position as small enough so as to not influence the U.S. industry. Three demand constraints specify that beef sent to each region from either of two production sites must be greater than or equal to demand in that region. Two production sites, the High Plains and the Eastern Corn Belt, represent U.S. fed beef production. Two constraints specify that the fed beef which leaves these areas must be less than or equal to that which was produced. In addition, for each area, the number of beef animals produced cannot exceed those which were purchased in, and transported from, (as feeder cattle) one of two areas, the Mid South Atlantic or the High Plains. These are the final two constraints. Figure 2.3 shows the constraint matrix for this problem.

COMPARATIVE ADVANTAGE IN THE FED BEEF INDUSTRY, EMPIRICAL EVIDENCE

Empirical evidence on the evolution of the beef industry is considered here. Background information on the U.S. beef industry is provided to set the stage for a detailed review of the role of comparative advantage in the changing location and structure of the industry. This background information provides detailed evidence to support the consideration of U.S. fed cattle production as a mature industry and on the changing location and structure of the industry. The section following this background information is devoted to describing the Michigan fed cattle industry and to identifying its comparative position relative to other regions.

Constraint	sign	Feeder cattle cost				Feedlot production cost		Cost of transportation from feedlot to demand					
		HP to HP	MSA to HP	HP to ECB	MSA to ECB	HP	ECB	HP to MSA	ECB to HP	HP TO HP	ECB to HP	HP to ECB	ECB to ECB
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Demand 1	< or =							1	1				
Demand 2	< or =									1	1		
Demand 3	< or =											1	1
HP feedlot	> or =					1		-1		-1		-1	
ECB feedlot	> or =						1		-1		-1		-1
Feeder cattle to HP	> or =	1	1			-1							
Feeder cattle to ECB	> or =			1	1		-1						

Figure 2.3 Constraint matrix for spatial equilibrium problem

The national fed beef cattle industry

1. Changes in U.S. beef demand

In Chapter 1, demand and supply shifters were identified as factors contributing to the increase, and the subsequent decline, in beef consumption. The influence of each is more fully explored here. Rapid growth in the beef industry prior to the mid 1970's was fueled by both increasing domestic demand and supply. Increasing demand was attributed to increasing consumer incomes and changes in consumer tastes and preferences, demographics, population, and lifestyles. Increasing supply was attributed to technological advances which enabled producers to decrease production costs of beef relative to other meat products. Advances included the movement from grass to confinement cattle fattening and other production technologies, improvements in animal genetics, and decreases in the price of feed grains. The development of interstate highways facilitated the movement of feeder and fed cattle and feed. The influence of each of these factors differs between regions such that these factors have also contributed to the structural and locational shifts in the industry.

Since the mid 1970's, per capita consumption of beef has declined significantly. This decline has been attributed to demand shifters including convenience and health concerns and the increased price of beef relative to other meats and meat products. The price of beef relative to its substitutes is significant since, in the mature domestic meat industry, any increases in per capita demand for beef must come at the expense of other meats and meat products[7]. The prices of pork, and particularly chicken, have fallen relative to the price of beef over the last three decades. For example, the price of beef relative to the price of chicken has increased 300% since 1965 (Bass, 1993). The relatively slow growth in the price of other meats relative to beef has been the result of greater efficiency gains in production and

[7] Net beef exports are also important to the U.S. beef industry. Due to the complex nature and, more importantly, the recent evolution, of international trade relationships, structural changes in fed and feeder prices due to expected changes in net exports are not considered.

distribution in those industries. Although recent evidence suggests that demand for beef has begun to stabilize, the search for technological improvements which will reduce the cost of beef should continue. In an effort to do so, one primary focus of this research is to identify production and marketing strategies which lower the cost of production within the beef sector.

2. Structural changes in the U.S. beef cattle industry

Structural changes over time in any industry are the result of comparative advantage held by particular regions or firms with particular characteristics. Two such structural changes which occurred, and continue to occur, in the beef cattle feedlot sector over the last three decades are the locational shift of cattle feeding and the change in size and number of feedlots.

2a. Locational shift of the U.S. cattle industry

Since the mid 1950's, the location of fed cattle marketings has shifted from the Corn Belt to the Central and Southern Plains states (USDA, various years). The regional shift in fed cattle production is attributed to a combination of factors which lowered costs and increased revenues for producers in the Central and Southern Plains states relative to those found in the Corn Belt states. Several factors give the Plains state's producers a cost advantage over those in the Corn Belt[8] [9]. Improvements in irrigation technology and crop varieties, particularly sorghum, have reduced feed costs. The close proximity of cow/calf herds has historically resulted in a lower cost associated with purchasing feeder cattle. A mild and dry climate reduces or eliminates the need for shelter or hard surfacing of dry lots and has facilitated the handling of manure. Favorable climatic conditions are also credited with higher feed

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[8] Most of the following are widely held throughout the industry as important factors leading to the regional shift of fed beef cattle production. This list of factors was compiled from several references including Blach (1991), Krause (1991), National Cattlemen's Association (1989), Allen and Riley (1984), Van Arsdall and Nelson (1983), Riley and Heimstra (1982), and Gee, et al. (1979).

[9] Regionally dependent factors affecting profitability are discussed in greater detail in Chapter 6.

efficiencies found in the Plains states. High turnover rates, in part a result of higher feed efficiencies, result in lower fixed costs per pound of beef produced. A sparse population makes certain pollution and odor control technology unnecessary and allows expansion to larger feedlots to more fully realize economies of size. Truck and rail deregulation throughout the 1970's, 1980's, and into the 1990's have reduced shipping costs for cattle and feed.

Fed cattle price received by feedlots in the Central and Southern Plains has increased relative to that received by Corn Belt producers. This is for two reasons. First, production in the Plains states has become closer to consumption as population has increased relatively quickly in the Western and Southwestern states (Gee, et al., 1979). Second, the slaughter capacity west of the Mississippi has grown, while that east of the Mississippi has declined. In fact, in 1991, only eight percent of fed cattle slaughter was east of the Mississippi although almost seventeen percent of the cattle on feed were located there. In addition, packers in the Great Plains are able to pay producers a higher price than their counterparts in the Corn Belt. Newer, larger plants found in the Central and Southern Plains operate with higher operational efficiencies, face lower wages and fringe benefit costs, and experience higher returns from processing byproducts and lower per head slaughtering costs (Riley, et al., 1984). Riley, et al. (1984) estimated slaughter costs at $24 - 28 and $36 - 50 for Kansas packers and the smaller Michigan packing plants, respectively.

The Southern and Central Plains comparative advantage in fed cattle production has put the feedlot sector in the Corn Belt states on the decline. Cattle production for the Corn Belt states peaked in the early 1970's, shortly before the first major wheat sale to the Soviet Union (U.S.D.A., 1992). The high feed grain prices resulting from the subsequent increased demand for U.S. crops increased the opportunity cost associated with feeding cattle in the Corn Belt states. One exception, South Dakota, lacking river barge traffic as an inexpensive grain export avenue, slightly increased cattle numbers from 1976 to 1989. Financial difficulties of the 1980's also fueled the locational shift of fed cattle production away from the Corn Belt. Many financially strapped Corn Belt farmer feeders were encouraged (often by their lenders) to turn to crop production, an enterprise made less risky by the presence of government programs (National Cattlemens Association, 1989).

Most industry experts predict that cattle feeding will continue to shift to regions with a comparative advantage in average daily gains, feed efficiency, and feed costs (in spite of higher feed prices) and with favorable climates (National Cattlemen's Association, 1989). The National Cattlemen's Association (NCA) cites the current locational concentration of packers in the highest fed cattle production area of the country as evidence that feedlot concentration will not shift away from this area, if at all, for many years to come[10]. The shift in fed beef production towards the Southern and Central Plains is consistent with the economic advantages found in this region. The conviction that these advantages continue to exist is not, however, universally held. Several researchers (Hasbargen and Kyle, 1977; Trapp, 1984; Clary, et al., 1986; and Sankey, et al., 1992) identified changes which would reduce advantages enjoyed by feedlots in the Southwest.

Hasbargen and Kyle identified changes which would reduce the advantage found for Southwest feedlots, including a decrease in the grain price, feeder or fed cattle price, investment cost, or labor cost advantage for feedlots in the Southwest. They also stipulated that the Southwest's advantage would, on the other hand, increase if the feeding value of milo

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[10] NCA does, however, concede that decreased water availability is expected to increase production costs for the arid plains region.

was increased through the development of an economical thin flaking technique, the South, Southwest, and West experienced more rapid beef demand growth than other areas of the country, or if better ration technologies evolved which were more likely to be adopted by larger feedlots. They made several recommendations by which producers in the Corn Belt could improve their competitive position. Among these recommendations were increasing the percent concentrate in the diet, purchasing more yearlings, and working to foster input and product market developments such as relaxed credit attitudes and increased fed cattle prices by producing a better product and obtaining and utilizing better information. These practices have, in large part, been adopted by the Michigan fed cattle industry.

Trapp (1984) found that differences in the cost of production between the Corn Belt and the High Plains had decreased from $13.29 per head in 1978 to $2.22 per head in 1983. This change in the relative cost of production between regions was found to be largely due to changes in the relative cost of feeder cattle and relative increases in fed cattle prices in the Corn Belt, although the High Plain's advantages in feed conversion and rate of gain remained.

Clary, et al. (1986) found that the Southwest continued to hold an economic advantage over the Corn Belt even under averse scenarios and that this encouraged the growth of a supporting superstructure of packers and marketing channels. They did, however, note how changes in specific factors could change the Southwest's advantage in cattle feeding. These factors include large changes in absolute or relative energy prices and/or transportation rates, reduction of feed grains available in the Southwest as a result of the depletion of groundwater reserves for irrigation, changes in the location of feeder cattle production, and increases in variable slaughter costs such as for labor or waste disposal.

More optimistically, Sankey, et al. (1992) found reason to believe that efficiency gains and other advantages that led to the rapid growth of cattle feeding in the Southern Plains at the expense of the Corn Belt have changed. Large increases in feed cost advantage for Iowa over Texas were noted. Sankey attributed this growing advantage to increased irrigation costs in the Southern Plains and the increased availability of byproduct feeds for Iowa cattle producers resulting from the growth of the grain processing industry in this area. Sankey also noted other changes which have reduced the advantage of the Southern Plains including the elimination of tax rules favorable to large Southwest lots, technological improvements reducing the cost of transporting cattle and meat, and a dramatic increase in foreign demand for highly marbled beef, a product for which areas with plentiful and low cost feed supplies are argued to have a comparative advantage.

2b. Shift in size and number of feedlots

A second important structural change in the fed beef cattle industry is the increase in size and the reduction in number of feedlots. The size of firms in an industry is determined by low cost producers. The speed at which the size structure changes depends on the profitability and asset fixity found in the industry, the presence of non-economic reasons for the livestock enterprise (Van Arsdall and Nelson, 1985), and the value of on-farm diversification of enterprises. Specific factors which have attributed to the movement towards large feedlots include federal tax laws which, although since changed with tax reform legislation in 1986 (Kelsey, 1993), provided incentives encouraging commercial feedlot investment, the development and improvement of products such as insecticides and vaccines which allow the confinement of large numbers of cattle in a single location, and existing economies of size. Economies of size have been shown to exist in activities which benefit from managerial and marketing specialization such as procurement and sale of cattle and procurement of feed, investment in facilities and equipment, and labor. The size of feedlots has also tended to increase as facilities and other productive assets of exiting feedlots are acquired by existing producers (National Cattlemens Association, 1989).

The largest casualty in the movement to fewer and larger feedlots has been feedlots of less than 1000 head capacity (National Cattlemens Association, 1989)[11]. The extent of the trend towards larger feedlots has varied by region. The Plains states have moved towards very large lots (> 30,000 head capacity), while these large feedlots have not appeared, and are not generally thought likely to appear, in the Corn Belt. Economies of size associated with feedlot investment in shelter, manure storage systems, and feeding and manure handling equipment and operating expenses, particularly labor, are exhausted relatively quickly in the Corn Belt. Also exhausted relatively quickly in the Corn Belt are economies of size in crop production for feed.

Comparative advantage, empirical research

Three empirical studies have explicitly considered the comparative advantage of the fed cattle industry of the Corn Belt states[12]. Hasbargen (1967), Loy, et al. (1986), and Gwilliam (1988) considered the comparative position of fed cattle production in the Northern Corn Belt states, Iowa, and Michigan, respectively, relative to that found in the Central and Southern Great Plains and to alternative in-state production opportunities.

Objectives of the Hasbargen study were to: (1) determine the types of feeding practices and management programs that would make cattle feeding more competitive on Northern Corn Belt farms, (2) determine the relative profitability of expanding cattle feeding versus cash crop

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[11] These "farmer feeders" often grow much of their feed and typically own all of the cattle in the feedlot.

[12] In Chapter 6, the results of these and other studies are considered in greater detail to more specifically identify the source of regional comparative advantage.

production on Northern Corn Belt farms, and (3) determine the relative profitability of feeding cattle in the Northern Corn Belt versus the Southwest. Linear programming was used. Biological and economic parameters including prices of cattle and feed, feed conversion, and non-feed costs for feedlots in the Midwest, Southwest, and Northern Corn Belt states reflected regional research data or were supported by partial budgets when such data was unavailable.

Managerial practices which would increase the profitability of Northern Corn Belt farms were identified. Feeding crossbred cattle, holsteins, and calves increased net return. A combination of grain and corn silage was found to be the most practical diet for most large Corn Belt feeders, with the optimal proportion of these two ingredients depending on the price of corn, farm resources, number of groups of cattle fed per year, and the profitability of the feedlot enterprise relative to alternative enterprises. Optimal facility type was found to depend on availability of bedding, feed storage, labor and machinery available for manure handling and feeding, and capital. Although slatted floor systems were found to have the highest initial cost and moderate annual operating costs, their use contributed to high animal performance. Slatted floor systems were found to be appropriate when labor was limited, real-estate capital was plentiful, and bedding was expensive. Conventional manure pack systems had lower initial investment cost, but high annual operating costs. An operation with no housing system had a low initial cost, relatively low annual costs, but the worst animal performance of any system. Open lot systems proved to be impractical under muddy conditions. Increased mechanization on the farm increased average daily gain and turnover, reducing per animal unit burdens.

The profitability of fed cattle production on large Corn Belt farms under optimal production and marketing strategies was compared with that of an alternative production opportunity (expanding the crop enterprise) and with that of farms located in a region experiencing a growth in market share[13]. This research indicated that Northern Corn Belt feedlots, even when employing optimal production and marketing strategies, realized lower profits than those in the Southwest. That is, Southwest feedlots enjoyed an absolute advantage in fed beef production.

Hasbargen distinguished between differences in profitability of fed cattle production due to an underlying comparative advantage (locational factors) and that due to managerial practices or differences in feedlot size. Locational factors were found to contribute the most to regional differences in returns to fed cattle production. Locational advantages realized by feeders in the Southwest included lower feed and feed storage and handling cost, higher feed efficiencies, and lower bedding and shelter investment costs. Non-feed costs were found to be higher in the Northern Corn Belt due to underutilization of feedlot facilities, the use of high forage rations, and the lack of pecurinary and nonpecurinary economies associated with specialization. Colorado's advantage was largely due to the use of less bedding and labor, although Hasbargen projected that Northern Corn Belt feedlots with abundant labor and an on farm bedding source (e.g. wheat straw) could virtually eliminate this advantage, while feedlots faced with paying market prices for these inputs could not. The effect of location on procurement of feeder cattle and selling of fed cattle was also found to be important. Both feeder and fed cattle prices were higher in the Southwest.

The Southwest's advantage was also attributed to difference in managerial practices. Producers in the Southwest fed high concentrate, well balanced rations to crossbred cattle, experienced lower morbidity rates, and fed to lighter market weights. Feed conversion was

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[13] Small scale enterprises were not considered because their success or failure was thought to add or subtract little from relative regional cattle numbers.

lower for the Northern Corn Belt producers who fed high roughage rations to heavier market weights and purchased inferior cattle.

In a useful format, Hasbargen and Kyle broke (dis)advantages into feed, non-feed, and cattle price regional differences due to location, scale, and management (Table 2.1). The advantage is realized by that region indicated in parentheses.

Table 2.1. Regional differences associated with feeding cattle in the Southwest (SW) versus the Northern Corn Belt (NCB)

Casual factor	Feed cost	Non-feed cost	Price margin
Location	Lower feed price (NCB) Climate effect on gain (SW) Less in-out shrink (SW)	Effect of climate (SW) on: housing needs concrete needs bedding needs Lower wages (SW)	Higher fed cattle prices (NCB)
Scale	Greater bargaining power in feed purchase (SW)	Greater bargaining power in non-feed purchases (SW) Lower labor requirements (SW) Lower building, lot, feed storage and handling costs (SW)	Greater bargaining power in buying and selling (SW)
Management	More efficient (SW) due to: lighter market weight higher ADG (& ration concentration) better health care more crossbred cattle fed	Fuller use of facilities (SW)	More "upgrading" (SW)

Adapted from Hasbargen and Kyle

Feedlot size differences were found to be the least important factor attributing to regional differences in net return. Large feedlots in the Southwest Plains states were found to have lower total non-feed costs as a result of economies of size, but still incurred higher feed and labor costs than farmer feeders using some homegrown feed and slack labor. Hasbargen concluded that, although economies of size existed for feedlots in the Southwest, similarly large feedlots in Michigan would experience diseconomies of size as increased feed and labor costs and decreased value associated with manure nutrients outweighed lower non-feed costs.

Hasbargen (1967) found that the net return per cwt of beef produced was approximately the same for Colorado and the Corn Belt, but that the net return per dollar invested was considerably higher for Colorado. He concluded that large commercial feedlots in the Northern Corn Belt would not be competitive with those found in the Southwest if it were not for their use of existing facilities and slack labor. New feedlot expansion, a key indicator of long run comparative advantage, was found to return at least $1.00 less per cwt in the Northern Corn Belt than in Colorado.

In later research, Hasbargen and Kyle (1977) estimated that Northern Corn Belt producers had a net disadvantage of $1.50 per cwt gain for calves and a slightly larger disadvantage for yearlings when compared to feedlots in the Southwest. Since the Southwest feedlots fed mostly yearlings, the average advantage for these lots was found to be almost $2.00 per cwt gain, but varied between $1.00 and $2.00, depending on location. As reported by Hasbargen (1967), the advantage for the Southwest was attributed to the lower labor and overhead costs and improved feed efficiency realized from more favorable weather conditions, lower feed costs, and lower feeder cattle costs. This advantage decreased when excess farm labor was utilized in the Northern Corn Belt. Hasbargen and Kyle correctly predicted that feedlot expansion would continue to be relatively rapid in the Southwest at the expense of the Northern Corn Belt. They further conjectured that this expansion would provide additional benefits through economies of size including lower per unit labor and facility costs, pecurinary advantages, and improved management practices due to specialization. The realization of advantages due to economies of size have been widely verified (see, for example, Krause, 1991).

Loy, et al. (1986) reviewed the marketing and production environment facing Iowa cattle feeders. As in Hasbargen and Hasbargen and Kyle, the affect of various production and marketing practices were considered. Capital budgeting techniques were used to calculate and compare the profitability of fed cattle production in Iowa with that found in other regions. Data from the Beef Feedlot Enterprise Record Program (a project facilitated by the Iowa State University Cooperative Extension Service) was used. Detailed production (production efficiencies, ration characteristics, environmental conditions, morbidity and death loss, and shrink), non-feed cost, marketing (buying and selling margins), and profitability data were available. Wide variations in net return were found between feeders employing differing production and marketing strategies. Cost of gain was found to be the key difference between low and high profit producers. Differences in cost per pound of gain were attributed to differences in average daily gain and feed efficiency. Average daily gains and feed efficiencies for the bottom one-third and top one-third of producers based on their profitability were 2.34 versus 2.64 lb per day and 9.13 versus 8.18 lb feed per lb gain, respectively. Higher average daily gains resulted in higher turnover rates, decreasing non-feed and overall cost per cwt gain for the high profit producers. Cost of gain for the high profit producers was $13.00 per cwt lower than for the low profit producers.

Differences in buying and selling margins for cattle were also found to be significant between low and high profit producers. The per head gross margin received by the high profit group exceeded that received by the low profit group by more than $5, with most of the difference due to a higher fed price. Innovative marketing practices, such as use of the futures markets, which offered opportunities for improved returns and reduced risk, were utilized more frequently by the high profit cattle feeders.

Factors affecting the comparative advantage of fed beef production between regions were investigated. Feed prices for Iowa, a surplus feed grain region, were found to be lower than those found in the Southern and Central Plains. Differences in buying and selling margins for cattle were found to be significant between regions. Feeder cattle prices were higher in Iowa than in other regions of the country. Fed prices, however, were found to be similar across regions. Animal shelter requirements increased production costs for Iowa feedlots over those found in other regions. The authors considered the wet, muddy spring conditions in Iowa even more detrimental to cattle performance than the severe winters. In Iowa, feed efficiency was higher for cattle with shelter than without[14]. Cattle fed in partial confinement and open lot systems were the most and least profitable, respectively. Environmental regulations were found to affect the comparative advantage of fed cattle production between regions. Regulations, primarily those associated with waste disposal, were found to be similar for most states, but due to climate and other considerations, the costs to achieve compliance varied by region. Iowa's cost of compliance was much higher than that of Great Plain's feedlots. Regulations regarding workmen's compensation, unemployment compensation, and income taxation were also found to affect a state's comparative advantage. Effects of population density on the need for additional time and expense involved in community relations was also discussed. Total cost of gain was found to be $1.60/cwt less for Iowa than for Texas feedlots over a two year period (1983 and 1984). This advantage was largely attributed to the lower feed costs found in Iowa.

Loy, et al. (1986) was updated in 1992 by the Iowa Beef Industry Task Force. Iowa's grain price advantage (compared with that of Texas) was found to have increased from 8% between 1975 and 1979 to 20% between 1985 and 1989. This is significant because feed costs make up approximately 65% of the cost of fed cattle production. The feed cost advantage was even higher when cattle were fed to heavier weights, such as those demanded by the growing Japanese market. Feed efficiency in Iowa, on the other hand, still lagged that of the Southern Plains states.

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[14] Two levels of improved feed efficiency due to shelter, three and six percent, were assumed.

In the most recent study on the comparative advantage of the Michigan fed beef cattle industry, Gwilliam (1988) investigated Michigan's position relative to the major cattle producing areas in the United States and identified potential means for Michigan cattle feeders to remain competitive. The industry's productive capacity as well as trends and attitudes of Michigan's cattle feeders and packers buying Michigan fed cattle were explored. Most information was obtained through independent surveys of Michigan cattle feeders and packers purchasing Michigan cattle. Practices of Michigan cattle feeders were found to be characteristic of farmer feeders and included low turnover rates, seasonal placement and marketings, use of on-farm produced feeds, and large variations in type and size of cattle fed.

Gwilliam concluded that, in Michigan, no natural resource favored cattle feeding over any other agricultural enterprise and that there was no major advantage or striking disadvantage in fed cattle production for Michigan relative to other parts of the nation. However, Gwilliam noted, Michigan cattle feeders largely made use of surplus feeds and existing facilities to maintain their position since "slight advantages in the central and southwest part of the nation precipitated investment." In contrast to Hasbargen, Gwilliam concluded that small scale feeders play a key role in the ability of the Michigan cattle industry to remain competitive.

THE MICHIGAN FED CATTLE INDUSTRY

A brief overview of the Michigan fed cattle industry provides background information important to understanding the current place of the industry in Michigan agriculture and in the U.S. beef industry. Beef cattle production is Michigan's fourth largest agriculture industry with approximately 800 cattle feeders and 300,000 fed cattle marketed per year. Most feedlots in Michigan are small compared to the national average, although Michigan has a larger proportion of commercial feedlots than other Corn Belt states (Ritchie and Rust, 1992a). Fed beef production is concentrated primarily in the east central (Huron and Sanilac counties) and southwest regions (Allegan, Ottawa, and Kent counties) of the state (Whims and Connor, 1991) (Figure 2.4). Production has migrated towards the center of the lower peninsula and the thumb area and away from major water and rail terminals (Gwilliam, 1988), although the decline in the southeast and southern counties has been modest (Whims and Connor, 1991).

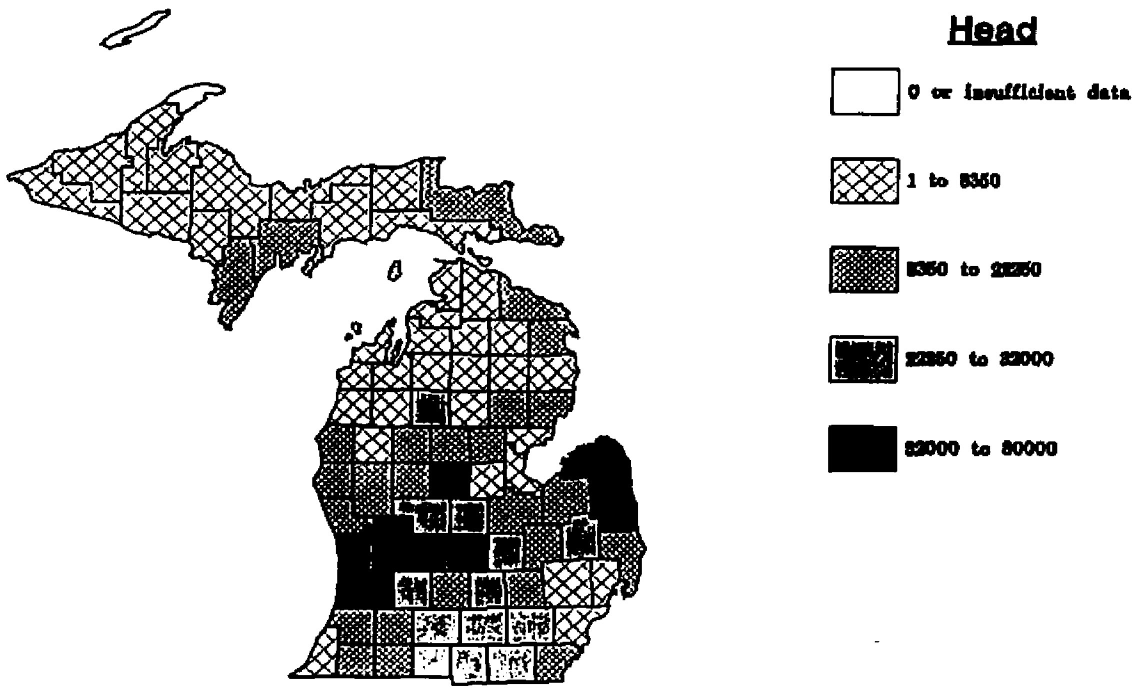

Figure 2.4. All cattle and calves by location

Michigan fed cattle production is marked by relatively low turnover rates and seasonal marketing (Gwilliam and Rust, 1988 and Allen, 1984). Gwilliam (1988) estimated turnover rates in Michigan feedlots at 1.28 using cattle on feed and production data from 1977 to

1981[15]. Low cattle turnover rates in Michigan are attributed, in part, to relatively lighter starting weights for feedlot cattle and, as is evidenced by seasonal patterns in marketing fed cattle, varying seasonal demand for available resources such as labor and machinery throughout the year.

Marketing of Michigan fed cattle, on average, brings producers a lower farm gate price than is realized by producers in states west of the Mississippi, although this disadvantage has narrowed in recent years (Bass, 1993). Michigan has less packer capacity than cattle marketed and therefore is a net exporter of fed cattle for slaughter (Gwilliam and Rust, 1988). The relatively low available packer capacity in Michigan and surrounding states is due to the closing of many of Michigan's slaughter facilities and those in surrounding states. For many years, Michigan imported both dressed beef and live cattle (Riley and Heimstra, 1982). In 1979, number of cattle marketed exceeded slaughter for the first time in recent history. As a result, in the early 1980's choice grade steer and heifer prices fell to $1.00 to $2.50/cwt below prices at Omaha, Nebraska, when earlier, Michigan prices had consistently been higher. The closing of most of Michigan's slaughter plants has been attributed to the lack of available fed cattle, and to competition from the larger, modern slaughter facilities in Illinois and Pennsylvania and the larger facilities in Canada (Gwilliam, 1988 and Allen, 1984).

Although Michigan has lost ground relative to the Western Corn Belt and High Plains regions in both cattle feeding and slaughter, the increase in Michigan's feedlot sector share of both the national and Corn Belt fed cattle market since 1980 indicates a comparative advantage for Michigan over other Corn Belt sates. There are several factors which have been identified as contributing to the comparative advantage of Michigan fed cattle production over other

[15] Turnover rates were estimated as number of cattle marketed during one year as a percent of January 1 inventory of cattle on feed.

Eastern Corn Belt states. Michigan feed grain prices are at a relative disadvantage to those received by farmers closer to export transportation on the Ohio, Missouri, and Mississippi rivers, resulting in an abundance of feed grains at relatively low prices for Michigan fed cattle producers. Additionally, although prices appear to be rising close to their feed equivalent, relatively low priced by-product feeds from nearby food processing industries have been readily available to many Michigan feedlots. A third factor, which, in the past, has given Michigan an advantage over other Corn Belt states is its position near the east coast and Canadian fed cattle markets. In more recent years, however, the number of Canadian packers has decreased rapidly. Finally, the presence of a strong marketing organization, Michigan Livestock Exchange, provides marketing expertise and financing to a large number of Michigan cattle feeders.

As is true for other Corn Belt states, livestock enterprises also often represent a means for Michigan farmers to generate additional income and make fuller use of family and hired labor needed during the planting and harvest seasons. Cattle feeding in Michigan often uses available slack or lower quality inputs and allows small crop farmers to increase utilization of farm machinery and other equipment.

The details of the Michigan fed cattle sector are not well known. Close examination of the sector through on-farm interviews will identify conditions under which fed cattle producers can maximize net returns. The question of whether these net returns will support significant expansion in the state will be addressed. Such expansion is dependent upon several factors including changes in the type of beef consumers prefer, changes in the relative cost of production between Michigan and other states, and legislative initiatives. A shift in demand towards leaner meats and more economical cuts may provide a premium to Michigan's fed cattle. Michigan producers utilize more forages and byproduct feeds to produce leaner beef than do the Central and Southern Plains states. Cost of fed beef production will decrease for Corn Belt feeders relative to that realized by Central and Southern Plains producers as water availability in the Plains states declines. Michigan's smaller feedlots may also be in a better position if stricter animal welfare laws are enacted. Several factors, on the other hand, could slow or reverse Michigan's fed cattle market share growth. Michigan faces relatively high costs of full time labor, a shortage of good available feeder cattle, strong and vocal residential and industrial pressures caused by high population density, large ground and surface water pollution potential, and higher opportunity costs both on and off the farm.

ECONOMIES OF SIZE

The remainder of this chapter is devoted to a review of literature addressing the presence of economies of size in livestock production. A definition for and general evidence of, techniques for identifying, and sources of economies of size are discussed. The results of past research on the size at which economies are exhausted and on the regional influence of this size are also discussed. A discussion on the use of evidence of economies of size in the analysis concludes the chapter.

Introduction

When consideration is limited to cost of production, economies of size is a decrease in the cost per unit of output due to changes in the level, mix, or cost of inputs required as the size of the farm or enterprise increases. When the definition of economies of size is expanded to define a decrease in the cost per dollar of output produced, changes in the price received for the output as the size of the operation changes are also included. The latter definition is adopted in this dissertation. If economies of size exist at some point, they will continue to exist with increasing firm size until further declines in cost are outweighed by an increases in cost. At this point, costs associated with additional production is said to experience diseconomies of size.

Economies of size in cattle feeding are generally acknowledged, with both labor and overhead costs per unit decreasing as the number of cattle fed increases (Simpson and Farris, 1982). Connor, et al. (1976) found economies of size present on Michigan feedlots for all energy and operating cost items except fuel, with the most significant economies found in labor, electricity, capital, and annual production costs. Van Arsdall and Nelson (1981) found that per unit feed costs were generally lower, but fixed costs were higher and production efficiencies lower, for smaller farmer feeders raising cattle. Van Arsdall and Nelson (1985) found economies of size in hog production. Returns per $100 of feed fed increased by $2.56 per 1000 cwt sold per year. Economies of size were found to be due to both lower production costs and higher fed prices for larger operations. The mean fed hog price advantage for the largest operations over the smallest was $2 per cwt over a four year period. Although large variations in profitability were found within all size groups, the larger operations had significantly higher average profits regardless of performance measure or year of operation.

Dietrich, et al. (1985), utilizing production records from farmers marketing 55% of Texas fed cattle during 1980-81, found a "distinct advantage" in per unit fixed costs for feedlots with greater than 16,000 head capacity. Madsen and Gee (1986) concluded that economies of size were present in Colorado feedlots, especially in purchasing equipment and facilities. Loy, et al. (1986) found economies of size in Iowa cattle production for waste handling, feed storage, and feeding equipment, but not for lot and shelter construction. Economies of size were attributed to specialization in technology and management, buying and selling advantages, and the flexibility in responding to changing market prices afforded by purchasing most inputs, particularly feed, found for larger farms. Findings of a National Cattlemen's Association commissioned study (National Cattlemens Association, 1989) also support the presence of economies of size in fed cattle production. National Cattlemens Association predicted that "economies of scale, to the extent they exist in different sectors of the beef industry, will continue to drive the industry to fewer and larger production units" and that "...lower margins will make it more difficult for smaller feedlot operations to remain in business..."

Loy, et al. (1992) found that the growth in Iowa's feedlot sector ran contrary to the national trend towards consolidation. The lack of economies of size once feedlot size surpassed 300 head capacity was attributed to the nature of the Iowa farm feedlot, where cattle feeding is one of several resource sharing enterprises. Larger Iowa feedlots were found to make better use of technology in record keeping and management, but smaller feedlots (< 1000 head) were found to compensate by using outside expertise. Feedlot size in Iowa was also found to be limited by corporate ownership laws, environmental regulations, and social concerns.

Identifying economies of size

Two methods used to empirically determine the presence of economies of size for a given industry are (1) the consideration of the current range of firm sizes and any recent change in the size of firms present in the industry and (2) the comparison of net returns achieved by firms of differing sizes. A third method by which to determine the extent to which economies of size are present in an industry is to model farms of different sizes. This method is particularly appropriate when empirical production cost and/or return data is limited. In this section, the basis for and use of each method is briefly considered.

Economic theory dictates that, in the absence of artificial controls, competitive behavior will drive the size of firms to the point at which minimum average production cost is reached (Van

Arsdall and Nelson, 1985). In the theoretical world of static perfect competition, if economies of size did indeed exist, the size of all firms in the industry would be of that size. Any firms which did not operate at this least cost size would be driven towards this size or driven out as output price moved towards minimum average total cost for the industry. Contrarily, if neither economies nor diseconomies of size existed, or were completely realized at a very low level of output, firms of all sizes would be found in the industry.

Simple observation to identify economies of size may, however, lead to incomplete or even inaccurate conclusions because feedlot investment results in asset fixity, making fed cattle production relatively unresponsive to changing conditions in the short to intermediate run. Movement towards the least cost size occurs over the long run, during which resources and technologies enhancing, and constraints restricting, their use also change. Even in light of the limitations associated with trying to explain empirical evidence using the theoretical foundations of perfect competition, feedlot size within a region will, over time, move towards the size associated with lowest average production cost for that region. The absence of a relatively large number of commercial feedlots in Michigan indicates that the climate, resource base, population characteristics, and/or markets do not favor large scale cattle feeding in this state.

A second method used to test for the presence economies of size is to examine a range of firm sizes, each identified by a fixed amount of a resource or a group of resources combined with other necessary inputs, from empty to full capacity (Van Arsdall and Nelson, 1985). In this way, the relationship between size and the long run cost of production is clearly depicted. If the total cost curves representing the various size feedlots at different levels of capacity utilization reach an equivalent minimum average total cost, no economies of size are identified.

Empirically, use of this model often results in the confounding of other factors affecting total cost and firm size. The larger the number of feedlots considered and the more uniform the resource availability, managerial ability, structure, and operation between sizes, the more appropriate is this method. Due to both the difficulty in obtaining detailed production cost data on a large number of feedlots and the large variability in resource availability, structure, and operation between feedlots of similar and different sizes in Michigan, this method is impractical for this research.

A third method used to determine economies of size is to create model feedlots. This method incorporates detailed empirical data specific to the region and feedlot size, yet allows for standardization of other factors affecting feedlot profitability. This method is appropriate when there is limited detailed production cost data available for firms in the industry, such is the case for the Michigan feedlot sector. This method is therefore used in this analysis.

The use of model farms to test for the presence and magnitude of economies of size requires that three issues be addressed. The scope of the enterprise under consideration must be defined and the extent to which biological efficiency and market price received varies by farm size must be identified. The scope of the farm or enterprise considered will affect the extent of and size at which economies of size are realized. For example, economies of size, if they exist at all, would extend to a larger size for a feedlot enterprise considered in isolation than for a whole farm which included a feedlot enterprise. In general, economies of size are considered for the whole farm when empirical data is used because it is difficult to separate costs among enterprises. However, several research efforts, particularly those which use modeling in lei of empirical data, consider economies of size in the livestock enterprise independent of other enterprises on the farm. For example, Van Arsdall and Nelson (1985) found small crop production cost differences between hog farms of different sizes, and therefore, used market price to represent feed cost for the livestock enterprise when testing for economies of size. In this analysis, in large part due to the assumption that land is required to dispose of manure generated by the feedlot enterprise, the existence of economies of size is considered over the whole farm, rather than for independent enterprises.

A second issue is the extent to which production efficiencies modeled should be related to farm size. Production efficiency measures such as gain per pound of feed, average daily gain, and death loss reflect both the efficiency of the operation and the uniqueness of the individual farm under consideration. Operations are unique in availability of, and alternative uses for, resources and in whether the livestock enterprise and/or the entire farm operation is entering or exiting the business or contracting or expanding (Van Arsdall and Nelson, 1985). Identifying the extent to which production efficiency depends on size is therefore difficult, if not impossible, particularly when using a relatively thin data set. Therefore, in this analysis, biological efficiency is not dependent on farm size.

A third issue is how marketing advantages from collective action (e.g. Michigan Livestock Exchange), rather than from economies of size for an individual operation, should be viewed in the identification of economies of size. The existence of an adequate number of feedlots in a community necessary to sustain input suppliers and cooperatives or other buying and selling services is vital to the success of smaller feedlot operations since they substitute for some of the advantages gained from size (Krause, 1991). Since collective marketing arrangements are common in Michigan agriculture, advantages gained from their use are incorporated in this analysis.

Sources of economies of size

1. Introduction

Economies of size originate from both the internal operation of the business and from the external relationship of the firm with the marketplace. Technical economies are those realized from the internal operation of a plant, farm, or firm (Krause, 1991). They result from the spreading of fixed costs over a larger volume of output or from more efficient use of resources. Available resources, competing opportunities, and constraints such as environmental regulations will affect technical economies (Krause, 1991). Classic studies of internal firm productivity describe average cost per unit of output in the short run as high at a very low level of capacity utilization, decreasing to a point of least cost, and then increasing due to crowding of the less variable resources. Most research on the presence and magnitude of technical economies of size (cattle, corn, and hogs), however, shows that, in the intermediate to longer run, average costs do not increase with increasing levels of output beyond the low point on the average cost curve (Krause, 1991), although the limited size of many livestock and crop operations in the Corn Belt contradicts these findings.

The second general class of economies of size result from the effect of feedlot size on availability and use of market opportunities. Market economies result from marketing advantages for larger firms and from decreased transactions costs associated with buying and selling inputs and products (Krause, 1991). Increased size improves market position for a producer purchasing feeder cattle, feed, capital, supplies, and investment goods and generally results in lower transaction costs for both the cattle feeder and the supplier or packer. Larger feedlots also have improved access to information and are more likely to utilize risk reduction tools.

In the following sections, specific research findings on economies of size resulting from advantages gained internal (technical economies) and external (market economies) to the firm are discussed.

2. Technical economies

Technical economies result from decreased ownership, operating, or management costs as firm size increases. Relevant findings in the literature are presented for each.

2a. Ownership

Differences in kinds and costs of capital assets and how effectively they are used is a major determinant of the presence of economies of size over time (Van Arsdall and Nelson, 1985). The spreading of lumpy fixed costs gives rise to decreasing per unit ownership costs as size of operation increases (Krause, 1991; Gwilliam, 1988; Loy, et al., 1986; Van Arsdall and Nelson, 1985; Hasbargen and Kyle, 1977; Connor, et al., 1976; and Hasbargen, 1967). In addition, regardless of feedlot size, facility and equipment investment costs make capacity utilization important to overall feedlot profitability (Hopkins, 1957). The tendency for smaller operations to take cattle on a seasonal basis due to competing demands for the farm's resources, particularly labor, further increases per head ownership costs over those experienced by larger feedlots (Van Arsdall and Nelson, 1985).

Although the results of most research indicates the existence of economies of size in cattle facility investment, evidence on its presence or magnitude is far from conclusive. Connor, et al. (1976) found economies of size in investment for all feedlot housing types considered. Van Arsdall and Nelson (1985) concurred, noting that because cost per head capacity decreases as building size increases, investment cost is usually higher for smaller operations even though they tend to use fewer technical advances. On the contrary, Loy, et al. (1986) reported similar lot and shelter costs across all size feedlots considered.

Evidence on economies of size originating from investments in feed storage facilities and feeding equipment are more conclusive. Connor, et al. (1976) and Loy, et al. (1986) found economies of size in feed storage and feeding equipment in Michigan and Iowa, respectively. Loy, et al. estimated costs associated with capital investment required for feed storage and equipment at \$100-\$110 and \$75 per head capacity for 500 and 10,000 head capacity feedlots, respectively, with the same type of storage facility and equipment used for each. Significant economies of size in waste handling were also found. Van Arsdall and Nelson (1985) reported similar findings for feeding and waste handling equipment, attributing economies to the tendency for equipment to pose a high initial cost that must be paid by the smaller operator when the equipment is often also adequate for a much larger operator.

In practice, there is probably less difference in per unit cost associated with investment and annual use cost between different size feedlots than is modeled in this dissertation. Equipment and facility costs are often held down for smaller firms by incorporating practices such as buying second hand or less specialized equipment and/or facilities and holding them longer. Increased repair, maintenance and labor costs, reduced productive efficiency, and/or reduced revenue for the farmer feeder likely result from these practices, countering lower investment costs. If labor is slack and many of the repairs and maintenance activities are performed by the farmer, these practices allow the operator to reduce overall cost. The assumption made in this dissertation is that labor and/or lost revenue has attached to it an opportunity cost which makes the total cost of utilizing less specialized equipment and facilities equivalent to that experienced by those purchasing and building new equipment and facilities. This is consistent with the consideration of the long run outlook for the industry.

2b. Labor and other operating costs, manure handling and use

Economies of size have been found for labor and other operating costs. Increased labor efficiency as the size of the livestock operation increases have been identified by researchers in several regions and over time (Krause, 1991; Gwilliam, 1988; Van Arsdall and Nelson, 1985; Connor, et al., 1976; and Hasbargen, 1967). Labor efficiencies result from specialization, reduced set-up time per unit output, and the use of larger equipment. The labor rate that the farmer feeder assigns to himself will influence the optimal size of smaller operations, while this is not true for larger feeders who must pay hired labor at a competitive rate.

Other operating costs influenced by size include bedding, electricity, fuel, and fertilizer costs. Hasbargen (1967) found that bedding costs increased with feedlot size as the transportation cost associated with hauling it increased. Connor, et al. (1976) concurred in concluding that there were diseconomies of size associated with fuel use originating from increased transportation requirements for larger farms.

Evidence on the economies of size associated with the handling and use of manure varies. Van Arsdall and Nelson (1985) concluded that the disposal or use of manure provides neither economies nor diseconomies of size. From a review of past literature, including one study of 500 hog farms and several studies of cattle feedlots marketing less than 500 head per year, they concluded that, in practice, the outlay for commercial fertilizers was virtually unaffected by the use of manure on cropland. The authors attributed this to three factors: that (1) the primary objective of most farmers with regards to manure handling has been simply to dispose of (versus utilize) the manure, (2) the large variability in manure nutrients drives producers to ignore its value and therefore to apply the same amount of fertilizer regardless of the amount of manure applied, and (3) the danger of reduced yields and legal action resulting from overapplication favors the use of manure as fertilizer at a level below its potential. The fact that it is difficult to sell or even give away excess manure indicates that its value to producers purchasing most feed inputs nears zero.

From their own analysis, Van Arsdall and Nelson (1985) found economies of size in manure use for hog operations because smaller farms lost more nutrients between collection and utilization. Overall nutrient recovery was found to be increasingly superior with increasingly intense systems of waste management and land application. Confinement systems with liquid storage and the practice of injecting manure, more commonly found on larger operations, were found to yield more nutrients per animal to the soil.

Others have shown that costs associated with handling and utilizing manure increase with farm size. Diseconomies from manure handling and use stem from the location of an acceptable cite for application. After the feedlot reaches a size nearly large enough to fully utilize equipment necessary to haul and spread manure, average costs increase because manure must be spread an increasing distance from the feedlot (Gustafson and Van Arsdall, 1970). In addition, larger farms, such as those common in the Southwest and Great Plains, do not have adequate crop land on which to apply manure. Arrangements for using crop land of farmers supplying forage to the feedlot are increasingly common, but this manure rarely provides value to the livestock enterprise in these areas (Van Arsdall and Nelson, 1985).

2c. Managerial capacity

Economies of size associated with management have been widely reported (Loy, et al., 1992; Krause, 1991; Wagner, 1990; Loy, et al., 1986; Van Arsdall and Nelson, 1985; and Madsen and Gee, 1980). The source of these economies is the spreading of administrative costs over a higher level of output and increased opportunities for technology adoption and managerial specialization, both of which allow for improved efficiency in resource use.

Managers of larger feedlots often have better access to information (Loy, et al., 1986). Continuous marketing of fed cattle and purchasing of feeder cattle provides larger volume feeders with information about day to day market conditions (Gustafson and Van Arsdall, 1970). Additionally, as sales volume increases, the cost of price analysis falls and is more likely to be utilized to increase revenues or decrease costs (Connor, 1989). Larger feedlots are also more likely to use or make better use of technology to improve efficiency of resource use including electronic media, feed processing, mixing, and weighing equipment, and computers (Wagner, 1990 and Loy, et al., 1986). Specialization of management found on larger feedlots may also improve ration balancing and cattle selection, each of which improves efficiency.

3. Market economies

In addition to those originating from internal efficiencies, economies of size also can result from differing market opportunities available to and utilized by different size producers. Increased size provides advantages when purchasing feeder cattle, feed, capital, supplies, and investment goods (Krause, 1991; Loy, et al., 1986;, and Hasbargen, 1967). Increased size also generally results in lower transaction costs associated with selling fed cattle. Larger feedlots offer an increased volume of uniform quality cattle (Gwilliam, 1988) and frequent transactions (Krause, 1991; Van Arsdall and Nelson, 1985; and Hasbargen and Kyle, 1977), which allow the producer to eliminate repetitive steps such as cattle specification. Lower transaction costs are also present for the packer when dealing with a larger feedlot for many of the same reasons and therefore allow the buyer to increase his bid. Larger feedlots also have improved access to information and experience with its use, as well as experience with risk reduction tools such as futures and options markets and year round purchasing and selling.

3a. Market economies -- fed cattle marketing

Economies of size in fed cattle marketing are realized through increased price per unit sold and/or decreased marketing costs as firm size increases. Differences in fed price received by smaller versus larger feedlots have been reported[16]. Van Arsdall and Nelson (1985) found differences between small and large hog producers in kind and weight of hog sold, type of market outlet used, quality of hog sold, and use of record keeping although, in their research, they assumed that price only varied by type of hog sold[17]. Farm size therefore affected price only as a result of differences in timing of marketing and sale weights between different size producers. Small producers received lower and more variable fed prices due to their tendency towards seasonal production and marketing. The larger volume of cattle to choose from to meet quantity, weights, and delivery date specifications can also increase fed price for larger cattle producers (Krause, 1991).

Economies of size result from decreased per unit transaction costs for larger farms. Several authors cite increased fed price resulting from reduced transactions costs for both the feedlot and the packer as a major advantage for larger farms (Krause, 1991; Connor, 1989; Van Arsdall and Nelson, 1985; and Gustafson and Van Arsdall, 1970). Transactions costs are decreased for larger feedlots as they develop a reputation with fed cattle buyers, making it

[16] The difference in price received between larger and smaller feedlots may exceed that reported because larger operations often record the price received as net of custom hire hauling while smaller operations tend to haul their own livestock and record actual price received (Van Arsdall and Nelson, 1985).

[17] Van Arsdall and Nelson (1985) found that larger lots were likely to obtain a higher price for hogs through increased use of direct marketing, and were more likely to use grade and yield pricing, suggesting that larger operators produce better hogs.

more likely that transactions can be made without inspection of the cattle at the feedlot (Krause, 1991). Krause found that, by using direct yard grouping of fed cattle and/or forward contracting and futures markets, large feedlot managers were able to increase the price of a fed animal $20 over those managing smaller lots.

3b. Procurement

Like those associated with selling, economies associated with purchasing are found both from increased efficiency associated with the internal operation of the farm and from market transaction advantages. External economies in purchasing are considered here. More frequent purchasing of larger volumes may contribute to lower prices for larger feedlots than is available for smaller feedlots which make irregular purchases (Hasbargen, 1967). Negotiating takes less time per unit purchased and may be more effective as feedlot size increases, including the negotiation of transportation rates and the quality of product purchased. However, many of these same external economies in purchase or sale can be realized by smaller feeders through participation in buying or selling groups such as cooperatives.

Advantages associated with the cost of feeder cattle and feed are the two most important areas associated with economies of size in purchasing because they are the inputs purchased in the largest quantity and those whose price tends to vary the most. Evidence discovered in the literature, however, does not support the hypothesis that more frequent and higher volume purchasing of feed may provide advantages (Van Arsdall and Nelson, 1985). Hasbargen rejected the hypothesis that greater bargaining power might give large scale producers a feed price advantage. In fact, Hasbargen cited the ability to buy feed directly from neighbors, thereby reducing transportation and transaction costs, as an advantage for smaller feedlots. Gustafson and Van Arsdall (1970) found that feed costs were not related to differences in size of operation as closely as non-feed costs and that larger operations may be at an advantage in buying feed and formulating rations, but at a disadvantage in feed conversion. Van Arsdall and Nelson (1985) found that ration cost was lower for larger hog operations only because of the differences in prices and proportions of commercial feeds used (the price of grain was assumed to be the same regardless of feedlot size). Differences between farms of different sizes were found in type and volume of materials purchased and in the number of services included in the price of the feed. Van Arsdall and Nelson estimated that feed cost declined $0.44 per 1000 cwt of hogs fed and that variance in feed cost decreased with increasing farm size. Lower variable cash costs for larger operations were largely attributed to improved feed management rather than to market power. Producers who formulate their own rations incurred more processing costs and increased managerial responsibility, but tended to save on ingredient costs.

Empirical evidence on optimal size feedlot

The existing magnitude of economies of size present for feedlot operations is not well explored. Although much of the literature tends to agree on the sources of economies of size, studies conducted for a particular region within a similar time frame often identify different points at which economies of size become completely exhausted. Other studies fail to identify this size, either because economies existed even at the largest sizes considered or because the effect of economies of size on several key production variables was unknown.

Early research on economies of size focused on identifying the optimal size of individual feedlots by studying feedlots of different sizes, with similar characteristics within a state or region, or by constructing synthetic budgets for various size operations (Krause, 1991). Early synthetic budgets were constructed under the assumption that cattle would be fed crops grown on the farm. Under this assumption, the crop enterprise expanded in proportion to increasing feedlot size. In these models, economies of size were exhausted rapidly (frequently by 1000 head) because farmers had limited labor and often kept other livestock, which competed for available feeds. For example, Connor, et al. (1976) found economies of size to be fully realized for Michigan feedlots by 200 to 300 head capacity while Gustafson and Van Arsdall (1970), who considered only non-feed costs, found most economies of size reached at a much higher level of 5000 to 7000 head capacity, with no diseconomies for feedlots of larger sizes.

Krause (1991) estimated the minimum capacity which exhausted available technical economies at between 10,000 and 30,000 head. The existence of 100,000 head capacity feedlots, he stipulated, is evidence that economies exist, or at least that significant diseconomies do not exist, beyond this size range. Gwilliam (1988) also noted the concentration in feedlot location and size as significant evidence of economies of size in production and processing in the Southwest. He suggested that because such large feedlots do not exist in Michigan, economies do not exist or that significant diseconomies exist for relatively small feedlots in Michigan.

Although most of the growth in cattle feeding has been, and will continue to be, on large commercial lots where economies can be realized, farmer feedlots continue to exist for several reasons (Krause, 1991). Farmer feedlots can make use of off season labor, particularly in the late fall and early spring, use low quality hay or inputs that otherwise have little or no economic value, share the burden of ownership costs associated with the crop enterprise[18], provide facilities available for other uses when cattle are not being fed, fill niche market demands (Krause, 1991), and capture the value of manure (Hasbargen and Kyle, 1977). Krause concluded that small farms (less than 1000 head) will also continue to exist where, for

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[18] However, the introduction of a cattle feeding enterprise to the farm operation may require mechanization specific to the feedlot enterprise such as silo unloaders or feed augers, actually increasing per unit fixed costs over some range of output.

example, the risk-bearing capacity or management and entrepreneurial ability for additional capacity is not available.

The point at which economies of size are exhausted varies by region. Feedlot size which fully exhausts economies of size also depends, in part, on the number and size of feedlots in the area. Smaller feedlots can achieve market economies available to larger feedlots through buying and selling groups and a strong infrastructure of input suppliers and packers. By information sharing, they can also experience some of the technical economies found in the much larger commercial feedlots. Since most research on fed beef production focuses on, or originates from, regions supporting large commercial feedlots, little attention is given to the effect of region on economies of size. Two studies which specifically address this issue are Hasbargen and Kyle (1977) and Loy, et al. (1992).

The wide acceptance of the existence of economies of size in labor and overhead costs would suggest that the Corn Belt feeder maybe at an even greater cost disadvantage than is due simply to location (Hasbargen and Kyle, 1977). Hasbargen and Kyle contrarily found that the 500 to 1000 head capacity Corn Belt feedlot was not at much of a disadvantage due to smaller size when compared to commercial feedlots in the Southwest. Beyond this size, production costs increased with size more for Northern Corn Belt feedlots than for those in the Southwest. Expansion in the Northern Corn Belt quickly became more expensive because feed and labor costs increased as underutilized feed and slack labor were exhausted and manure changed from an asset to a liability. All factors considered, a total net advantage to size was found in the Southwest versus operating a large feedlot independent of land ownership in the Northern Corn Belt. Hasbargen and Kyle correctly predicted that, due to large diseconomies of size, the latter were unlikely to develop. Feedlots in Colorado, however, did not appear to face significant diseconomies of scale because labor wage rates were found to be unaffected by feedlot size. Per unit feed costs also did not increase significantly with size because most grain was purchased. With no internal reason to limit feedlot size in the southwest and because of the presence of market economies including lower interest rates and lower feeder and feed prices, feedlot size grew. Loy, et al. (1992), citing similar factors, found that nearly all economies of size for Iowa feedlots were exhausted by a 300 head capacity feedlot.

Using evidence of economies of size

The presence of economies of size is difficult to capture through survey or the use of secondary data due to virtually unavoidable confounding between feedlot size and other variables such as capital availability and cost and management ability. Intercorrelation stems from many relationships within the feedlot and between the feedlot and other enterprises. For example, the intensity and type of diet will affect average daily gain and therefore feedlot turnover and average non-feed costs. Labor demand for crop production may preclude full utilization of feedlot facilities. Lower feed efficiencies may be the result of feeding a higher roughage diet as dictated by a plentiful supply of forage.

Important assumptions which will influence the presence and magnitude of economies of size found in the Michigan fed cattle industry include assignment of labor cost for farmer feeders versus commercial feedlots and the value assigned to the manure produced by the feedlot enterprise. Throughout this dissertation, assumptions regarding differences in production costs due to feedlot size are clearly indicated. When possible, secondary data is verified from interviews with cattle feeders and other industry experts to separate economies due to size from other factors. Price paid for purchased inputs, including feeder cattle, and price received for fed cattle is not, however, modeled as a function of feedlot size.

CHAPTER 3 METHODS

INTRODUCTION

Methods used to evaluate net returns to fed cattle production under various production and marketing strategies are described in this chapter. Methods used to address each of the first four objectives set forth in Chapter 1 are discussed. Methods for determining the investment, production, and marketing strategies and costs of the various components of fed cattle production in Michigan are presented (objective 1). Methods employed to determine the cost of fed beef cattle production in Michigan through the development of representative feedlots are then described (objective 2) as are methods used to determine the gross margins faced by Michigan cattle feeders (objective 3). Selected literature upon which the methods are based is presented throughout the chapter.

Modeling the whole farm system

There are many interrelationships between enterprises on a single farm (Figure 3.1). Successful producers must be able to quantify the impact of each enterprise, or component of an enterprise, on the net return realized by the whole farm operation. A farming operation can no longer afford to subsidize an unprofitable component. Unfortunately, the interrelationships between crop and livestock enterprises make it difficult, if not impossible, to fully assign costs and returns to an enterprise independent of other enterprises on the farm.

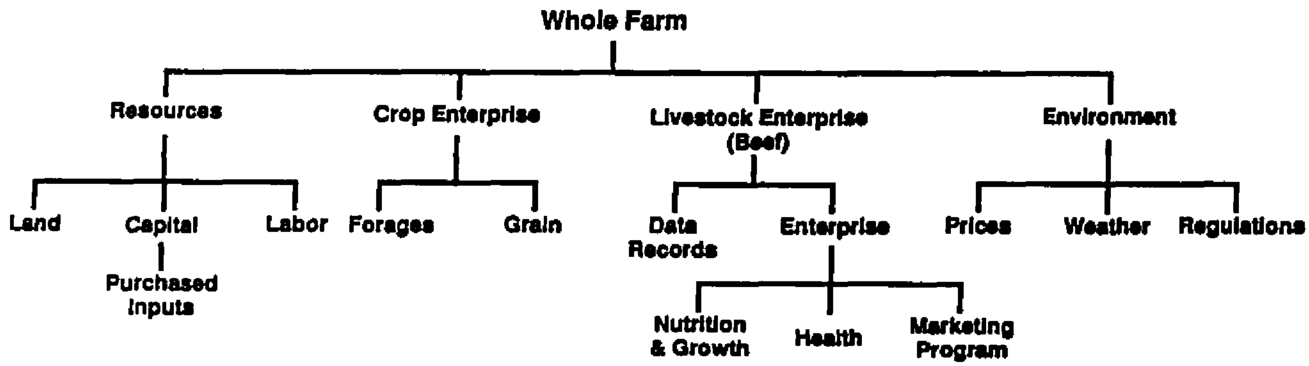

Figure 3.1 The whole farm system

The components of a farm can, however, be modeled as independent units with each accepting the constraints imposed by other components as exogenous[19]. In this form, exchanges between the crop and feedlot enterprises of a farm operation are viewed as a transfer pricing problem. The livestock enterprise purchases feed from, and in turn sells nutrients back to, the crop enterprise. In this case, the products exchanged between enterprises are, or can be directly substituted for, products sold in the marketplace (i.e. can be easily priced). The feedlot purchases feed from the crop enterprise at the market price and sells manure to the crop enterprises at the price of equivalent commercially purchased fertilizers less any additional application costs. In actual market transfers, the price of manure may be either more or less than its value as a soil nutrient, depending on the

[19] Connor, et al. (1976), for example, divided the feedlot operation into three subsystems; feed production, the beef enterprise, and waste collection, storage, and distribution, each of which was independently modeled.

availability of neighboring cropland and on the perceptions of buying agents on the value of other nutrients or soil benefits provided from the manure, depending on how the interrelationships between enterprises are modeled[20]. The value of modeling the whole farm as a system, rather than as the sum of several independent enterprises, and the reason it is utilized in this dissertation, is for its implicit consideration of interactions between components. Profitability of the whole farm is therefore determined, rather than that of individual enterprises.

Whole farm budgeting

Profitability of the whole farm is determined by subtracting production costs associated with the crop and feedlot enterprises from gross margin received from marketing the cattle. Positive returns are considered necessary, but not sufficient, to encourage investment in the industry. Economic theory defines that, in order to sustain long run production, the return to cattle feeding must be at least as great as that of the next most profitable alternative. Cattle feeding must compete for the land base and managerial expertise[21]. Reality expands this definition to include a strong preference for feeding cattle or large benefits associated with portfolio or enterprise diversification.

The whole farm budget used to determine profitability of feeding cattle is comprised of components of the feedlot enterprise, the crop enterprise, and those shared between enterprises. Components of the feedlot enterprise include cattle procurement and marketing,

[20] This problem can be avoided by considering the feedlot enterprise as a value added step by which to obtain a higher return from the crop enterprise. The residual returns to feeding corn through livestock can be calculated to determine the value of corn as a feed. This value is then compared with the market price of corn to determine the value added by the feedlot enterprise.

[21] In the Central and Southern Plains, where a large feedlot can exist independent of an extended land base, investment in cattle and facilities must compete with non-farm investments such as stocks, certificates of deposit, and real estate holdings (Loy, et al., 1986).

cattle and feed storage facilities and equipment, manure storage and handling, and labor associated with the management and operation of the feedlot. Components of the crop enterprise include machinery and operating inputs, use of manure, and labor associated with operating crop production and transportation equipment.

Representative budgets[22] are developed to calculate net return to fed beef production in Michigan. Representative farm budgeting involves developing a budget for a (synthetic) feedlot representative of a group of those found within the industry. Production and marketing strategies and their associated costs are reflective of feedlot operators with moderate to high managerial skills. The resource environment within which decision makers operate is defined by soil type and feedlot size[23]. Input and output coefficients associated with each component of the whole farm are, by assumption and, as much as possible by design, representative of better managers. Management skill is, however, not considered a substitute for comparative advantage.

Each synthetic feedlot is modeled such that the ownership cost for facilities and equipment is represented by the depreciation charge. Representative production and operating costs, particularly those associated with the crop enterprise, are modeled commensurate with the long term existence of the operation (steady state). The latter assumption is particularly

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[22] The use of representative farm budgeting as a tool for analyzing the profitability of the industry arises from the difficultly in accurately portraying a wide variety of actual feedlots. Although a survey of selected feedlots by region or actual long term feedlot performance, cost, and return data may provide better assessment of the Michigan fed beef industry, lack of specific data and the wide dissimilarities between feedlots make the use of such methods infeasible. Time, cost, and reliability considerations make the use of synthetic budgets more appropriate.

[23] The influence of current and expected operating constraints such as those associated with environmental legislation are incorporated directly into production and marketing cost, rather than independently tested using sensitivity analysis. This progressive approach to production is adopted to reflect attitudes of Michigan fed cattle producers.

useful when modeling the use of manure as a soil nutrient in the crop enterprise because much of the nitrogen from manure is released over several years following application.

Each whole farm budget is constructed as follows. Feedlot capacity and labor requirements are identified. Marketing strategy (type, placement weight, and sale weight), capacity utilization strategy, and diet fed are specified. Feed requirements, feed storage facilities, and the manure output of the feedlot enterprise are determined. The crop enterprise is specified as that required to meet the ration requirements of the feedlot enterprise. Machinery and operating costs are determined for the crop enterprise. Operating costs associated with the feedlot enterprise such as for bedding, preconditioning, and health are calculated.

Just as it is difficult to generalize from diverse feedlots, it is also difficult to produce conclusions and recommendations for a specific feedlot from a general analysis. The wide variety of cattle feeding operations in Michigan makes direct application of the results of this analysis to an individual feedlot unwise. The purposes of this study are, rather, to make inferences about the current comparative advantage of the Michigan feedlot sector and to identify production and marketing strategies which may improve feedlot profitability for the individual producer, depending on the resources and alternative opportunities available and constraints faced.

Capital budgeting is used to determine net returns to the feedlot operation. Net present value (NPV) and average annual return (AAR) are calculated for feedlots of four sizes under different production and marketing schemes. Average annual return is used as a measure of returns to fed cattle production rather than return on investment to reflect the focus on choice of enterprise, with land investment considered exogenous. Marketing and production strategies providing the highest net returns are identified[24].

Risk

Although net returns to unallocated resources provide one picture of the sustainability of an enterprise, a firm, or a sector in a particular region under a given set of circumstances over time, it is a risk neutral measure. It is generally well accepted in economic and finance theory and in the application of this theory that most persons exhibit risk aversion (Robison and Barry, 1987). That is, they require a higher expected return on investment to take on additional risk. In order to be a sustainable enterprise over the longer run, cattle feeding must provide returns greater or equal to those provided by alternative investment opportunities exhibiting a similar level of risk. A feedlot operation is of substantial risk relative to other, particularly non-agricultural, investment alternatives (Cooney, 1993). Farmer feeders or participant cattle feeders may, however, be willing to realize lower net returns than would be required by other investors in face of the risk due to the willingness of other market participants, particularly agricultural lenders, to carry them through limited periods of negative net returns and/or insufficient cash flow. Outside investors, on the other hand, are much more likely to exhibit risk aversion.

An analysis of willingness and ability to invest in the Michigan feedlot industry must then, at least qualitatively, include some mention of the riskiness of such an investment relative to alternative investments. The purpose of including risk into an analysis is two fold. The first is to use the degree of risk associated with feeding cattle, once net returns have been identified, to estimate its future in a particular region by comparing it with alternative

[24] In Chapter 5, similar calculations are made for farms with identical land bases, but only crop enterprises, to reflect opportunity cost of feeding farm raised feed through livestock.

opportunities of comparable risk. Equally important, estimating the risk of cattle feeding facilitates identifying the potential usefulness of risk reducing schemes such as forward contracts, futures and options markets, year round feeding systems, and vertical integration and thereby, their potential for making cattle feeding more attractive.

For purposes of this dissertation, under the assumption of well managed farmer feedlots with substantial investment in facilities and equipment and sound financial statements, the importance of risk for predicting entry into or exit from the industry is diminished. Cattle feeders are assumed to have the financial reserves on their balance sheets to handle moderate to large losses over several years. The question therefore becomes, can farmer feeders, over the intermediate to longer run, achieve returns to cattle feeding competitive with those achieved in other alternative uses of available resources[25].

[25] This is not to say that the risk level associated with an enterprise does not have significant impacts. Risk is substantial in all phases of beef cattle production and includes that associated with commodity prices and access to markets, production, capital availability and cost, input performance, input prices and availability, technology, people, institutional factors, and macroeconomic factors. Risk of negative net revenues, particularly for the beginning producer who presents a weaker financial statement, may be large enough to discourage investment in the cattle industry given what would otherwise qualify as adequate returns. For some, but not all, of these farmers, risk reduction techniques may position cattle feeding as a viable alternative. Risk reduction tools available to Michigan cattle feeders are based, in large part, on reducing price risk of fed cattle. Techniques such as forward contracting and crop insurance have increasingly become an important means by which farmers with less well established balanced sheets can obtain financing and by which more well established farmers, can obtain additional financing (Cooney, 1993). Futures markets provide another alternative to lay off risk by reducing price risk to basis risk (NCA, 1989). Contractual alignments with packers are yet another means by which producers can reduce fed price risk. This is a particularly good option for firms which currently utilize auction or terminal markets (NCA, 1989), although it has implications for cattle type and quality which may present a real cost to the producer. Michigan cattle feeders may be at a disadvantage in price and production risk when compared to the larger, better capitalized firms found in the Southwest (NCA, 1989). Also, although direct marketing and contractual arrangements have become increasingly important to reduced risk in this competitive industry, only one responding meat packer buying Michigan cattle was engaged in forward contracting of cattle, and then only occasionally (Gwilliam, 1989).

Data sources

In order to be useful, an economic model must provide a straightforward means of analyzing complex reality (Cramer and Jensen, 1991), yet consider each important factor of this reality. Although economic theory can predict the structure and function of the marketplace, variations will arise from details not included in the analysis, dynamics of the marketplace, the use of incorrect or incomplete assumptions, or improper use of the theory. To be an effective decision aid, it is therefore essential that validity of the economic model and its accompanying assumptions represent actual conditions in the marketplace. Primary or secondary data is generally used to generate and check predictions set forth by the theory.

Data used to analyze net returns to cattle feeding varies widely. Frequently, the model used is chosen based on the form and richness of the data available to the investigator. Five forms of data are available for this study: (1) Telfarm records[26], (2) a 1988 survey of Michigan cattle feeders, (3) that collected from farm visits and from visiting with extension personnel and other industry experts, (4) closeout budgets for fed cattle production in various regions, and (5) various price series for feeder and fed cattle.

Telefarm records, in general, lack the level of detail necessary to accurately reflect cost and production characteristics associated with different production and marketing strategies (Gwilliam, 1988). For example, in these records, feedlot animals of all weights and of varying characteristics are grouped together in only two categories, calves and yearlings. In addition, this data has become increasingly thin as the number of subscribing farms feeding

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[26] Telfarm Microtel is a record keeping support system for Michigan farmers. Farmers submit monthly journals showing receipts, disbursements, and other farm activities. From this data, financial statements including a tax package, depreciation schedule, income statement, balance sheet, net worth reconciliation statement, enterprise budgets, and cost of production report are generated. Crop yield information and a three year comparative business analysis are also provided. Under strict procedures which guarantee confidentiality for the individual farm, Telefarm occasionally makes summary statistics available to University and Extension personnel.

cattle as their primary source of income has declined. Data on less than ten such farms is currently available. While therefore not used as primary data source by which to define net returns to various production and marketing strategies, Telefarm data is useful in verifying and clarifying data obtained from farm visits, particularly for calculating investment costs.

The second source of information on production and marketing practices and performance on Michigan feedlots is a 1988 survey of Michigan cattle feeders. Although, in the published results of this survey (Ritchie, et al., 1992), individual feedlots are classified into only three groups based on size, the raw data was made available to the author to provide further detail. While no information is provided on costs and returns to fed cattle production, this data is particularly useful in this analysis because it depicts the production and marketing strategies practiced, and efficiencies realized, by Michigan cattle feeders.

The third form of data utilized is that obtained from on farm interviews and interviews with extension personnel and other industry experts conducted in the summer and fall of 1992. Feedlots run by operators with upper level management skills were selected for on-farm interviews based on criteria such as current and past size of operation, location, and production and marketing characteristics. Feedlot operators selected were those who have demonstrated a desire for Michigan's cattle feeding industry to survive, and who are likely to not only accept an interview, but to share detailed information on the farm's operations and profitability under a guarantee of confidentiality.

In order to guarantee confidentiality for feedlot operators interviewed, two strategies are employed to elicit, record, and utilize data. First, data was mainly utilized to verify and adjust secondary data collected from the literature on various components of feedlot operations. Data used directly from farm interviews does not reflect an individual operator, but is, rather, an aggregate description of feedlot characteristics, costs, and revenues and the relationships between the components in the operation (e.g. the relationship between number of labor full time equivalents and feedlot size). Secondly, in several cases, farmers are asked to estimate revenue, cost, and production parameters of hypothetical feedlots, rather than divulge specific information on their own feedlot. A similar methodology was used by Ward and Sersland (1986) to increase the likelihood of obtaining more direct responses and to insure confidentiality when interviewing packing plant personnel. On-farm interviews were administered with two researchers visiting twelve feedlots for approximately one-half day per feedlot. Interview questions are included as Appendix 1. Follow up questions and clarification of, or expansion on, previous responses were handled by phone.

Budgets prepared for cattle operations in other states were particularly useful to verify selected details of representative budgets[27]. For example, DeKalb Feeds publishes an annual summary of budgets for Illinois feedlots closely approximating those in the upper one-third of all Illinois feedlots, as measured by profitability (Dekalb Feeds, 1993). Iowa State University also publishes annual feedlot budgets for Iowa. Lastly, price data is available for feeder cattle sold in Michigan, Kentucky, and Kansas and fed cattle sold in Michigan and Kansas.

MODEL SYSTEMS

Early in this chapter, the general framework by which returns to cattle feeding are measured was presented and data sources utilized were identified. The remainder of this chapter is devoted to describing specific methods used to develop whole farm budgets representing fed

[27] Budget cutbacks by the U.S.D.A.'s National Agricultural Statistics Service prior to 1982 eliminated Michigan from the regular Cattle on Feed reports (Gwilliam, 1988).

cattle production in Michigan. Feedlot systems which reflect the range of existing feedlots in Michigan are described and whole farm budgets for these systems developed. The systems include what can be described by the full time labor equivalents devoted to the feedlot enterprise as (1) a part-time operation (400 head capacity), (2) a one full-time equivalent (FTE) operation (1200 head capacity), (3) a 2 FTE operation (3000 head capacity), and (4) a 4 FTE operation (6000 head capacity). The type of cattle chosen to represent Michigan fed cattle and methods utilized to estimate production costs are described as well.

CATTLE TYPE

Characteristics of feeder cattle used to represent those typically fed in Michigan are selected based on a review of literature on the effect of characteristics of feeder cattle on their biological and economic performance in the feedlot, Ritchie, et al. (1992), and from on farm interviews and visits with extension personnel and other industry experts. Sex, frame size, and purchase and sale weight of cattle represent those commonly fed in Michigan feedlots. Since the majority of Michigan cattle feeders follow the same preconditioning (off the truck) program regardless of evidence of prior preconditioning, feeder cattle were not differentiated by preconditioning program or background condition in this analysis.

PRODUCTION COSTS

Introduction

In this section, methods used to determine production costs are discussed in detail. Description of methods used to determine production costs is divided into seven sections including (1) livestock facilities and equipment, (2) livestock rations and feed requirements, (3) feed storage facilities, (4) waste handling and manure nutrients, (5) crop enterprise costs, (6) other operating and overhead costs, and (7) financing. A description of the methods utilized to estimate cattle gross margins for Michigan producers follows. Marketing costs, including those associated with transportation, shrink, and commissions are included in the gross margin calculation.

1. Livestock facilities and equipment

1a. Introduction

Increasing feedlot size and specialization, improvements in technological and managerial capacity, and environmental concerns have made facility investment choices increasingly important (Van Arsdall and Nelson, 1985), particularly for states in the Midwest and Corn Belt regions. This is particularly true for Michigan, where greater use has traditionally been made of partial and total confinement facilities than in other Midwestern states (80% versus 50%, respectively) (Gwilliam, 1988). Michigan has wide variations in climatic conditions including temperature and relative humidity, snow, wind, and rain, which affect energy requirements, feed intake, and performance of cattle (McNeil) compared to the Southern and Central Plains states, and to a lesser extent, the Corn Belt. Evidence suggests that increases in average cattle performance in Michigan (versus the Midwest) have resulted from increased use of facility investment, moderating the effect of environmental factors.

Climatic effects stem from the fact that cattle must expend energy to maintain their body temperature when the temperature external to the animal is outside of their thermeoneutral zone. This additional energy requirement for maintenance reduces that available for gain, given the same level of energy intake. When the temperature drops below the thermeoneutral zone, cattle can make up for this increased energy requirement by increasing their dry matter intake. Weather conditions which create excessive mud or produce strong winds or high moisture conditions, in combination with cold weather, thereby influence feed efficiency, but do not necessarily lower daily gains. Excessive temperatures, on the other hand, tend to reduce dry matter intake but do not substantially reduce feed efficiency. In both cases, production cost increases. Rapid weather changes such as those frequently found in Michigan are particularly likely to hamper animal performance because the animal is not allowed time to acclimate to new conditions.

Choosing the facility which will maximize profits for a particular operation involves weighing the increased cost of investment against the associated benefits, particularly improved cattle performance, convenience, and reduced future costs of compliance with potentially forthcoming environmental legislation[28]. Other benefits associated with facility investment may include decreased operating costs involved with bedding and labor and increased ability to capture manure nutrients (Hasbargen, 1967).

Facility investment also carries with it ownership and operating costs, as well as that associated with asset fixity. Although more alternatives to fed cattle production exist for operators in the Corn Belt than those in the West, Corn Belt livestock operations often have substantial asset fixity that results in decreased responsiveness in product mix in response to changing product prices (Connor, 1989) and creates increased per unit costs as capacity utilization falls.

While there have been numerous studies on the effect of facility on performance, there have been far fewer studies on the economic worthiness of increased confinement. Hasbargen (1967) found that systems of medium investment were the most economical in the Corn Belt. He identified the choice between slatted and concrete or dirt floors as the key decision, since little overall economic difference had, to date, been found between net returns to various

[28] For example, current environmental legislation dictates that either slats be used or that a large portion of the feedlot be in concrete if muddy lots cannot be avoided.

shelter types. His conclusion was that the choice whether or not to use slatted flooring was contingent on whether the cost of the flooring, including the cost of additional long term credit less the value of retained manure, was worth the decrease in bedding costs and fewer restrictions in timing of labor use. While use of a conventional manure pack required a great deal of straw and labor and resulted in lower feedlot performance, investment was less than for the slatted system. Systems with no housing had lower bedding and investment requirements, but had higher feed and operating interest costs. Hasbargen found that, when labor and bedding were scarce resources, confinement systems with liquid manure storage became more attractive.

In order to be economically viable, additional investment cannot substantially increase production cost per unit of a relatively homogeneous output. Connor, et al. (1976) found, for Michigan, that mean cost per cwt of beef produced was highest for an open lot system and lowest for a confined housing system, largely due to higher feed efficiencies and turnover associated with confinement systems. Loy, et al. (1986) found that expected profit for both yearling and steer calf programs in Iowa was higher for partial confinement systems than for open lot systems when a six percent advantage in feed efficiency was assumed for the confinement system. The cost of construction and maintenance of total confinement systems was found to add two to three dollars per head to the cost of feeding cattle over an open lot system. Additional investment cost was approximately offset by improved animal performance over the range of facilities.

Rust (undated) compares the cost, cattle density, and convenience of four Minnesota feedlot systems. An open lot system required the most feed per unit of gain, but resulted in a higher average daily gain than either of the other non-slatted floor facilities considered, presumably due to a higher intake level. A second system, which included a pole barn shelter and used a scrape and haul manure system, provided the best economic return (both the lowest non-feed cost and total cost) and required less investment than any of the other systems. Feed costs per cwt gain were the lowest for two slatted floor (cold and warm confinement) systems considered. Rust expanded the economic analysis to include increased dressing percentages realized for cattle finished on slatted floors. The additional value ($0.50 per cwt) made the cold confinement slatted floor the most profitable system. For this reason, and because more extensive housing uses less labor and increases ease of cattle handling, Rust recommends that feedlot operations with the intention of utilizing facilities over 10-20 years should consider building at least part of feedlot capacity with slatted floors. Disadvantages of slatted flooring systems are increased injuries for all cattle types and decreased performance when feeding holsteins or calves. The use of partially covered and open lots and slatted floor systems have been very popular in Michigan. Ritchie, et al. (1992) report that 42% of feedlots marketing over 500 head in 1988 had at least some slatted floor capacity. Fifty-three percent reported having open lots and fifty-eight percent reported using an open lot with partial cover. Fifty-eight percent reported using a covered lot with solid floor[29].

1b. Facility design

Facility investment, by defining capacity, puts an upper limit on the size of the total operation. Facilities are designed for four representative feedlots, one each with one time capacities of 400, 1200, 3000, and 6,000 head. Feedlot capacities were chosen to represent the range of feedlot sizes present in Michigan and to be in relatively close alignment with full time labor requirements. Feedlots with capacities of less than 400 head do exist in Michigan, and are perhaps more common than all other sizes combined. They are not, however, included in this analysis as it is unlikely that, given the apparent lack of diseconomies of size

[29] Total percent exceeds 100 because many operations employ more than one type of cattle facility.

at this relatively low level, smaller feedlots would have an advantage over the 400 head capacity feedlot modeled.

Choice of investment in the shelter and flooring system of the facility is based on expert opinion, feedlot interviews, and insight from past literature. An initial feedlot design resulted from several iterative meetings with Michigan State University (MSU) Beef Extension Specialists and was adopted as a point of departure. Input on feedlot design was then elicited from Michigan beef producers and construction experts. Past literature and current facility recommendations were utilized to catalyze discussion among and provide data for persons involved in designing the feedlot. For example, the effect of shelter on cattle performance and the benefits of finishing cattle on slatted floors was considered. Apart from the formation of model feedlot designs and adjustments to reflect field observations, no further attempt was made to improve the facility design or characteristics.

1c. Ownership cost calculation

Due to the long run nature of facility investment decisions, capital costs (outlays for depreciable assets including facilities and machinery and equipment) are calculated using current replacement cost[30] [31]. Investment capital requirements are presented for feedlot and feed storage facilities in Chapter 4. Capital investment for the cattle facility includes

[30] This method is also referred to as calculating capital costs on a new investment basis.

[31] Capital cost calculations include the cost of all materials and labor used in the design and construction of facilities. Feedlot managers can often reduce these costs by utilizing the existing work force in construction activities, using competitive bidding and/or existing equipment, buying used rather than new equipment, and/or retrofitting existing facilities (Loy, et al., 1986). Options to building a new facility include retrofitting and renovating existing facilities or buying existing feedlots. Loy, et al. discussed these facility investment possibilities in depth. Retrofitting existing facilities can significantly reduce the initial investment capital requirements as compared to new construction. Retrofitting a 500 head capacity facility decreased ownership costs (depreciation, taxes, insurance, interest, and repairs) 48% as compared to a new facility. Although these alternatives to new investment exist, for consistency in time (longer term) and across different systems and farm sizes, current capital investment costs were utilized in all cases in this analysis.

investment in the lot, shelter, and manure storage system, animal handling equipment, complete watering system, and all plumbing and electrical work necessary to establish the feedlot. All materials and labor are included for the construction of the facility[32].

Average annual ownership cost for the livestock and feed storage facilities are calculated as:

$$(3.1)\quad \textit{Annual average cost} = \frac{\textit{Present cost of investment}}{DF_a}$$

$$\textit{Where } DF_a \textit{ (Discount factor of annuity)} = \frac{m}{k}(1-(1+k)^{-mn})$$

k	=	discount rate
n	=	life of project (years)
m	=	times discounted per year

Lives of various components of the facility are reported in Chapter 4 as are construction details and price source information. A discount rate of 10% is used to calculate average annual cost.

2. Livestock rations and feed requirements

2a. Introduction

Feed costs represent between 60 and 75% of total cost of gain for growing and finishing cattle (Sankey, et al., 1992; Kuhl, 1992). Good ration management is therefore an essential part of a profitable feedlot. The identification of the cattle ration, and thereby, individual animal feed requirements, is one link between the feedlot and crop enterprises. Cattle specification, diet fed, and marketing strategy employed determine the specific feed requirements which

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[32] Actual land and construction costs can vary significantly with local conditions. The use of average cost estimates validates the general applicability of the model. Additional factors such as the need for extensive site clearing requiring demolition and removal of existing structures or extensive filling, grading, or piling improvements can increase costs substantially above those estimated here.

must be supported through the growth and storage of corn and corn silage on the farm. In addition to providing much of the ration needs, crop land makes use of manure produced from the livestock enterprise.

The feed demand the livestock enterprise places on the crop enterprise is quantified first on a per animal basis. This is then extrapolated to yearly crop output necessary to sustain the livestock enterprise for a given feedlot size and fill rate. Daily requirements are formulated by first specifying type of cattle (including purchase and sale weight) and diet fed. With these as inputs, BEEFSIM, a computer simulation of the California Net Energy System (CNES) adapted using the results of Fox and Black (1984), is used to calculate daily dry matter intake (DMI) and average daily gain. Protein requirements are calculated to match levels recommended by industry experts.

2b. Model selection

The CNES, first proposed by Lofgreen and Garrett (1968), is used to determine the energy requirements of the cattle. As does the system proposed by Blaxter (1962) and adopted by the Agricultural Research Council (1965), the CNES differentiates between the net energy (NE) required for maintenance and that required for production[33]. The fact that NE obtained from feed is influenced by the level of intake is the basis for the importance of this differentiation. In the CNES, the metabolizable energy (ME) of a feed is determined by a conventional metabolism trial and the value is separated into NE for maintenance and NE for production using data from a comparative slaughter feedlot trial (Shirley, 1986). The specific procedure for the separation of the total energy is described in detail in Lofgreen and Garrett (1968). The CNES is considered the more precise of two methods utilizing separate NE terms

[33] Shirley (1986) presents a through discussion of the implications of using a single value to describe NE requirement of an animal.

(Shirley, 1986) and has more widespread usage. It is also the model reflected in BEEFSIM. It was selected to calculate feed requirements in this analysis for these reasons. Details important in the use of the CNES are thoroughly covered in the ruminant nutrition literature and are therefore not discussed here. The importance of ration formulation to the performance of the farm system, however, makes it appropriate to highlight limitations of the CNES relevant to this analysis.

Limitations of the CNES include the lack of an adjustment for the (1) variability caused by differing chemical and physical properties of feed which make it inappropriate to assign a definitive NE to any particular feed, (2) processing of feeds, which will affect the extent and location of energy absorption, which, in turn, determines the total energy provided by the feed, (3) fact that the net energy for production is influenced by feed intake and the digestibility and efficiency value of nutrients, (4) fact that the net energy per unit of feed decreases at high levels of intake because of decreased density and therefore tends to be overestimated at levels near maintenance, and (5) difference in efficiency of energy use in gaining fat versus protein. Since the CNES was proposed and has come into common usage, researchers have proposed adjustments to overcome these, and other, limitations. These are briefly described.

It has long been shown that the NE values for individual feeds is variable[34] and that the combination of feeds, especially the relative proportions of roughages and concentrates, in a diet affects this (see for example, Blaxter and Clapperton (1956) or Lofgreen and Otagako (1960)). Woody, et al. (1983) suggested adjustments to the NE for gain of feeds to account for the association effects between feeds in the diet, which are not considered by the CNES

[34] Procedures for predicting energy values associated with different feeds used to satisfy animal nutrient requirements are outlined in several references (see Mertens, 1983; NRC, 1984; and VanSoest et al., 1984). Once predicted, these energy values can be used to predict DMI and energy intake.

(Shirley, 1986). Knox and Handley (1973) and Fox, et al. (1977) have suggested adjustments for differing environmental conditions to the NE for maintenance, which is currently defined in the CNES using data from trials conducted under experimental, rather than feedlot, conditions. The need for adjustments for exposure to cold and stress are emphasized.

The inability of the CNES to reflect differences in composition (fat versus protein percentages) of body weight gain, which are well described by frame size and use of growth stimulants as dependent on rate of gain has led to the development of other models. Large frame steers lay more protein and are more efficient in energy use than smaller frame steers at the same weight, which lay more fat. To reflect this, equations have been developed which adjust gain for frame size (McCarthy, et al., 1985). For example, Fox and Black (1984) present a breed adjustment factor for Holstein or Holstein-British cross cattle. Formulas for calculating, and tables presenting, various combinations of adjusted gain projections for breed or use of growth stimulants are presented in several sources (see Shirley, 1986 or Fox and Black, 1984). In this analysis, cattle are depicted as average frame size and the use of growth stimulants is assumed. These assumptions make the conditions of this study, and the conditions under which the CNES parameters were developed, equivalent. No adjustments for frame size or use of growth stimulants is therefore made.

2c. Ration calculation procedures

In this section, the specific procedure used to calculate the yearly feed requirements for the livestock operation is described. Calculation of the feed requirements requires a description of the cattle and definition of the rations used. Per animal requirements are then extended over a year's time and for the average mix of animals in the feedlot. The aggregate requirements of the feedlot enterprise specifies corn and corn silage which must be produced by the crop enterprise. The daily gain which results from the intake and diet specification is, in turn, used to indicate turnover and specify timing of fed cattle marketing.

2d. Animal specification

The characteristics of the various animals depicted in the analysis, including age, weight, sex, and type (breed and frame size) are defined in Chapter 4. The base animal modeled in the representative budgets is a british breed steer of average (6) frame size (National Research Council, 1984 and Fox and Black, 1984). The cattle type chosen is representative of cattle in Michigan feedlots.

Yearling steers were the most common age and sex type marketed in Michigan in 1988, with more than twice as many yearling steers marketed as the next most common category, yearling heifers (Ritchie, et al., 1992). The majority (73.7%) of Michigan producers who market over 500 head of cattle per year prefer to purchase cattle in the weight range of 550 to 749 lb, with average initial and final weights for yearling steers marketed of 726 and 1169 lb, respectively. To reflect those elicited from beef cattle specialists at Michigan State University (MSU) and to closely resemble these Michigan averages, yearlings are purchased at 600 or 750 lb and sold at 1175 lb or 1250 lb. Calves are purchased at 500 or 650 lb and sold at 1175 lb. Heifers, animals of differing breeds and frame sizes, and animals entering and leaving the feedlot at different weights than those specified are not considered.

2e. Ration composition

The second step in identifying total ration requirements is to describe the composition of the diets considered. Corn and corn silage are the most extensively utilized sources of energy for ruminants in the United States (Shirley, 1986), as well as for feedlot cattle in Michigan

(Gwilliam, 1988). High moisture corn and corn silage are therefore used as the principal concentrate and forage in the representative budgets.

Although corn and corn silage contribute to an animal's protein requirement, they alone are inadequate for efficient animal growth. A supplementary nitrogen source must therefore be included in the diet. Commercial supplements, used in 43% of Michigan beef cattle feedlots, are the most common source of supplemental protein (Ritchie et al, 1992). Soybean meal (31.3%) and urea (20.5%) are also commonly used. Due to the large price variability found between commercial supplements, soybean meal and urea are used as nitrogen sources on the representative farms, with each supplying one half of the supplementary nitrogen[35].

Evidence gained from initial on farm interviews suggests that byproducts supplied by food processing plants including off quality dry cereal, beet pulp, cull potatoes, potato waste, potato chips, and marshmallows are frequently used by larger feedlots in Michigan to replace grain in the cattle diet (Rust, 1988). Several Michigan cattle feeders interviewed supplemented byproduct feeds directly for corn. As recycling efforts expand and food processing profits narrow, byproduct feed availability and cost may alter the comparative advantage of particular regions of the U.S. in relation to their proximity to food processors. It is unclear whether the availability of byproduct feeds could increase enough to significantly affect total feed supply and thereby, cost, in Michigan. This lack of data on the availability, cost, and performance of cattle fed byproduct feeds precludes its consideration in this analysis. Nevertheless, byproduct feeds will continue to offer locational advantages to particular producers.

[35] White, et al. (1972) reported that replacing soybean meal with urea in diets fed steers had no effect on energy or crude protein digestibilities.

The composition of diets used in these representative farms reflects those currently used on Michigan cattle farms which marketed greater than 500 head during 1988, a set of hotter diets closer to those fed in the Plains states, and others identified during on farm interviews. Rations which closely reflect the diets of Michigan feedlot animals (Ritchie, et al., 1992) are modeled with concentrate as 22.6, 34.0, and 60.9 percent of total dry matter for the starter, grower, and finisher rations, respectively. Hotter rations (those using a higher percent concentrate) were elicited from industry experts in Michigan and approach, but do not equal, the energy provided in rations used in feedlots in the Central and Southern Plains.

Three rations, a starter, a grower, and a finisher are fed in each diet included in the representative budgets. A 30 to 60 day starter ration is used to reflect the majority (78.9%) of moderate to large sized Michigan feedlots which feed a special diet to incoming cattle. Calves (< 600 lb), short yearlings (600 - 749 lb), and yearlings (> 750 lb) spend the first 60, 45, and 30 days, respectively, on the starter diet. Although hay is commonly fed as the principal forage to incoming cattle, corn silage is used for simplicity in developing the crop and feeding budgets. Successive diets fed over the life of the animal have a higher percent concentrate and a lower percent crude protein to reflect the changing nutrient needs of the animal as it grows. The number of days spend on the grower and the finisher ration is equalized. The starter, grower, and finisher rations for a sample diet are shown in Table 3.2. The range of diets considered are described in detail in Chapter 4. An early version of SPARTAN Beef Ration Evaluator -- Balancer for Beef (Rust, et al., 1994) is used to balance complete rations.

Table 3.1 Representative feedlot diet

Starter diet	
Feedstuff	**Percent of diet (dry matter basis)**
Corn grain, high moisture	57.5
Corn silage, well eared	38.0
Soybean meal, 44%	3.3
Dical	0.6
Urea	0.6
Diet characteristics	
Dry matter per animal per day (kg)	6.5
Percent crude protein	12.5
Percent supplemental crude protein from urea	49.0
Number of days on feed	30.0
Grower diet	
Feedstuff	**Percent of diet (dry matter basis)**
Corn grain, high moisture	63.5
Corn silage, well eared	33.0
Soybean meal, 44%	2.5
Dical	0.6
Urea	0.4
Diet characteristics	
Dry matter per animal per day (kg)	7.4
Percent crude protein	12.0
Percent supplemental crude protein from urea	80.0
Number of days on feed	80.0
Finisher diet	
Feedstuff	**Percent of diet (dry matter basis)**
Corn grain, high moisture	79.0
Corn silage, well eared	18.6
Soybean meal, 44%	1.5
Dical	0.6
Urea	0.3
Diet characteristics	
Dry matter per animal per day (kg)	8.3
Percent crude protein	11.5
Percent supplemental crude protein from urea	50.0
Number of days on feed	79.0

2f. Determination of dry matter intake

Once cattle characteristics and rations are specified, intake levels are calculated. Intake is the basis of both nutrient requirements and gain (Hicks et al., 1987). Except for special conditions under which limit feeding is viable, feedlot profits depend on maximizing feed intake. It is therefore important to briefly consider the physiological, environmental, and managerial factors that influence feed intake (National Research Council, 1987).

Physiological factors affecting dry matter intake include current and mature body size and energy available for maintenance and growth (Van Soest, 1982; National Research Council, 1984; Plegge et al., 1984; Fox and Black, 1984). Dry matter intake (DMI) is influenced primarily by limitations in gastrointestinal capacity, when cattle are young, and by maintenance needs and potential for production, as expressed through physiological demand (chemostatic and thermostatic controls), as the animal grows and the diet becomes less fibrous. These controls begin to limit intake when the diet is approximately 65% concentrate. Between this point and a diet with approximately 90% concentrate, daily energy intake and gain remain fairly constant as intake falls as the level of energy in the diet increases. After the diet concentration has surpassed 90%, daily gain begins to fall as dry matter intake decreases at an increasing rate. Mature size and sex also affect intake levels since they affect the level at which the animal will reach a given level of fatness. Fox and Black (1984) adjust the CNES intake equation for animal size and sex by converting intake levels to those of an average frame size steer of equivalent body composition, but do not adjust for placement weight.

Evidence that age, and therefore the previous diet of the animal, may affect intake has been reported (National Research Council, 1987). Animals of similar weights and frame sizes, but of differing ages, show differing intake levels in a phenomenon similar to that of compensatory growth. Yearlings have been shown to consume approximately 10% more than calves of comparable weight and frame size. Hicks, et al. (1987) found that for each additional 100 lb the animal weighed at placement, mean daily feed intake increased 1.5 lb, supporting the concept that the weight at which animals are initially provided free choice access to high concentrate diets will dictate the level of feed intake they achieve[36]. Contrarily, other researchers have found that, over the time spent in the feedlot, daily dry matter intake for cattle coming in undercondition is not different than for those entering the feedlot in good condition (Shirley, 1986).

Environmental affects which impact intake levels include temperature, weather, photoperiod, and timing of feeding. Temperature and weather effects on intake are generally thought to be limited to temperatures of greater than 25 degrees celsius, when intake is decreased, and of less than 15 degrees celsius, when intake is increased, and when animals face exposure to winter storms and cold, muddy conditions (National Research Council, 1987). In this analysis, model facilities are designed to minimize the effect of environment on intake and feed efficiency. Therefore, no adjustments for extreme environment are made.

Dietary factors which affect dry matter intake include degree of control over water intake (Utley, et al., 1970; National Research Council, 1984), degree of feed fermentation, dietary protein, and feed processing. Diet digestibility decreases if the nitrogen requirements of the rumen are not met (Van Soest, 1982). To meet these needs, crude protein levels of 6-8% and 9-10% are necessary for yearlings and calves, respectively (National Research Council, 1987). In line with recommendations provided by Michigan State University Beef Extension Specialists, substantially higher crude protein levels are used in the representative budgets.

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[36] A limitation of Fox and Black (1984) is the exclusion of initial weight in their model. Another limitation of the Fox and Black model is its depiction of metabolic weight as a constant exponential of actual weight over the range of animal weights (Hicks, et al., 1987).

With physiological, environmental, and dietary factors considered and appropriate adjustments made for any which are likely to be limiting for Michigan feedlots, average intake of each of the starter, grower, and finisher rations are calculated. Intake levels are used to determine average daily gain and feed usage during the period. Intake level peaks by 28-42 days on feed, plateaus and is constant during the growing phase and into the finishing phase, and later declines. DMI is therefore calculated separately for the starter ration (adaptation stage), for the grower ration (first part of the plateau stage), and for the finisher ration (second part of the plateau stage and the retard stage). In the first stage, adaptation, feed intake is directly proportional to metabolic body weight. The plateau stage begins when intake is at or near its maximum level and is marked by a period of constant DMI. This stage usually lasts from 2-4 months and is shorter for cattle started on feed at heavier initial weights. As the animal nears slaughter weight, intake is decreased in the retard phase.

Numerous models have been developed in an attempt to use the CNES to quantify the balance between input and output as influenced by the interface of factors controlling feed intake and those regulating the energy balance of the diet (National Research Council, 1987). A few of the more widely used DMI models are described here as background information on the methods employed in this analysis.

Ownes and Gill (1982) formulated an intake model with DMI as a function of body weight, body weight squared, and initial weight of the animal upon entry into the feedlot. Calculated DMI is adjusted for energy concentration of the diet, frame size, feed additive use, and environmental conditions (National Research Council, 1987). Plegge et al. (1984) formulated an intake equation based on feedlot conditions in Minnesota under shelter. Calculated intake is further adjusted for sex, breed, use of feed additives and growth stimulants, and season using tabular values (National Research Council, 1987). National Research Council (1984) quantifies DMI as a function of weight and net energy of the diet. Intake is adjusted for sex, age, and frame size of the animal. Fox and Black (1984)[37] used data from experiment station bulletins and research reports to develop further adjustments of the National Research Council (1984) predicted DMI equation (Equation 3.2)

$$(3.2)\quad (DMI\ (kg/day) = 0.1 * W^{0.75})$$

for animal weight, age, and breed, net energy of the diet, the use of growth promotants, and environmental temperature[38].

Thorton (1985) developed an intake model using data from a large unsheltered feedlot in Western Kansas. Cattle used to estimate DMI were implanted with growth stimulants and fed an ionophore supplement. DMI was estimated as a function of initial and current animal weight and days on feed. Thorton concluded that intake patterns in High Plains feedlots were well established by 28 days on feed, and that beyond this point, initial animal weight and days on feed could be used to accurately predict intake. Although the model has been criticized for its low R^2 value, it may be more appropriate than other models for this analysis because it is based on actual, rather than experimental, conditions. Hicks et al. (1987) tested several other intake models against actual data obtained from large feedlots in Western Kansas and Western Oklahoma. The range of intake estimates given by the various models was high, although most predicted well when cattle weighed approximately 900 lb.

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[37] Also see NRC (1987) 'Applications of equations and adjustments -- yearlings and calves' for further adjustments.

[38] The NRC DMI prediction equation was adopted for an average frame size steer with an equivalent weight of 364 kg (800 lb). The calculated base intake is decreased by $2g/W^{0.75}$ for each additional 22 kg in animal weight. Intake is further decreased by $2g/W^{0.75}$ for each 0.02 Mcal/kg increase in diet net energy for maintenance above 1.27 Mcal/kg. Intake is increased 10% for yearlings and 17% for holsteins of any age and is decreased by 10% or 2% for use of monensin (Rumensin) or lasalocid (Bovatec), respectively. Intake is decreased for overly hot weather and increased for temperatures below 15 degrees celsius.

Several DMI prediction models were evaluated for use in this analysis using several criteria. A model was required which could accurately predict intake under environmental conditions found, and for managerial practices utilized in, Michigan under actual (versus experimental) conditions. The model proposed by Fox and Black (1984) was chosen. This model has been tested in Michigan and throughout the U.S, includes adjustments for ration energy and cattle type, and has been found to consistent in predicting actual intake, outperforming intake predictions based on National Research Council (1984) which does not include an adjustment for stage of growth. Although National Research Council predicts better under experimental conditions, Fox and Black (1984), which uses a lower net energy for gain, predicts better for both yearlings and calves under commercial feedlot situations.

2g. Total ration requirements

Specification of the diet and intake level are used to calculate the rate of gain and define the nutrient requirements of the animal. BEEFSIM is then utilized to calculate total feed disappearance. Adjustments are first made to BEEFSIM to depict the ration, initial and final weight, sex, and age of the animal, weights over which each ration is fed, death loss, and average day of death loss for each production and marketing strategy considered. Feed disappearance of each component of the ration is then calculated[39]. Total ration requirement is calculated as (Equation 3.3)

$$\textit{Total feed requirement/year} = (\textit{weighted mean requirement of feed/animal} * \textit{fill rate} * \textit{turns/year} * \textit{feedlot capacity}) \tag{3.3}$$

[39] Soybean meal, urea, dical, limestone, and salt are purchased. Corn and corn silage requirements are produced on the farm.

Where:

$$\textit{Weighted mean requirement of feedstuff}_i\textit{/animal/day} = ((RFS_i * S) + (RFG_i * G) + (RFF_i * F))$$

Where:

RFS_i	=	Requirements of feed i per animal in the starter diet
S	=	Percent of days on the starter diet
RFG_i	=	Requirements of feed i per animal in the grower diet
G	=	Percent of days on the grower diet
RFF_i	=	Requirements of feed i per animal in the finisher diet
F	=	Percent of days on the finisher diet

Fill rate is determined under each of two marketing scenarios, one turn with full capacity utilization and continuous marketing at 80% capacity utilization.

Total annual corn and corn silage requirements for cattle feed and harvest and storage loss are calculated. Acreage requirements are based on yields of 120 bu/acre corn or 16 ton/acre corn silage. The harvest loss adjustment (i.e. that grown but not available for storage) is 4% and 6% for high moisture corn and corn silage, respectively. Storage loss (i.e. that available for storage but not available for feed) is assumed to be 15% for both high moisture corn and for corn silage.

3. Feed storage facilities

A second component of ownership cost is the annual cost associated with investment in feed storage facilities. Selection of type and size of and methods used to calculate investment costs associated with storage facilities for the corn and corn silage components of the diet are considered here.

High moisture corn and corn silage must be stored anaerobically. Although other technologies, such as silage bags, exist, and are used to some extent by Michigan livestock farmers, due to their widespread use on Michigan farms, silos are used to store all feed grown on the farm[40]. Both horizontal and upright silos are used by Michigan livestock producers. Horizontal silos are more cost efficient in construction and operation than upright silos for medium to large feedlots (Hasbargen and Kyle, 1977). During the last three decades, large horizontal silos (including bunkers, trenches, and stacks) have become the most common means of feed storage for feedlot operations throughout the country (Dickerson, et al., 1992). Bunker silos are the most commonly used facility for feed storage on Michigan farms feeding cattle (Ritchie, et al., 1992). To accurately reflect current investment and managerial practices on Michigan feedlots, horizontal bunker silos are therefore used to calculate feed storage investment cost.

One major criticism associated with the use of bunker silos is the resulting large organic loss from spoilage of the exposed surface (Dickerson, et al., 1992). These spoilage losses, however, can be dramatically reduced by covering the exposed feed. As this analysis is to be reflective of Michigan feedlot operators with moderate to high level management skills, the use of cover to minimize spoilage losses is assumed. To further minimize spoilage loss, constraints are imposed on the length of the silo so that at least four inches of feed is removed from the face of the silo daily.

To calculate feed storage facility investment cost, annual feed storage capacity required for the operation is first defined. The quantity and mix of feedstuffs to be stored is previously defined. Although practices regarding the purchase and sale of grains and other feedstuffs vary largely among Michigan's feedlots, ranging from producing to buying all the feed for the cattle enterprise on the farm, all feeds (with the exception of protein and mineral supplements)

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[40] Storage needs for purchased feeds including soybean meal and minerals are minor due to the feedlot operators ability to obtain these inputs at regular intervals. Storage for these feeds is assumed to be supplied within the existing facility.

are assumed to be produced and stored on the farm. Therefore, silo capacity must exist to store the annual corn and corn silage requirements plus a reasonable amount of capacity for above average yields. In this analysis, storage capacity exceeds feed requirements by 10%.

The least cost silo configuration is determined to accommodate annual storage requirements for corn and corn silage. Various configurations of separate silos for high moisture corn and corn silage were modeled[41]. Silo capacities were converted from tons to square feet using densities of 45 and 55.6 lb per ft^3 for high moisture corn and corn silage, respectively. Least cost designs were selected for each diet for the 400 and 1200 head capacity feedlots operating under the one turn and continuous marketing strategies as a function of total capacity required for corn and for corn silage, feedlot size, and level of capacity utilization. Using this linear estimate, feed storage investment cost was defined for each size feedlot under each production and marketing strategy combination. Details are provided in Chapter 4.

4. Waste handling and manure nutrients

4a. Introduction

In this section, the role of manure as a link between the feedlot and crop enterprises is described, relevant legislation is highlighted, and the procedure followed to determine the balance between available nutrients from manure and crop land nutrient requirements is presented.

Issues regarding the storage, handling, and use of manure are increasingly on the forefront of production agriculture. Justifiably so, since practices regarding the utilization of manure can make the difference between its use as a valuable input to the crop enterprise and its role as a liability to the feedlot enterprise. In the past, manure has been viewed as a necessary side

[41] The separate silos were "built" such that they shared one wall.

affect of production (Garsow, 1991). Manure must be stored, hauled and disposed of under increasingly stringed regulations. In the face of relatively cheap fertilizer costs, producers have traditionally applied manure to their available acreage as a disposal method, without explicitly considering its value as a substitute for fertilizer. Over the past decade, however, researchers and producers alike have begun increasing their focus on the use of manure as a valuable resource.

Manure nutrients offer short run benefits such as building and maintaining soil fertility and supplying water, as well as longer term benefits associated with increased soil productivity such as increased soil water holding capacity, lessened wind and water erosion, improved aeration, and the promotion of beneficial organisms (Midwest Plan Service, 1985). In spite of the many benefits, the economic value of the manure to the crop enterprise is usually calculated solely by its contribution in terms of nutrients replacing commercial fertilizers (nitrogen, phosphorous and potassium)[42]. Depending on the species of animal, approximately 70-80% of the nitrogen, 60-85% of the phosphorous, and 80-90% of the potassium fed to animals is excreted into the manure (Klausner et al., 1985 and College of Ag. and Natural Resources, 1992) and is therefore potentially available to the crop enterprise.

Although economic benefits are reaped from the value of manure as a fertilizer replacement, from its organic matter, and other characteristics which make it enhance crop production, the variability of the benefits provided between, and sometimes within, farms can be quite large.

[42] The value of manure is theoretically easy to define under conditions of perfect markets. With perfectly competitive and efficient markets, the value of manure is priced at its value to the crop enterprise as fertilizer. Therefore, manure, less any costs over and above those which are required to apply the fertilizer it replaces, can be sold as an output from the livestock enterprise. While manure contains all of the essential plant nutrients (Klausner et al, 1985), and thereby provides a valuable resource to the crop enterprise, the crop enterprise also provides a necessary customer for a product which would otherwise vary greatly in price, and may even require the use of a disposal service.

Nutrient content of the manure varies depending on the composition of the ration, amount and type of bedding used, method of manure collection and storage, method and timing of land application, water content, soil and crop characteristics, and climate (Christenson et al., 1992; Brown, 1988; Klausner et al, 1985). In practice, the large variations in nutrient value of the manure to the soil make both manure testing and soil testing important tasks.

Application of excess manure to crop land can harm crop growth[43] and waste nutrients (Midwest Plan Service, 1985). More importantly in light of environmental regulation, excess manure can contaminate soil, cause surface and ground water pollution and nitrogen leeching, and create excessive odors. The need to minimize odor impacts on neighbors has become a critical issue in the determination of the level of technology and management used in the design and implementation of a waste management system (College of Ag. and Natural Resources, 1992). The Generally Accepted Agricultural Practices for Manure Management and Utilization state that a nonsignificant goal of animal producers is to "design, construct, and manage their operations in a manner that minimizes odor impact upon neighbors[44]." The choice of a manure system (including collection, storage, and use) modeled after generally accepted practices ensures that the farms described here represent environmentally sound systems.

[43] Plant growth can be inhibited directly in three ways: (1) very high levels of phosphorous can inhibit uptake of certain trace elements by the growing plants, (2) the addition of manure to the soil causes an immediate and marked drop in O_2 and an increase in CO_2 in the soil air, and (3) heavy manure application can increase soil salinity (Midwest Plan Service, 1985).

[44] Odors are defined by Right to Farm laws to become a "nuisance" when they are "an act that unreasonably interferes with an individual's enjoyment of his/her property." The Michigan Right to Farm Act (P.A. 93 of 1981, amended in May, 1992) provides considerable protection to farmers.

In the development of the representative farms, estimates from Midwest Plan Service (1985) are initially used to represent manure nutrient values. These values are adjusted as nutrient values of manure produced, stored, and utilized on Michigan feedlots is elicited. Equilibrium crop replacement rates (Christenson et al., 1992) are used to represent crop land nutrient needs.

The manure system enters both the feedlot facility and equipment and labor components of the whole farm budget (Figure 3.2) through its specification of manure storage, handling equipment, and labor requirements. The manure storage and handling system (part of the feedlot facility) must be designed to accommodate manure production as specified by feedlot capacity and the marketing strategy employed.

The storage system and equipment and labor associated with application of manure is defined through an iterative process beginning with information obtained from Ritchie, et al. (1992) and adjusted to reflect system designs described by Michigan State University Beef Cattle Extension Specialists, Agricultural Engineers, and Crop and Soil Scientists, and from information elicited from Michigan beef cattle producers about their operations. Descriptions and annual use cost of the manure system are included in the cattle facility section of Chapter 4.

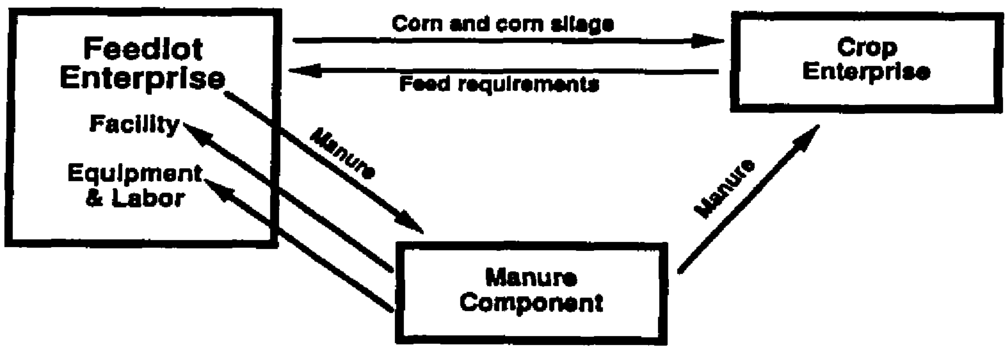

Figure 3.2 The manure system as a component of the whole farm system

The influence of the storage, handling, and use of manure on the nutrients it provides to the cropland are incorporated as is the influence of timing of manure application and incorporation. Machinery and equipment used in, and timing of, manure application is thoroughly discussed in the machinery and labor section of this chapter. It is assumed that the manure is incorporated into the soil within four days of application. Additional time between application and incorporation results in the volatilization of additional ammonium nitrogen from the manure such that an equal quantity of manure would provide less nitrogen to the soil. Although fall application generally results in greater nitrogen loss (College of Ag. and Natural Resources, 1992), a storage system capable of accommodating 12+ months of storage is not economically feasible. Therefore, the representative budgets contained within this dissertation reflect both fall and spring application of manure. Land application of manure is done with a liquid manure tank or solid manure spreader for the pit and the scrap and haul systems, respectively. Liquid manure is broadcast followed by a disk harrow (fall) or chisel plow (spring) pass. Labor requirements associated with the application of manure are included in the FTE assigned to the feedlot enterprise. The disk harrow or chisel plow operation which incorporates the manure is considered in the crop enterprise.

4b. Calculating manure availability

Attention is now focused on describing the process by which the value of manure to the crop enterprise is determined. A procedure for balancing the major nutrients provided by manure from the livestock enterprise and those required by the crop enterprise well documented in the literature is used (see, for example, Jacobs, et al., 1992; Midwest Plan Service, 1985; Klausner, et al., 1985). The method consists of (1) determining nutrients available from manure produced by the livestock enterprise, (2) calculating the nutrient requirements of the crop enterprise, and (3) balancing availability and requirements for the least limiting nutrient to determine the level at which manure can or should be used to provide nutrients to the crop enterprise. Commercial fertilizer is then used to provide additional nutrient requirements of the crop enterprise.

Details of each step in this procedure are discussed. The first step is to calculate nutrients (nitrogen, phosphorous, and potash) provided by manure produced on the farm. Estimates of production levels and nutrient content of manure produced by beef cattle taken from Midwest Plan Service (1985) are shown in Tables 3.2 and 3.3, respectively. These standards are later adjusted to more accurately reflect quantity and quality of manure produced on Michigan feedlots. Values elicited during on-farm interviews and results of Michigan Experiment Station research are used in this adjustment. Actual values used in this analysis are presented in Chapter 4.

Table 3.2 Quantity of beef cattle manure

Total manure production			
Animal size (lb)	manure (lb per day)	manure ft^3 per day	gallon per day
500	30	0.50	3.8
750	45	0.75	5.6
1000	60	1.00	7.5
1250	75	1.20	9.4

Table 3.3 Nutrients in beef cattle manure (animal per year)

Nutrient content (lb per year)				Nutrient content (lb per day)		
Animal size (lb)	N	P_2O_5	K_2O	N	P_2O_5	K_2O
500	62	45	53	0.17	0.127	0.145
750	93	68	80	0.26	0.191	0.229
900	112	82	96	0.31	0.229	0.261
1000	124	91	106	0.34	0.254	0.290
1250	155	114	133	0.43	0.318	0.373

Where:

N	=	Total Nitrogen
Elemental P (phosphorous)	=	$0.44 * P_2O_5$
Elemental K (potassium)	=	$0.83 * K_2O$

Manure nutrients are adjusted to reflect their availability to the crop depending on its storage, handling, and use (Patni and Culley, 1989; Much and Steenhuis, 1982). Nitrogen is the most volatile of the nutrients provided by manure and can be lost to the air as ammonia and in open lots due to runoff and leeching (Midwest Plan Service, 1985). Loss is therefore much greater for open lots than for liquid storage systems. Special manure handling techniques such as injecting manure or incorporating manure immediately (within 48 hours) following application are recommended because prolonged surface exposure of the manure increases nitrogen loss. Estimated values for nitrogen loss associated with handling and storage of manure for different systems are shown in Table 3.4 (Midwest Plan Service, 1985). These estimates are used as general guidelines in adjusting total nitrogen provided to reflect storage, handling, and application practices depicted in the representative budgets.

Table 3.4 Nitrogen losses during storage and handling

System	Nitrogen Loss (in percent)
Solid	
Daily scrap and haul	15-35%
Manure pack	20-40%
Open lot	40-60%
Liquid	
Anaerobic pit	15-30%
Above ground storage	10-30%
Earth Storage	20-40%
Lagoon	70-80%

In addition to losses during storage, handling, and application, another reason manure nutrients are less available than commercial fertilizers is that some nutrients, most notably nitrogen, are present in both inorganic and organic form. The organic form of nitrogen must be decomposed before it is available to the crop. It is partially released during the year of application and then mineralizes (becomes available) over several years. Percent of organic nitrogen available to the crop in the year of application is called the mineralization factor. The nitrogen mineralization factor associated with several different manure collection and storage systems is shown in Table 3.5. The description of the rate at which organic nitrogen becomes available to the crop in successive years is called the decay or decomposition series. Although this rate varies by region since it depends largely on soil characteristics and climate conditions (College of Ag. and Natural Resources, 1992), the organic nitrogen released in the second, third, and fourth years following application is commonly estimated at 50%, 25%, and 12.5%, respectively, of that available in the first year (Midwest Plan Service, 1985). For example, organic nitrogen availability associated with manure stored as an anaerobic liquid is 30% in the year of application and 15%, 7.5%, and 3.75% in the second, third, and fourth years, respectively.

Table 3.5 Percent organic nitrogen available in the year of application

Manure Handling	Mineralization Factor
Solid without bedding	0.35
Solid with bedding	0.25
Anaerobic liquid	0.30
Aerobic liquid	0.25

Representative budgets are formed such that nitrogen from the current year and each of the three previous years is mineralized is available. This steady state condition is reached in the fourth year of application when 56.25% (30% + 15% + 7.5% + 3.75%) of the organic nitrogen in the manure is available. A detailed example of calculating nitrogen availability from manure is presented in Appendix 2.

Contrary to nitrogen, the immediate availability of phosphorous and potassium nears 100% (College of Ag. and Natural Resources, 1992; Midwest Plan Service, 1985). There is very little phosphorous lost from manure during storage, agitation, transport, application, and incorporation. Therefore, if manure application is balanced on the nitrogen requirements of the crop enterprise, phosphorous is usually overapplied. As the phosphorous level builds, the amount in the soil limits manure application. In this analysis, manure over that required to meet the most limiting of the nitrogen or phosphorous requirement is assumed to be disposed of at the cost of application.

Nutrient levels required by the crop enterprise reflect soil nutrients utilized by the previous year's crop. This is in compliance with current Michigan Right to Farm Standards, which recommend phosphorous application be reduced to a level which does not exceed that removed from the previously harvested crop when the current level of phosphorous in the soil exceeds 150 lb/acre.

A spreadsheet model, designed after that presented in Jacobs, et al. (1992), was developed for use in balancing manure nutrient availability with crop fertilizer requirements. Nitrogen, phosphorous, and potassium requirements above those made available by manure produced on the farm are purchased at 1992 price levels. Commercial fertilizer price estimates are taken from Nott, et al. (1992).

5. The crop enterprise

5a. Introduction

Michigan's cattle producers have historically produced all or most of the feed used in the livestock enterprise, in effect, marketing their crops through cattle[45]. In this analysis, the

[45] Although recent evidence suggests that this may be changing as an increasing number of Michigan cattle producers sell cash crops and purchase off quality and byproduct feeds.

crop enterprise plays an important role in the whole farm operation by providing the corn and corn silage used in the feedlot enterprise.

The major costs associated with the crop enterprise are those associated with the ownership of equipment and storage facilities, labor, and other variable costs including crop and machinery inputs such as fertilizer, fuel, and repairs and maintenance on equipment. The variable resource needs associated with the crop enterprise are identified and the methods used to assigned costs to these resources defined. Methods used to calculate labor, capital expenditure, fuel and repair costs for machinery are described in the section entitled machinery and labor.

5b. Operating costs

Since variable costs in crop production rarely exhibit economies of farm size[46], total variable costs for all farm sizes can be calculated on a per acre basis. Total variable costs per acre are then simply multiplied by the number of acres of corn or corn silage grown to identify total variable cost associated with each crop. The first step in determining variable costs is to identify inputs required by the crop enterprise. Fertilizer levels required are specified as those extracted from the soil during the growth of the crop such that, once nutrients are replaced, the soil condition is comparable to that which existed previous to plant growth. This is referred to as the replacement method. Commercial fertilizers are purchased to supplement those provided by manure. Replacement rates for corn and corn silage grown in Michigan are taken from Christenson, et al. (1992). Seed and pesticide requirements are defined at levels recommended by the Michigan State University Cooperative Extension Service in Nott, et al. (1992) for 120 bu/acre corn or 16 ton/acre corn silage and adjusted for

[46] Although purchasing discounts or managerial expertise may reduce per acre costs for farms with large crop enterprises, organized purchasing groups, most notably cooperatives, provide many of these same advantages to farms with smaller crop enterprises.

a continuous corn rotation. Cost of herbicides, limestone, insecticide, and fertilizer are also taken from Nott, et al. (1992). Costs initially taken from Nott, et al. (1992) are verified by consulting with mid-Michigan dealers.

A land use charge is included such that net return from fed cattle production in Michigan can be compared with that in the Central and Southern Plains states. As it is difficult to provide a soil and land characteristic type that will prove descriptive for a majority of Michigan cattle feeders in the study area, land values and their associated rents are taken from Hanson, et al. (1992) for the lower one-half of the southern peninsula of Michigan. In their survey of Michigan land owners, Hanson, et al. (1992) found rental rates for ground used in the production of corn, soybeans, and hay to be "roughly in proportion to the corresponding values of each land type."

Representative budgets do not reflect the use of preservatives or additives in corn silage. As a high degree of managerial ability is assumed throughout the analysis and adequate packing and covering of silage has been shown to adequately minimize silage losses (Dickerson, et al., 1992), a preservative is not necessary. A silage additive is not required since all supplemental protein requirements are supplied by soybean meal and urea.

5c. Machinery and labor

Machinery requirements for the farm are determined by identifying the machinery components necessary to perform all field activities and matching those components by size and power to the acreage needs and time constraints of the farm. Depreciation and repair costs associated with machinery purchase and use, housing, interest, and insurance charges and labor, fuel, and timeliness costs are then calculated based on these machinery requirements.

Within the crop enterprise, there exist interactions among machines and between machinery, labor, land, and weather. The key to the selection of farm machinery is identification of the right balance between these factors (Bowers, 1987). A commonly used method with which to identify machinery investment required is to determine what activities need to be accomplished and to select machinery in light of these activities, time constraints, and labor cost and availability. To properly consider the effect of the various interactions, a systems approach is appropriate (Rotz, et al., 1983). A computer model can simplify the complex systems approach to selecting and costing farm equipment when there exist a large number of alternative combinations, as is the situation Michigan farmers face. A model developed by Siemens, et al. (1990), herein referred to as MACHSEL, was chosen to select machinery requirements in this analysis for its capability to select and match equipment and for its flexibility in specification of field activities, working hours per day specific to each field activity, time windows within which each operation must be performed without penalty, machinery, implement, and labor costs, and yield levels.

A key assumption in the use of his model is that the producer is purchasing a complete, well matched set of machinery at one point in time. Under this assumption, equipment requirements are affected only by the competing demands for the equipment and labor available on the farm (Lohr, et al., 1991)[47]. Although, in reality, a producer buys equipment dynamically over a period of many years to match the evolving farm situation, the single point of purchase assumption is appropriate for long run budgeting of representative farms and is consistent with the methods used throughout this dissertation.

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[47] Competition for machinery and labor is of particular importance, however, within the context of this analysis since only corn and corn silage are grown. Nearly identical activities need to be completed across all fields within similar time frames.

The final cost associated with machinery and labor use is a timeliness cost. For each field operation, there are a limited number of days available for field work due to climatic and soil conditions (Parsch, 1982). A timeliness cost is assessed when labor, with the given machinery, cannot complete the field operations within the specified time period. A timeliness cost is applied when it is the least cost alternative over additional machinery investment and/or additional labor cost. For a given operation, timeliness costs are zero if all planting and harvest operations can be completed within the specified time period and are otherwise specified as a percent of yield per day planting and harvest activities are delayed beyond the identified time window. Timeliness costs are higher with smaller machinery sizes and fewer available operators.

Details of the model's operation complete this section. To account for weather uncertainty, field days within each period are limited to those for which there is an 80% probability that the particular field operation can be performed. A conventional tillage system is used to define activities, although as conservation practices become more common, their consideration as viable alternatives has become warranted and in many cases, desired (Lohr et al., 1991). Conventional tillage practices employed include fall manure and fertilizer application (incorporation), followed with a chisel plow pass. In the spring, manure is again applied and the field is disked, cultivated, planted, and sprayed for weed and insect control. Row cultivation and NH_3 operations are performed in the early summer. Harvest is completed in the fall.

The first step in determining the optimal machinery set is to specify field activities required to grow corn and corn silage. The dates within which each activity must be completed with no loss in yield are also specified. Available field days during the spring and fall months are taken from Rotz, et al. (1983). Field day probabilities from Parsch (1982) were adjusted to represent available field days in the summer months. As MACHSEL does not have an activity to reflect spreading manure or hauling and packing corn silage, custom hire rates are used for these activities. Specific activities associated with the crop enterprise, and biological and other assumptions used in the analysis, are presented in Chapter 4. Machinery specifications and associated costs can be obtained from the author.

A linear model was used to estimate per acre cost associated with machinery and labor necessary to supply feed under each production and marketing strategy. Per acre machinery and labor cost is estimated as a function of acres of corn and of corn silage. Dummy variables are included for each system as described by feedlot size and capacity utilization. The specific estimation used is reported in Chapter 4.

As MACHSEL is constrained to the use of no more than six tractors, three combines, and six operators, the machinery and labor associated with growing crops for the 3000 head capacity feedlot marketing cattle year round and the 6000 head capacity feedlot operating under both capacity utilization scenarios could not be calculated using this program. However, since economies of size associated with the machinery and labor components of the crop operation were exhausted by the 3000 head one turn system, per acre machinery ownership and operating costs for this system are used for systems feeding additional numbers of cattle as well.

The annuity approach is used in MACHSEL to calculate annual use cost for alternative machinery combinations. Default prices are verified against those calculated from prices reported in Harrigan (1993). Machinery and implement prices provided by Harrigan were regressed on horsepower (machinery) or width (implements) to estimate prices for a wider range of machinery and equipment sizes. Since, in practice, purchase price is generally lower than list price due to the widespread use of purchasing incentives and other short run and site specific discounts, 90% of estimated list price is used to reflect actual investment. The life of each machine, repair and maintenance costs, and labor requirements are based on those reported by Rotz and Bowers (1991). Rotz and Bowers developed these cost estimates to provide a set of reasonable cost values consistent across different types of machines and varying amounts of machine use. They are a revision of repair and maintenance parameters published by American Society of Agricultural Engineers. Labor and use costs include those associated with machine prep time, travel time to and from the field, field time, turning time and time crossing waterways and other obstructions, and time to load and unload crop inputs. Time associated with adjusting, maintaining, and repairing machinery is included in repair and maintenance cost.

Labor involved in the crop operation is calculated using a per hour wage rate of $10, which includes the employers portion of unemployment taxes and benefits. Adjustments are made in the labor hours estimated by MACHSEL to more accurately reflect time spent off machinery. Repair costs reflect hired (shop) repair. Management is not included in the available labor hours for the crop enterprise because there is no marketing of crops in most years and the crop decisions are based on feedlot requirements.

6. Other operating and overhead costs

6a. Introduction

In this section, treatment of operating and overhead costs not considered elsewhere are discussed. Where not specified as otherwise, costs are based on 1992 market prices in Central and Southern Michigan. Feedlot closeout information from throughout the country is used to verify operating costs.

6b. Operating costs

Operating costs not included, or only partially included, in a forementioned component of the farm operation include labor, implants, fly control, and other processing costs and costs associated with morbidity (medicine and veterinary costs) and for bedding, beef checkoff, feedstuffs not grown on the farm, and feed additives. Operating costs are estimated using local or regional requirements and prices. Costs associated with marketing cattle including cost of feeder cattle, transportation, interest on feeder cattle, and commissions are included in the calculation of the gross margin from marketing cattle.

Labor

In a feedlot, labor is used for feeding and waste handling, observing, treating, and handling cattle, and in overhead activities such as repairing facilities, buying and selling cattle, purchasing feed, and record keeping. In this analysis, labor associated with equipment, but not facility, maintenance and repair, as well as labor used in the crop enterprise is calculated using an hourly wage rate. Labor required for these activities is not included in labor assigned to the feedlot. Other labor used for the feedlot facility is defined by number of full time equivalents (FTE) less adjustments for the custom hire of manure handling.

Several attempts have been made to estimate labor requirements of activities involved in fed cattle production. Labor requirements per head have been found to vary by type of system (open lot versus partial or total confinement)[48], capital intensity and size of operation (Hasbargen, 1967; Van Arsdall and Nelson, 1981), labor productivity, and availability of family labor (Arsdall and Nelson, 1985). Labor requirements also vary between regions. Gwilliam (1988) and Hasbargen (1967) found that labor requirements per head were higher on

[48] For example, labor requirements for an open lot system with shelter can be 20% higher than for a partial confinement system (Loy, et al., 1986).

Michigan feedlots that for those in much of the rest of the Corn Belt and in the Southwest. Higher labor requirements were the result of additional maintenance, management, and other activities (such as laying bedding) required as a result of Michigan's cold damp climate. Labor was also found to be more expensive in Michigan than in either the Southwest or the rest of the Corn Belt as the result of strong competition from industry.

Per head capacity feedlot labor requirement estimates vary. Per head labor requirements reported by Van Arsdall and Nelson (1981) for feedlots with differing annual sales are shown in Table 3.6. Weight put on cattle in the feedlot under which these requirements were estimated was 475 lb, 640, and 550 lb for yearlings, calves, and averaged over yearlings and calves, respectively.

Table 3.6 Labor hours required per head marketed (Van Arsdall and Nelson, 1981)

	All	Calves	Yearlings
Annual sales	hours per head		
20 - 99	11.6	11.8	11.5
100 - 199	6.0	6.3	5.7
200 - 499	4.3	4.7	4.1
500 +	3.0	3.7	2.8
All	6.1	6.3	5.8

Loy, et al. (1986) estimated labor requirements of feedlots for which cattle feeding is an integral part of the farm operation and with the farm operator supplying necessary labor, as one full time equivalent (FTE) for every 8-900 head. Nott, et al. (1992) also suggested using a decision rule of 1000 head per FTE, although he notes that it is virtually impossible to determine per head labor requirements for a feedlot enterprise since labor is used for both the crop and livestock enterprises. To incorporate the existence of economies of size in labor use, Nott, et al. described labor requirements for the feedlot enterprise as (Equation 3.4)

$$(3.4)\quad \textit{Beef feeders (hrs/head)} = 5.27 + \frac{339.07}{\textit{no. feeders}}$$

Labor requirements implied by this formula are transformed into FTEs for the four feedlot sizes considered in this analysis (Table 3.7). The resulting labor requirements are substantially higher than those reported in other literature and those observed for Michigan feedlots.

Table 3.7 Full time labor equivalents by feedlot size

Feedlot capacity (no. head)	No. FTE	FTE per 1000 head
400	0.98	2.45
1200	2.67	2.23
3000	6.46	2.15
6000	12.78	2.13

In this analysis, labor requirements for cattle handling, and feeding, bedding, manure handling and disposal, and managerial activities is determined from information gained during on-farm interviews.

As the proportion of family labor available increases over the short to intermediate run, direct labor costs fall as feedlots operate without adequate return to unpaid family labor (Arsdall and Nelson, 1985). The residual claimant, return to unpaid labor, is considered by many to be the reservation wage required to keep the producer in business. In long run economic analysis, the wage rate for other available work in the region for which the person(s) is (are) qualified represents the opportunity cost of labor used in the feedlot operation. In order to continue feeding cattle in the longer run, Michigan fed cattle producers will need to be rewarded consistent with the value of their time and skills to alternative production activities. In this analysis, salaries will reflect these wages as necessary to obtain and retain skilled workers.

Other operating costs

Other operating costs include material costs for processing incoming cattle and providing secondary implants, material and veterinary costs associated with morbidity, bedding cost and the cost of feed not grown on the farm and feed additives. Material costs associated with processing incoming cattle include implants, vaccinations, fly tags, and dewormers. Use of growth implants as part of a feedlot management program is commonplace in Michigan and throughout the U.S. Use of growth promoting implants has been found to be profitable, particularly the first implant (Rust, 1990), with the combined use of estrogenic and androgenic implants providing the greatest return. Animal response to implants depends on sex (steers > heifers > bulls), maturity (grower > finisher > suckling calves), and gain (greater when ADG > 1) (Ritchie and Rust, 1992b). Implant costs and active life are described in several publications (see, for example, Ritchie and Rust, 1992 and Nott, et al., 1992).

Cost associated with processing incoming cattle (including secondary implants when appropriate), initially elicited from industry experts and extension personnel, are $4.00, $4.25, and $4.50 for cattle on feed <90, 90-120, and >120 days, respectively (Rust, 1993). The validity of these values for Michigan cattle feeders are verified through farm interviews and through secondary data sources. Chute charges associated with processing incoming cattle and providing secondary implants are included under facility and labor cost. Only materials and veterinarian costs are considered here.

Morbidity reduces feed intake and gain and generally requires treatment. Since, in this analysis, intake and gain is adjusted for morbidity and because chute charges are included in facility and labor costs, the cost of morbidity to the feedlot enterprise shows up only in the cost of required medicine and veterinarian services. Estimates from several secondary data sources, as well as from feedlot interviews are used to represent morbidity rates and associated costs. Morbidity is represented by percent of cattle requiring treatment and varies depending on the age at which cattle enter the feedlot.

Bedding costs are taken from secondary data sources and elicited from Michigan cattle feeders. Initial interviews suggest $7.00 is a good estimate for annual bedding costs per head capacity on non-slatted flooring.

Feeds not grown on the farm (soybean meal, urea, and supplement) and feed additives are purchased to provide a complete cattle diet. Historic average prices are used to calculate purchased feed cost. Feed additives are purchased at 1992 price levels. Available feed additives include ionophores, MGA, and antibiotics[49]. Most Michigan cattle feeders use ionophores (Ritchie, et al., 1992). Ionophores reduce feed intake, increase gain, and improve feed efficiency and may also decrease coccidiosis, acidosis, and bloat occurrence (Ritchie and Rust, 1992b). Feed intake is reduced approximately 5.2% and 2.5%, gain is increased 2.5% and 5.2%, and feed efficiency is improved 7.2% and 8.1% when Rumensin (monensin) and Bovatec (lasalocid), the two most common ionophores, respectively, are used (Ritchie and

[49] The feeding of MGA or low level antibiotics is not considered in this analysis as their use is not widespread in Michigan.

Rust, 1992b). Each costs approximately 1.5 cents per head per day when used at recommended levels. The use of an ionophore (Rumensin) is modeled in this analysis. The two affects of its use are changes in ration requirements and growth and increased operating cost. The changes in ration requirements are reflected in BEEFSIM. The cost of the ionophore is included as an operating cost. No additional feeding time or machinery use is required since the product can be readily mixed with the feed.

6c. Overhead costs

Overhead costs not included, or only partially included, in a forementioned component of the farm operation include general farm overhead (e.g. telephone, office supplies, and dues and fees), insurance, and energy other than machinery fuel and oil. Repair and insurance costs are calculated as a percent of investment in facilities or equipment (Table 3.8). General farm overhead and energy use values by farm size and type are taken from secondary data sources, elicited from interviews with Michigan cattle feeders, and verified with industry experts.

Table 3.8 Feedlot ownership costs

Description	Repairs	Taxes and insurance
Lots, shelter, and buildings	3.00	0.25
Waste handling		
Structures	6.00	0.25
Equipment	5.00	0.25
Feeding equipment	5.00	0.25
Handling equipment, facilities, wells, offices, etc...	2.00	0.25

7. Financing cost

7a. Introduction

The availability and cost of financing has taken on an increasingly important role for U.S. agriculture. In the 1950's, there was a favorable attitude towards investing in the cattle industry. In the mid 1960's investment attitudes changed as interest rates increased and the money market became an international entity (Allen and Riley, 1984). Agriculture experienced a depression in the early 1980's that led to foreclosure on many loans. The decade of the 1980's were a time of volatile and often high interest rates and tightening borrowing standards. Contrarily, during the first 3 years of this decade, interest rates have fallen to record lows.

Capital availability and cost has, does, and will continue to affect the profitability of the beef industry (National Cattlemens Association, 1989). In order for the Northern Corn Belt to remain competitive in fed beef production, financing must be readily available at competitive rates. The purposes of this section are to briefly define sources of funding used to finance feedlot operations and identify interest rates faced by Michigan feedlot operators.

7b. Sources of financing

Cattle feeders who are without ample internal financial liquidity must either borrow or find alternative financing arrangements involving persons who have available capital, such as investors interested in leasing or contract feeding (National Cattlemens Association, 1989). There are many such sources of credit available. Alternative marketing arrangements such as contracting fed cattle may increase borrowing potential and lower the cost of credit to the feedlot (Cooney, 1993). Other feedlot operators may have to give up marketing control or set a price in advance in order to retain control of production (National Cattlemens Association, 1989).

Alternatives are available to cattlemen who do not qualify for or are unable to afford traditional sources of capital (National Cattlemens Association, 1989). One such short term credit source available to Michigan cattle feeders is Michigan Livestock Exchange's Livestock

Feeding Program (LFP). LFP was established in 1986 to maintain cattle trading volume in Michigan because conventional sources of livestock financing were becoming less available. LFP is a wholly owned subsidiary of the Michigan Livestock Credit Corporation (MLCC), which was formed in 1989 to operate LFP. Under this program, a farmer can finance cattle, hogs, and lambs. The gross margin from marketing cattle less costs incurred by MLSE and MLCC (commission for the purchase and sale of livestock, cost of placement of feeders, and a service fee), are received by the farmer.

7c. Selection of an interest rate

Interest rate paid by cattle feeders will vary by credit worthiness of the individual and type, length, and source of loan. Producers having long-term contracts which minimize production and price risk will be able to obtain credit for equipment and facilities at relatively lower interest rates than producers with greater risk exposure (National Cattlemens Association, 1989). Short term loans will often carry higher interest rates than long term loans. Interest costs increase with debt load as firms grow to stay competitive.

Krause (1992) presents several arguments to support his assertion that a wide range of cost of capital values are supported in any industry wide analysis. These arguments are (1) the appropriate discount rate should be the weighted average of returns to equity and interest on debt (Aplin, et al., 1977) and the relative weights of debt and equity differ between farmers, (2) risk affects expected rate of return on investment and risk differs substantially between operations, and (3) the calculation of any average rate of return depends on historical data which may be biased as dependent on economic conditions. Indeed, interest used by researchers studying similar problems over similar time frames are rarely consistent.

Given the focus of this analysis on producers with upper level management skills and with strong balance sheets, the assumption is made that producers are able to obtain a competitive rate of interest. Interest rates are therefore taken directly (without adjustment) from the Agricultural Finance Databook published by the Board of Governors of the Federal Reserve System. A national interest rate is justified for two reasons, (1) wide differences in cost of credit exist between firms within a region and (2) national credit markets (such as national commercial banks) are frequently utilized by Michigan farmers. Interest rate used will correspond with the purpose of the loan. It is assumed that inputs other than facilities and equipment and feeder cattle, such as labor and feeds not grown on the farm are purchased as needed and therefore, do not require equity or debt financing.

DEVELOPMENT OF CATTLE GROSS MARGINS

Introduction

In this section, the second component of feedlot profitability, gross revenue from marketing cattle, is discussed. Terminology is first presented. The Michigan fed cattle market is discussed in some detail. Methods by which to use various price series to represent the gross margin in a region are presented. Finally, the presentation of marketing costs used in the analysis is discussed.

Terminology

In a feedlot operation, a large portion of the farm revenue is generated from the sale of fed cattle. Total revenue from the sale of cattle is total weight of beef sold times the weighted average price per weight unit (Equation 3.5).

$$(3.5) \quad Revenue = Price_{fed} * Weight_{fed}$$

Net revenue is total revenue less the cost of procuring, transporting, and growing feeder cattle, and marketing and transporting fed cattle. Net revenue, then, represents the return to unallocated resources, such as management (Equation 3.6).

$$(3.6)\quad NR = Price_{sale} * Weight_{sale} - \left[[1.0 + (\frac{i\ (\%)}{100}) * (\frac{days\ on\ feed}{365}) * Price_{purchase} * Weight_{purchase} \right] - (Price_{feed} * feed + Price_{other\ inputs} * other\ inputs)$$

Net revenue, a function of production costs and cattle prices, indicates the profitability of an operation and, over a year, is equivalent to average annual return.

Gross margin is another descriptive term useful for defining the revenue of the operation[50].

[50] Other measures commonly used in the industry to represent the margin between fed cattle and feeder cattle prices are the (1) purchase versus sale price ratio and (2) the purchase versus sale price margin where:

$$(3.7)\quad Purchase\ v.\ sale\ price\ ratio = \frac{P_{sale}}{P_{purchase}}$$

$$(3.8)\quad Purchase\ v.\ sale\ price\ margin = P_{sale,\,t,m+k} * IA_{t,m+k} - P_{purchase,\,t,m} * IA_{t,m}$$

Where $IA_{t,\,m+k}$ is the deflator associated with selling fed cattle in year t, k months after the month in which feeder cattle were purchased as denoted by m and $IA_{t,\,m}$ is the deflator associated with purchasing feeder cattle in year t, month m.

The purchase versus sale price ratio is a convenient measure. It approximates the gross margin for cattle purchased and sold at specific weights unless there is significant inflation, in which case the ratio is biased upward. Use of the purchase versus sale price margin, on the other hand, adjusts for inflation. While both measures are commonly used among feedlot operators, the level at which the relationship between sale and purchase prices is favorable depends heavily on the weight at which cattle are purchased and sold. For cattle purchased lighter, and therefore held on feed longer, the spread between purchase and sale price can be relatively large as compared to a favorable spread when heavier cattle are purchased. Therefore, as the only method common across all purchase and sale weight strategies, gross margin from the purchase and sale of cattle is used throughout this dissertation. Purchase versus sale price ratios or margins elicited during feedlot interviews are changed to gross margins using other information gathered during the interview including the weight at which cattle are purchased and sold.

Gross margin is the revenue from marketing fed cattle (Equation 3.9). Depending on how gross margin is defined, transportation, marketing, interest, and other operating and overhead costs may or may not be included.

$$(3.9) \quad Gross\ margin = sale\ value - purchase\ cost$$

$$= (Price_{sale} * Weight_{sale}) - (Price_{purchase} * Weight_{purchase})$$

Total annual gross margin associated with marketing cattle is average gross margin times the number of animals fed or (Equation 3.10)

$$(3.10) \quad GM_{head} = GM_{average\ fill} * number\ of\ turns\ per\ year$$

$$Where:\ Number\ of\ turns\ per\ year = \left[\frac{Total\ number\ cattle\ days\ per\ year}{Average\ days\ on\ lot\ per\ animal}\right] \quad and$$

$$where:\ Total\ number\ cattle\ days\ per\ year =$$

$$\left[\frac{average\ fill\ rate\ (\%)}{100} * number\ of\ days\ per\ year\right]$$

Gross margin is adjusted for inflation as is shown in Equation 3.11.

$$(3.11) \quad Real\ GM = (Sale\ Value_{m+k}\ /\ CPI_{m+k}) - (Purchase\ cost_{m}\ /\ CPI_{m})$$

Where:

CPI	=	Consumer price index (1992 = 1)
m	=	month and year in which feeder animal is purchased
k	=	number of months after m

The advantage of using gross margin to represent the revenue portion of the operation separately from production cost is that it facilitates the comparison between returns generated from the purchase and sale of the cattle and costs of production. Additionally, by isolating costs associated with transportation, commissions, and interest associated with the purchase and sale of cattle, efficiency of the on-farm operation can be more easily differentiated from that associated with sale and procurement.

Representing relative gross margins

Availability and use of price series to represent actual gross margins in, and relative gross margins between, Michigan and Kansas are discussed in this section as is the method used to depict seasonality of purchase and sale of cattle

1. Use of inter-regional data

There are several alternatives for calculating gross margins for use in defining the actual and relative gross margins. One alternative is to adopt the assumption that, although price levels may be different for feeder and fed cattle in Michigan and Kansas, the gross margin faced by each is the same. Under this assumption, relative (dis)advantages between the two regions stem solely from operating and marketing costs. In an even stricter form, the assumption depicts gross margins less marketing costs (including commissions and transportation) as identical between the two regions. Neither of these models, particularly the first, impose unreasonable assumptions when, for example, the objective is to define only those differences between feedlots in different regions attributable to production costs. These models are much too restrictive, however, for an analysis in which aspects from the entire operation, including procurement and sale activities, are considered. These alternatives are thus rejected.

Another alternative is to use a more complete Kansas price series to calculate Kansas gross margins and, from them, formulate an expected Michigan gross margin based on transportation cost between regions. Theoretically, a transportation model should be able to predict the relative gross margins between the two regions because both Michigan and Kansas import substantial numbers of feeder cattle from the southeast and the location of packers utilized by feedlots in the two states is fairly well defined. Gross margins experienced by Kansas feedlots, adjusted for importing feeder cattle to, and exporting fed cattle from, Michigan, should approximate those faced by Michigan cattle feeders. If this were not true, the buying and selling behavior of cattle producers and packers would shift in order to make it true[51], although short run deviations from predicted price differences are not unexpected.

The final alternative is to calculate gross margins for Michigan and for Kansas independently. The disadvantage of this alternative is that it requires a much richer data set than either of the other alternatives discussed. Ideally, the choice of method used should depend solely on the purposes of the research. In many practical situations, including this analysis, the use of a particular methodology is largely dictated by data availability. While it is preferred to utilize series of feeder and fed cattle prices actually faced by Michigan cattle feeders over time, data on Michigan feeder cattle prices is limited. Therefore, a combination of the latter two alternatives is used. Gross margins faced by Michigan producers as calculated using Michigan feeder and fed cattle prices are compared with those faced by Kansas producers.

Marketing avenues used to represent those utilized by Michigan cattle producers will affect the accuracy by which gross margins they face are depicted. The focus of this study is portraying practices of good feedlot managers in Michigan. No attempt is made to discover optimal marketing plans for a Michigan producers. Other factors influencing cattle prices, including the source of feeder cattle, where fed cattle are sold, and the type of trading scheme utilized (e.g. negotiation versus formula pricing) are rather simply chosen to reflect practices of Michigan cattle feeders.

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[51] This price adjustment behavior is called arbitrage, a term which refers to the purchase and immediate sale of securities and related instruments in order to profit from a price discrepancy (Lesser, 1994).

Fed cattle prices received by Michigan cattle feeders were provided by Michigan Livestock Exchange (MLSE). MLSE provided a ten year series of fed cattle prices freight on board (FOB) farm[52]. The value of this series depends on how representative farm gate prices paid to producers commissioning Michigan Livestock Exchange to sell fed cattle are of the fed price received by Michigan fed cattle producers in general. As MLSE acts as a broker for approximately 75% of all fed cattle sold (Gwilliam and Rust, 1988), this price series is highly representative of fed price received in Michigan.

Michigan feeder cattle prices are calculated from feeder cattle auction prices in the Southeast. Since 87.7 percent of cattle fed by Michigan producers marketing >500 head per year are purchased in the Southeast, feeder cattle prices from this area plus transportation and commission costs and a shrink charge are expected to be representative of those paid by Michigan producers. A relatively rich Lexington, Kentucky price series is used. To validate the use of this relatively richer price series, it is adjusted for transportation, commission, and shrink and compared with the price of feeder cattle purchased in Michigan, less similar costs. Lexington feeder cattle prices are reported over a range. A symmetric distribution is assumed and the midpoint is used to represent the unknown true mean since it is not possible to estimate a weighted average and there is no strong reason to believe the data is severely skewed. Average real prices from 1984 to 1992 are used.

[52] Due to the inability of Michigan packers to consistently bid competitively with larger packers in Illinois and Pennsylvania, the majority of fed steers and heifers from Michigan feedlots marketing over 1000 head per year are sent to packers over 250 miles from the feedlot. This is unlikely to change in the foreseeable future. Therefore, throughout this dissertation, price received for fed cattle by Michigan cattle feeders will be based on that received from direct marketing with IBP in Joslin, Illinois.

2. Turnover and seasonality

Seasonal purchasing and selling of cattle will affect gross margin. Assumptions made about feedlot capacity utilization influence the method by which the yearly gross margin for the feedlot enterprise is calculated from gross margin for an individual animal. If cattle are purchased and sold during some, but not other, months of the year, calculation of annual gross margin must reflect seasonality of prices. In this case, total gross margin is calculated as a weighted average of that for each group of cattle bought and sold throughout the year (Equation 3.12).

$$(3.12) \quad GM_{group} = (P_{sale} * W_{sale} * number\ sold) - (P_{purchase} * W_{purchase} * number\ purchased)$$

$$With\ each\ group\ weighted\ by: \left[\frac{Average\ number\ of\ days\ on\ lot\ for\ the\ group}{total\ number\ of\ cattle\ days\ per\ year}\right]$$

If cattle are purchased and sold throughout the year, total gross margin is calculated from a weighted average annual feeder and fed cattle price.

In this study, two capacity utilization strategies are considered: (1) one hundred percent fill rate with one turn of cattle fed annually with cattle purchased on October fifteenth and the sale date determined as a function of purchase weight, sale weight, and average daily gain and (2) an eighty percent fill rate with continuous marketing resulting in multiple turns. In each case, price paid for feeder cattle reflects weight purchased. Fed price is the same regardless of sale weight.

Marketing costs

Once cattle gross margins are estimated, total gross margin from the marketing of cattle is determined by subtracting additional costs associated with marketing cattle. Although there are numerous others[53], the three major marketing costs explicitly considered in the calculation of gross margin are transportation, shrink, and commissions.

1. Transportation

Live cattle transportation costs vary quite markedly, depending on size of truck used, total distance animals are hauled, volume and frequency of business between the shipper and the client, and whether backhauls loads are arranged[54].

Michigan State University Beef Cattle Extension Specialists estimate the average hauling rate for hauling cattle a distance greater than 50 miles to be approximately 4 cents per mile for a potload[55]. At full capacity this translates into approximately $1.75 per loaded mile. Gwilliam (1988) concurred in adopting a rate of $1.75 per loaded mile for potload trailers, noting that this rate had decreased or held steady between 1980 and 1988. He further noted than because transportation costs had stabilized, they were therefore not likely to contribute to a shift in regional comparative advantage. Transportation costs are calculated for feeder cattle to the farm from Lexington, Kentucky. Freight rates are provided by MLSE. These rates are compared with those elicited from Michigan cattle producers.

2. Shrink

Shrink cost is associated with the physical movement of cattle. Shrinkage in beef cattle is the loss in body weight associated with transit from the scales used by the seller to those used by

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[53] Other costs including operator management time involved in selecting the appropriate type of cattle, determination of feeder and fed cattle market(s) in which to participate, gathering price and other information, telephone and travel charges, and death loss. In this study, these items are included in production cost.

[54] Livestock trailers are often not suitable for other loads and the arrangement of back hauls is often time consuming and inconvenient.

[55] Potloads are double decker semitrailers with over the road weight limits of 50,000 lb.

the buyer. The magnitude of this loss is a function of type of feed fed prior to shipping, time of day, animal handling, weather, prior preconditioning, physical type (sex, breed, age), change in environment, and distance and time associated with the movement of livestock (Brownson, 1986). Most actual body weight loss, or transit shrink, occurs during loading, the first part of a haul, and unloading (McNeil).

Transit shrink is a combination of excretory and tissue shrink. Excretory shrink occurs first and is the loss of belly fill (Brownson, 1986). If there is substantial executory shrink due to excess fill, time for an animals return to pay weight is extended, resulting in a less desirable feed/gain ratio and higher feed costs (McNeil). After 12 hours without feed or water, most body weight loss is due to tissue shrink, a decrease in the carcass weight of the animal. Tissue shrink occurs during extended hauls or long periods of fasting and requires a longer recovery period than excretory shrink (Brownson, 1986). When feed and water are made available, most executory shrink is recovered, but it takes 2-3 weeks to regain tissue shrink (i.e. reach pay weight) (McNeil).

Pencil shrink, the percent of gross weight deducted to determine sale weight, is used to represent estimated tissue shrink. Although pencil shrink standards exist throughout the cattle industry, depending on the weight of cattle on feed, distance hauled, and the nature of past transactions between the buyer and seller, variations are found throughout the literature and in practice. Loy, et al. (1986) used a 6% pencil shrink for incoming steer calves and a 3% pencil shrink for incoming yearling steers and outgoing fed cattle (outshrink), as did Hasbargen (1967). McNeil, however, reports a higher outshrink of 4%. In this analysis, shrink figures used by Michigan cattle feeders, as elicited during on-farm interviews, are used.

3. Commissions

Commission costs appropriate for the type of marketing channels utilized will be applied as a cost of marketing cattle. Commission costs are elicited from Michigan cattle feeders. Again, due to the large number of Michigan fed cattle run through MLSE, commissions charged by this organization serve as a benchmark for that paid by Michigan cattle feeders.

CHAPTER 4 RETURNS TO MICHIGAN FED CATTLE PRODUCTION

INTRODUCTION

Methods described in Chapter 3 are employed to calculate production costs, gross margins, and net returns to fed cattle production in Michigan. Specifics used in the calculation of and the resulting values are reported and discussed in this chapter for farms of different sizes and utilizing various production and marketing strategies. Economies of size within and for the whole farm operation are also discussed. Comparison of net returns to Michigan fed cattle production to those available from alternative land uses in Michigan and to net returns to fed cattle production in Kansas are discussed in Chapters 5 and 6, respectively.

The format of this chapter closely follows that of Chapter 3. The discussion begins with a description of the characteristics of feeder cattle used in the analysis. Specifics used in calculating production costs are then described for each of the several components discussed in Chapter 3 (livestock facilities, livestock rations, feed storage facilities, waste handling and manure nutrients, the crop enterprise, and other overhead and operating costs). Gross margins calculated for each alternative production and marketing strategy are presented. Net returns to Michigan fed cattle production are presented and discussed for production and marketing strategies considered. The affect of feedlot size on cost of production and net return to fed cattle production is also discussed.

COMPONENTS OF THE WHOLE FARM

Cattle type

Through its influence on dry matter intake and feed efficiency, cattle type is a major determinant of animal feed requirements and animal performance. It thereby also influences feed storage investment and annual use cost, machinery and labor use, and crop enterprise operating costs, waste handling requirements and available manure nutrients, and gross margins. For this analysis, cattle types were defined to reflect a limited but representative range of animals fed by Michigan cattle producers.

Animals are medium frame (frame size 6) steer calves (< 600 lb), short yearlings (600-749 lb), and yearlings (>750 lb). The feeding of heifers and animals of other frame sizes, particularly holsteins, is not considered. Cattle are assumed to be in good health and weaned, but not preconditioned. Although several producers interviewed purchased preconditioned feeder cattle, most revaccinated and implanted these cattle as they arrived in the feedlot as though they had not been preconditioned. Additionally, the use of Kentucky feeder cattle auction prices in this analysis does not reflect the purchase of preconditioned feeder cattle.

Production costs

1. Introduction

In this section, details regarding the determination of fed cattle production costs are described and their values reported. Make up and resulting costs associated with each component is described independently following the format of Chapter 3. Resulting total production cost and details regarding its makeup for each production, marketing, and capacity utilization strategy and feedlot size is then reported to conclude the section.

2. Livestock facilities and equipment

Production cost associated with annual capital investment in livestock facilities and equipment is calculated for Michigan feedlots of different sizes. In the following pages, livestock facilities modeled in the analysis are described as are details regarding investment cost calculation. Total and average annual investment cost for each system are reported.

As more fully described in Chapter 3, feedlot facilities were defined in an iterative process between the author and Michigan State University Beef Cattle Extension Specialists to reflect those found in Michigan and address environmental and other constraints faced by Michigan producers. Feedlot interviews were used to verify and refine the details of these systems. Michigan cattle feeders interviewed tended to use system designs which were, in most aspects, similar to those initially defined by Michigan State University personnel.

The feedlot design includes a combination of concrete and slatted pens, except for the smallest feedlot size, which has only concrete floor pens. Selection of the type of flooring utilized in the system involved assessing the tradeoffs between different floor systems. Advantages of concrete over slatted pens include lower investment cost, lower death loss and health problems[56], and more flexibility in animal type and use. Advantages provided by slatted flooring include increased timeliness and decreased labor hours and equipment use associated with manure removal, as well as better manure containment and higher yields for finishing cattle. Manure containment is particularly important for feedlots located near growing urban areas. Increasing attentiveness by Michigan cattle producers to environmental and odor considerations is reflected with the construction of pits to hold manure generated in pens on

[56] The assertion of lower death loss and health costs in concrete floored pens assumes that the frequency of scraping and hauling manure and the amount and type of bedding are adequate to keep animals dry.

slatted floors as well as that generated from animals in the concrete floored pens. Dirt lots were not considered.

Facility designs by feedlot size (400, 1200, and 3000 head capacity) are shown in Figures 4.1 through 4.3. The 6000 head capacity feedlot is not shown since the layout, as well as nearly all investment costs, are identical to twice that of the 3000 head capacity feedlot.

Two-thirds of the feedlot capacity of the 1200, 3000, and 6000 head capacity feedlots has concrete floors with 40% of floor space under cover. The remaining one-third of pen capacity has slatted flooring with full cover. Cattle in these feedlots are started on feed in concrete pens and transferred to slatted floor systems for the final 50-90 days on feed. In the 400 head capacity feedlot, all pens have concrete flooring and 40% cover. The implicit assumption in this design is that the 400 head capacity feedlot is part of a whole farm system for which ample slack labor exists, so that the investment required to build slatted floors is not economically justified by labor saving advantages. This assumption is not necessary limiting, even in the case of land characteristics, feedlot proximity, and/or environmental constraints which make manure runoff a problem since, if required, small manure holding pits can be added on the down slope of each pen to catch manure runoff.

In the feedlot design used in this analysis, as in almost ninety-five (94.7) percent of Michigan feedlots marketing >500 head annually (Ritchie, et al., 1992), there is a separate hospital area. A working and handling facility, including a load gate, chute, livestock scale, and pens for sorting cattle, is also included. The loading facility for each feedlot is designed to have the same capacity as one pen so it is not necessary to mix animals from different loads except when cattle are initially brought into the feedlot. Maximum pen size (3000 and 6000 head capacity feedlots) is designed so as not to exceed that recommended by Beef Cattle Specialists

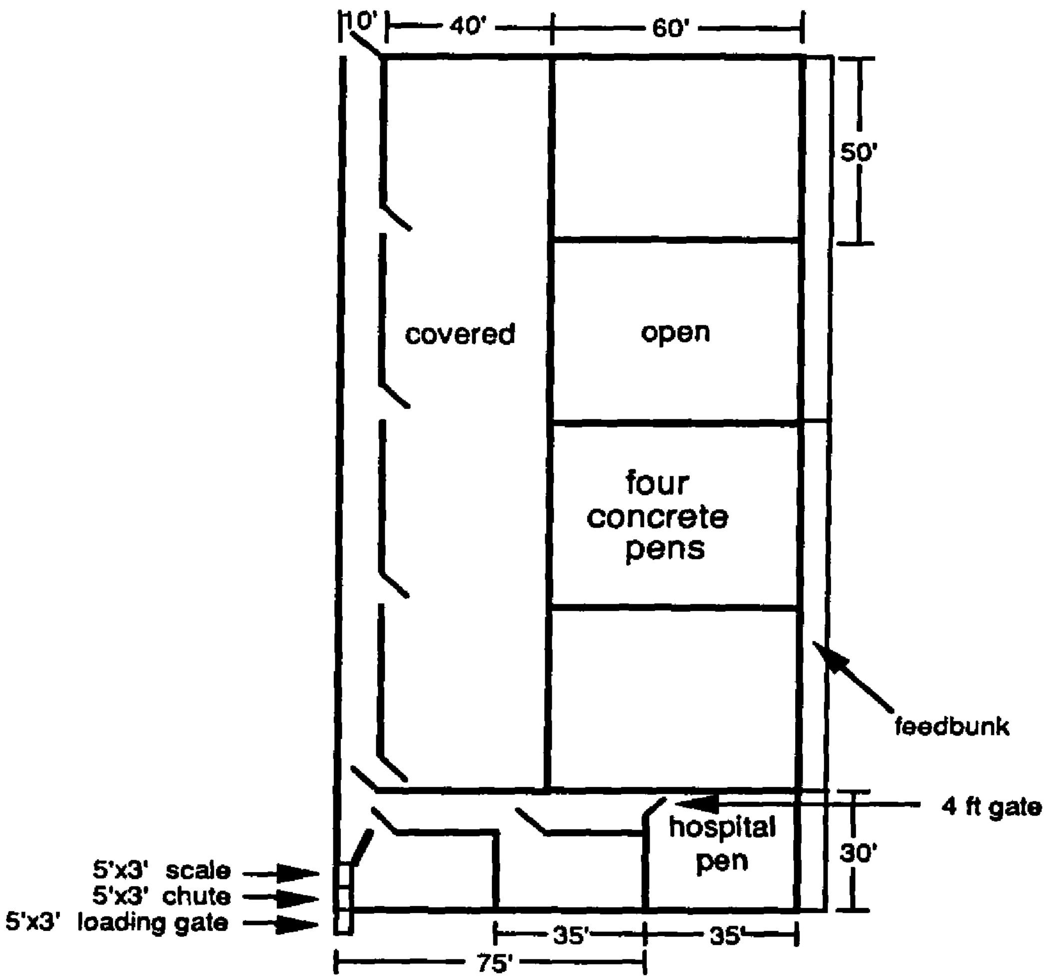

Figure 4.1 400 head capacity feedlot

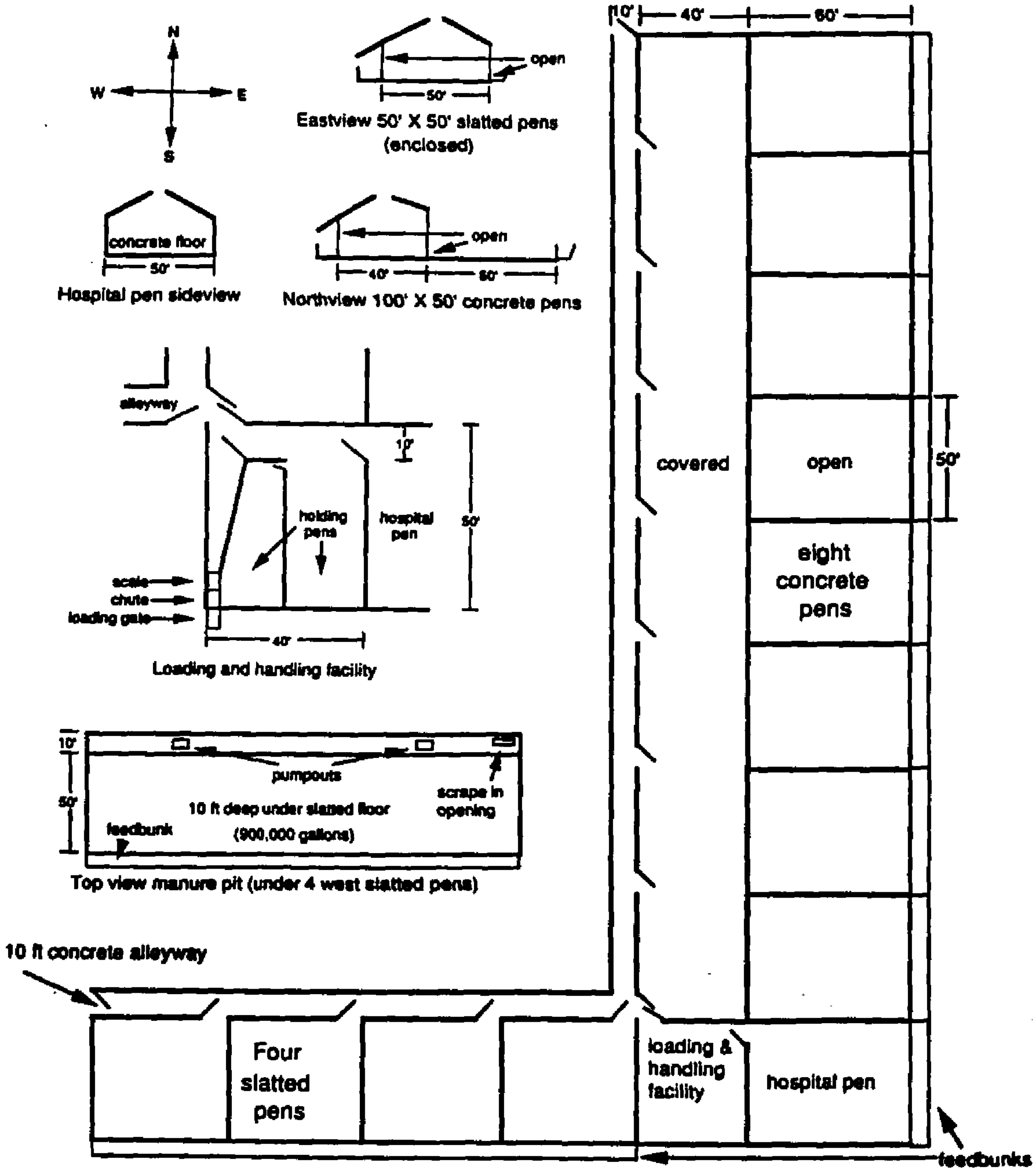

Figure 4.2 1200 head capacity feedlot

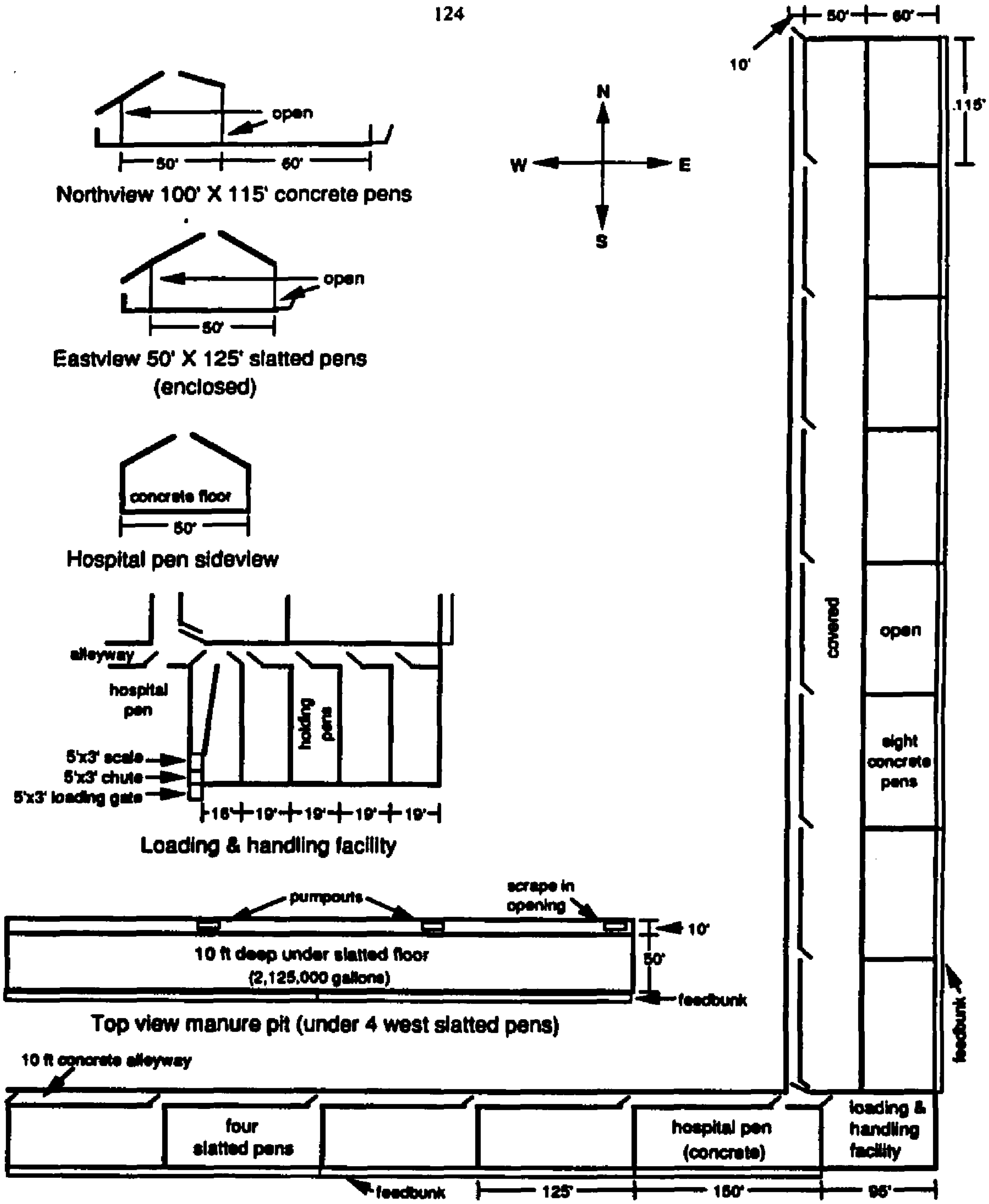

Figure 4.3 3000 head capacity feedlot

(Rust, 1993) at Michigan State University. The design and size of the facility are adapted from Midwest Plan Service (1987). Table 4.1 shows the square feet allowed per head for the concrete slatted floor pens, the hospital pen, and the loading and handling facility by feedlot size.

Table 4.1 Space allocated per head for the livestock facility components

	400 head capacity	1200 head capacity	3000 head capacity
Concrete pens square feet per head capacity	50.0	50.0	50.6
Slatted floor pens square feet per head capacity	NA	25.0	25.0
Holding pen area square feet per head capacity square feet per head in one load load size	 3.49 13.98 100 head	 1.15 13.84 100 head	 1.49 17.89 250 head
Hospital pen square ft per head capacity	2.6	2.5	2.5

A detailed budget depicting the various components of the livestock facility is presented in Table 4.2. Total, per head, and average annual investment costs are shown for each feedlot size. Specific investment and labor costs incurred in the construction of this facility, as well as details regarding its design, are presented in some detail within, and as footnotes accompanying, the table. An initial industry bid (ADL) and several iterative personal communications with an industry specialist (Grant, 1992 and Grant, 1993) provided investment cost of the feed bunk and the slatted floor pens. Cost of the slatted floor pens includes a manure pit with capacity to hold 6 months manure from animals in both the slatted and concrete floor pens. Roof and sidewall investment costs are a direct quote from Bergan Construction, Inc. specific to these feedlot designs. Other costs (concrete, fencing, gates, waterers, and livestock chute(s), scale(s), and loading ramp(s)) were calculated as a trimmed

Table 4.2. Facility ownership costs

Capacity	400 hd	1200 hd	3000 hd	6000 hd
Description of Facility Component[1]				
Building[2]				
· Area				
Partially Enclosed Area (sq. ft.)	1,050	17,000	39,000	78,000
open area (sq. ft.)	10,000	20,000	55,200	110,400
· Cost				
Partially Enclosed Area (sq. ft.)	$3,465	$56,100	$128,700	$257,400
Open Area (sq. ft.)	$28,000	$56,000	$154,560	$309,120
. Total Cost	$31,465	$112,000	$283,260	$566,520
Fence[3]				
· Total Feed of Fence				
Standard (ft.)	988	1,937	4,054	8,108
Over Feed Bunk (ft.)	230	650	1,570	3,140
· Cost				
Standard (ft.)	$1,867	$3,661	$7,622	$15,324
Over Feed Bunk (ft.)	$ 281	$ 793	$1,915	$ 3,830
Total Material Cost	$2,148	$4,454	$9,577	$19,154
Labor Cost	$2,148	$4,454	$ 5,577	$19,154
. Total Cost	$4,296	$8,908	$19,154	$38,308
Gates[4]				
· Number of Gates				
4 ft.	1	0	1	2
10 ft.	8	18	22	44
Wooden Blocking Gate(s)	1	1	1	2
· Cost				
4 ft.	$32	---	$32	$64
10 ft.	$400	$900	$1,100	$2,200
Wooden Blocking Gate(s)	$ 25	$ 25	$ 25	$ 50
. Total Cost	$457	$925	$1,157	$2,314
Concrete[5]				
· Area (sq. ft.)				
Alleyways		3,900	9,200	18,400
Pens		39,000	101,200	202,400
Working Facilities		---[6]	5,700	11,400
Hospital Pen		---	7,500	15,000
Total Area (sq. ft.)	25,300	42,900	123,600	247,200
. Total Cost	$34,813	$59,030	$159,754	$319,508
Manure Pit[7]	NA	$189,000	$399,000	$798,000
. Total cost				
Fence Line Feeder[8]				
. Length (ft)	230 ft.	650 ft.	1570 ft.	3140 ft.
. Total cost	$4,140	$11,700	$28,260	$56,520
Waterers[9]				
. Number of Waterers	5	13	26	52
. Total Cost	$1870	$4,862	$9,724	$19,448
Chute	$1,643	$1,643	$1,643	$3,286
Scale	$1,470	$1,470	$1,470	$2,940
Other overhead (wells,...)	$7,000	$11,000	$20,000	$35,000
Total cost	$87,154	$400,538	$923,422	$1,841,844
Average annual cost	$14,889	$66,736	$153,365	$305,916
Investment cost per head	$218	$334	$308	$307

[1]See Figures 4.1, 4.2, and 4.3 for detailed diagrams of the 400, 1200, and 3000 head capacity feedlots. The 6000 head capacity facility is equivalent to twice that of the 3000 head capacity facility.

[2]The building is partially to mostly enclosed in the following areas of the feedlot facility as shown in the Figures depicting the facility systems: slatted floor pens, loading and handling facility, and hospital pen. In these areas, roof and side wall construction (including labor) and material costs are $3.30 per square foot. The roof is 3-12 to 4-12 pitch clear span. The sidewalls are rough except for a 1 foot height along the floor which is constructed from finished boards to protect the wood from manure and other materials which may cause erosion. The remaining area of each facility (the solid floor pens) has only a roof (50 ft trestle) and supports over the floor. The cost of construction and materials in this area is $2.80 per square foot.

[3]Fence is constructed using $4'' \times 4'' \times 8'$ posts supporting 4 crossboards of untreated wood $(2'' \times 6'' \times 16'')$. The cost of labor is equivalent to that of materials so that total cost of construction is twice the cost of materials. Cost of posts and board is determined as the average of three observations resulting from trimming off the low and high cost of five quotes from lumber yards in the Lansing, MI area. Total cost per foot is calculated as:

$$4 \text{ boards} \times \frac{\$5.35}{16'} + \frac{\$4.41}{8'} = \$1.89/\text{ft.}$$ where $5.35 is the average cost per 16 foot board and $4.41 is the average cost per post.

Posts are spaced approximately every 8 foot. Only 2 boards are used at the feed bunk, reducing the per foot cost to $1.22 along the feed bank.

[4] Aluminum gates are priced from the Quality Farm and Fleet catalog. Gates of 4 feet and 10 feet are priced at $32 and $52, respectively. The cost of a wooden blocking gate is calculated as the cost of 2-8 foot posts plus the cost of enough boards to build a 6 foot high door (3). Total cost of a wooden blocking gate is $25.

[5]Concrete is laid $6''$ thick so that in one cubic yard there are 54 square feet of concrete. Concrete cost per cubic yard is $50 or $0.93 per square foot. Total labor and other materials cost is $0.45 per square feet. Total material and labor cost of laying concrete is $1.37 per square feet.

[6]The concrete floor for the hospital pen and working facilities are included in the manure pit calculations due to the extension of the pit under these facilities.

[7]The 400 head capacity feedlot has no slatted floor system and therefore no manure pit. The 1200 head capacity feedlot has a $60' \times 300 \times 10'$ pit of which $10' \times 200'$ and $60' \times 100'$ areas of the pit extend beyond the slatted floors. The pit has been extended so that manure from the concrete pits can be scraped into the pit, eliminating the need for weekly and haul chores. The pit for the 3000 head system is $60' \times 650' \times 10'$. Both pits have two pumpouts and a scrape in opening.

[8]The fenceline feeder costs $18/ft for materials and construction.

[9]Watering tanks are Mirafont 150 head beef cattle tanks. Each tank has 2 openings, holds 2 gallons,and costs $374 ($350 + 7% handling fee).

average of material and labor quotes from not fewer than 5 area dealers or contractors. Gates and cattle waterers are listed at cost and do not include a labor charge for installation. The lifetime of each component used to calculate annual average investment cost is presented in Table 4.3.

Table 4.3 Facility component lifetimes[57]

Component	Lifetime (yr)
building	15
cattle scale	10
chute	10
concrete	15
fence	7
fence line feeder	15
gates	10
loading ramp	7
other overhead (such as wells)	25
slats/manure pit	15
waterers	10

Investment cost per animal fed and per head per day are shown in Table 4.4. Because it does not include the higher cost slatted floors, the 400 head capacity feedlot has the lowest per head capacity investment cost ($218) of any system. Economies of size in cattle facility cost are apparent over the 1200 to 3000 head capacity range as the per head capacity facility investment cost drops from $334 to $308. Per head per day facility investment costs are

[57] Lifetime for each facility component used to determine average annual cost from investment cost is described as the recovery period for MACRS depreciation. Although facilities and equipment may be used longer, it is assumed that after this period, repair costs become high enough to warrant reinvestment.

$0.13, $0.19, and $0.18 for the 400, 1200, and 3000 head capacity feedlots, respectively, when the feedlot is operated year round at 80% capacity. When only one group of cattle are fed, per head per day facility investment costs range from $0.14 to $0.23, $0.21 to $0.35, and $0.19 to $0.32 for the 400, 1200, and 3000 head capacity feedlots, respectively.

Table 4.4 Total, per head, and per head per day cattle facility annual use cost[58]

System	cost per animal fed	cost per head per day
400 OT	37.22	0.14 - 0.23
400 CM	20.37 - 33.53	0.13
1200 OT	55.62	0.21 - 0.35
1200 CM	30.28 - 50.09	0.19
3000 OT	51.12	0.19 - 0.32
3000 CM	27.84 - 46.04	0.18
6000 OT	50.99	0.19 - 0.32
6000 CM	27.84 - 46.04	0.18

3. Livestock rations and feed requirements

To reflect the wide range of diets fed on Michigan cattle farms, budgets were prepared using each of seven different rations. The diets were chosen to closely reflect the range of diets fed to yearlings and calves on Michigan feedlots visited. Yearling diet 1 (Y1) is a hot diet with cattle starting on a diet described as 62.8% concentrate and finishing on a diet comprised of

[58] The range presented for the continuous marketing system represents investment cost per animal fed for producers purchasing and selling cattle of differing weights and feeding different rations. Investment cost will be relatively high when cattle are purchased light, sold heavy, and fed a higher roughage ration since each of those practices increases days on feed. The range presented for the one turn system represents investment cost per head per day for producers purchasing and selling cattle of differing weights and feeding different rations. Investment cost will be relatively low when cattle are purchased light, sold heavy, and fed a higher roughage ration as each of those practices increases days on feed, spreading investment costs over a larger number of days.

82.7% concentrate. Y2 closely reflects the average diet fed by Michigan feedlots marketing >500 hd per year, beginning with a 25% concentrate starter diet and increasing in percent concentrate to 60% in the finishing diet. Y3 contains the moderate starter diet found in Y2, but quickly increases in percent concentrate, with the finisher diet at 82.7% concentrate, as in Y1. Percent concentrate in each diet in diet Y4 is approximately midway between that found in Y1 and Y2. The first calf diet (C1) is nearly identical to Y4. C2 has a starter diet with no corn (8% concentrate), has no grower diet, and has a moderately hot (70.8% concentrate) finisher diet. C3 is the most concentrated of any diet at each stage. Percent concentrate for each ration and diet is shown in Figure 4.4.

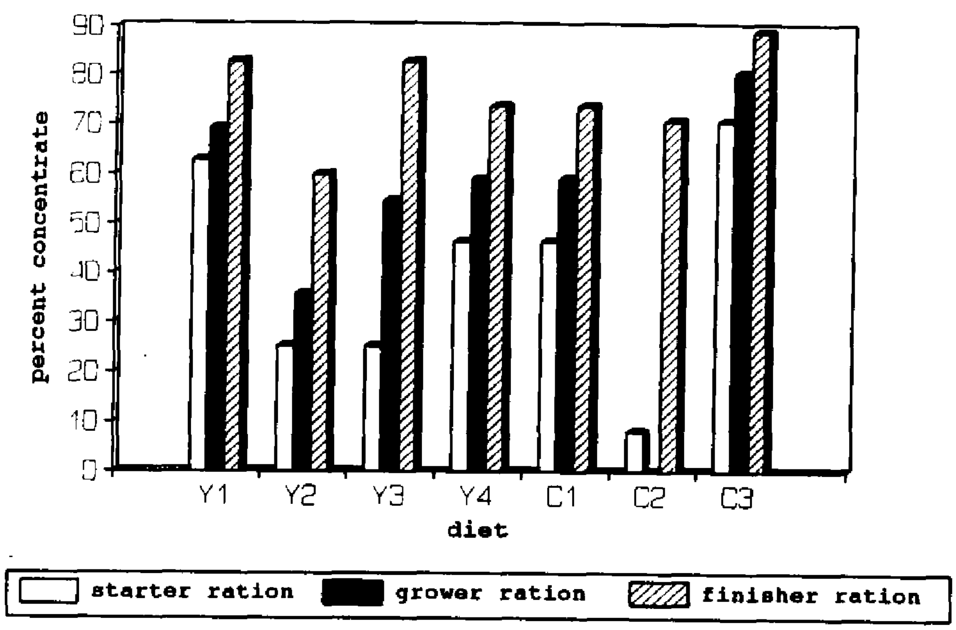

Figure 4.4 Percent concentrate by diet

In order to later identify the affect of different purchase and sale weights on net return, each diet is fed under two or three purchase and sale weight scenarios. Cattle fed Y1 and Y2 are purchased at both 600 lb and at 750 lb and sold at 1175 lb. These diets are also fed to yearlings purchased at 750 lb and sold at 1250 lb. Cattle fed Y3 and Y4 are purchased at both 600 lb and at 750 lb and sold at 1175 lb. Each calf diet is fed to cattle purchased at 500 lb and at 650 lb and sold at 1175 lb.

Intake and cattle performance associated with each diet are simulated using BEEFSIM as described in Chapter 3. Key assumptions under which intake and performance were simulated include animal type, the use of rumensin and implants, tissue shrink. Death losses are assumed to occur on the twenty-first day on feed for 2.0, 1.5, and 0.75 percent of calves, short yearlings, and yearlings entering the feedlot, respectively. Tissue shrink of 1.5% of total body weight is subtracted from purchase weight to indicate the weight at which the animal enters the feedlot and of 0.75% is added to payweight to determine weight at which animals will leave the feedlot. The standard NRC intake equation was adjusted upward by 10% for yearling animals and downward by 10% and 6% for the use of Rumensin and under the starter diet, respectively, and for an energy level at which physiological factors limit intake. Net energy available for maintenance and gain are modeled as a function of previous nutritional condition of the animal (body condition), use of rumensin, and net energy of the feed. Net energy required per unit gain is a function of breed (frame size 6), sex (male) and body weight. No adjustment of either intake or gain was made for environmental influences.

For each diet and purchase and sale weight combination, a starter, grower, and finisher ration is described as percent corn, corn silage, protein supplement (soybean meal and urea), and mineral (limestone, potassium chloride, and white salt) on a dry matter basis (Table 4.5). Net energy for maintenance and that for gain provided by each diet are shown as are days on feed, animal performance (average daily gain and lb feed per lb gain), and total consumption

Table 4.5 diet and Performance Descriptions[1]

Source of Diet Description	Steve's "Eat It Up" Diet			"Survey Says" Diet			Yearling Diet #3		Yearling Diet #4		Calf Diet #1		Calf Diet #2		Calf Diet #3	
Cattle Descriptions																
Beginning Weight	600	750	750	600	750	750	750	750	750	750	500	650	500	650	500	650
Sale Weight	1175	1175	1250	1175	1175	1250	1175	1250	1175	1250	1175	1175	1175	1175	1175	1175
"Age"	SRYL	YRL	YRL	SYRL	YRL	YRL	YRL	YRL	YRL	YRL	Calf	Calf	Calf	Calf	Calf	Calf
Number of Days on Ration[2]																
	45	30	30	45	30	30	30	30	30	30	60	45	60	45	60	45
Starter	81	65	78	100	79	97	70	89	70	86	99	88	0	0	86	70
Grower	82	64	83	100	79	99	70	85	70	87	99	88	204	164	86	70
Finisher																
Ration (% DM)[3]																
Starter																
Corn	57.00	57.00	57.00	17.80	17.80	17.80	17.80	17.80	40.00	40.00	38.70	38.70	0	0	65.00	65.00
Corn Silage	37.20	37.20	37.20	75.00	75.00	75.00	75.00	75.00	53.50	53.50	55.00	55.00	92.00	92.00	29.40	29.40
Soybean Meal	3.91	3.91	3.91	5.46	5.46	5.46	5.46	5.46	4.73	4.73	4.50	4.50	6.20	6.20	3.68	3.68
Urea	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.60	0.60	0.50	0.50
Limestone	1.07	1.07	1.07	0.90	0.90	0.90	0.90	0.90	0.98	0.98	1.02	1.02	0.90	0.90	1.09	1.09
Potassium Chloride	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.04
White Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
NEm (Mcal/kg)	1.94	1.94	1.94	1.68	1.68	1.68	1.68	1.68	1.83	1.83	1.82	1.82	1.56	1.56	1.99	1.99
NEg (Mcal/kg)	1.26	1.26	1.26	1.08	1.08	1.08	1.08	1.08	1.18	1.18	1.18	1.18	0.99	0.99	1.30	1.30
% Concentrate	62.80	62.80	62.80	25.00	25.00	25.00	25.00	25.00	46.50	46.50	45.00	45.00	8.00	8.00	70.60	70.60
Grower																
Corn	65.20	65.20	65.20	30.30	30.30	30.30	50.00	50.00	55.00	55.00	52.00	52.00	--	--	76.00	76.00
Corn Silage	30.70	30.70	30.70	64.30	64.30	64.30	45.20	45.20	40.90	40.90	42.50	42.50	--	--	79.30	79.30
Soybean Meal	2.29	2.29	2.29	3.93	3.93	3.93	3.22	3.22	2.29	2.29	3.93	3.93	--	--	3.00	3.00
Urea	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	--	--	0.50	0.50
Limestone	0.91	0.91	0.91	0.73	0.73	0.73	0.81	0.81	0.91	0.91	0.73	0.73	--	--	0.90	0.90
Potassium Chloride	0.11	0.11	0.11	0	0	0	0	0	0.11	0.11	0	0	--	--	0	0
White Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	--	--	0.30	0.30
NEm (Mcal/kg)	1.99	1.99	1.99	1.76	1.76	1.76	1.89	1.89	1.92	1.92	1.91	1.91	--	--	2.07	2.07
NEg (Mcal/kg)	1.30	1.30	1.30	1.14	1.14	1.14	1.23	1.23	1.25	1.25	1.24	1.24	--	--	1.35	1.35
% Concentrate	69.30	69.30	69.30	35.70	35.70	35.70	54.80	54.80	59.10	59.10	57.50	57.50	--	--	80.70	80.70

Source of Diet Description	Steve's "Eat It Up" Diet			"Survey Says" Diet			Yearling Diet #3		Yearling Diet #4		Calf Diet #1		Calf Diet #2		Calf Diet #3	
Finisher																
Corn	79.00	79.00	79.00	55.70	55.70	55.70	79.00	79.00	70.00	70.00	67.00	67.00	67.00	67.00	85.50	85.50
Corn Silage	17.30	17.30	17.30	40.00	40.00	40.00	17.30	17.30	26.30	26.30	29.20	29.20	29.20	29.20	11.00	11.00
Soybean Meal	1.77	1.77	1.77	2.82	2.82	2.82	1.77	1.77	2.10	2.10	2.30	2.30	2.30	2.30	1.50	1.50
Urea	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Limestone	0.96	0.96	0.96	0.84	0.84	0.84	0.96	0.96	0.90	0.90	0.90	0.90	0.90	0.90	1.00	1.00
Potassium Chloride	0.30	0.30	0.30	0	0	0	0.30	0.30	0.13	0.13	0	0	0	0	0.40	0.40
White Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
NEm (Mcal/kg)	2.08	2.08	2.08	1.93	1.93	1.93	2.08	2.08	2.03	2.03	2.01	2.01	2.01	2.01	2.12	2.12
NEg (Mcal/kg)	1.36	1.36	1.36	1.26	1.26	1.26	1.36	1.36	1.32	1.32	1.31	1.31	1.31	1.31	1.39	1.39
% Concentrate	82.70	82.70	82.70	60.00	60.00	60.00	82.70	82.70	73.70	73.70	70.8	70.8	70.8	70.8	89.00	89.00
Percent Death Loss[4]	2.00	0.75	0.75	2.00	0.75	0.75	0.75	0.75	0.75	0.75	2.00	1.50	2.00	1.50	2.00	1.50
Performance																
Days on Feed	208	159	191	245	187	225	170	204	170	203	258	205	263	209	232	185
ADG (lb)	2.85	2.80	2.73	2.42	2.38	2.31	2.62	2.55	2.62	2.56	2.68	2.65	2.63	2.60	2.98	2.94
ADG (kg)	1.29	1.27	1.24	1.10	1.08	1.05	1.19	1.16	1.19	1.16	1.22	1.20	1.19	1.18	1.35	1.33
Feed/Gain	6.21	6.75	6.89	7.29	7.92	8.18	7.18	7.40	7.18	7.37	6.30	6.82	6.35	6.90	5.68	6.17
Total Feed																
kg of Corn (DM)	1128.4	904.9	1109.2	756.4	604.8	749.7	791.6	977.9	794.0	980.9	1078.5	903.6	1072.9	894.8	1349.4	1138.1
kg of Corn Silage (DM)	425.1	342.6	405.6	1047.9	844.5	1013.3	529.6	625.5	527.3	614.5	756.0	641.1	783.7	675.3	313.6	266.5
kg of Soybean Meal (DM)	38.4	30.7	36.2	69.8	56.1	67.1	41.2	48.7	41.1	48.1	64.5	54.8	58.1	49.9	43.9	37.4
kg of Urea	6.7	5.4	6.5	9.5	7.7	9.3	5.7	7.0	5.7	6.9	8.0	6.8	6.9	5.9	7.2	6.2
Total kg feed	1621.2	1300.9	1578.1	1901.5	1526.3	1855.2	1384.8	1679.2	1384.8	1670.6	1921.8	1623.9	1943.2	1644.3	1738.2	1468.3

1. Calf, short yearling (SYRL), and yearling (YRL) describe the age at which animals enter the feed yard.

2. For each diet considered, rumensin is utilized in the quantity recommended by the manufacturer. Cattle are implanted as is appropriate for the time spent in the feedlot. All cattle are frame size 6 and are described by condition score. For each steer, 1.5% of total body weight is lost in real tissue shrink during loading, transport, and unloading. Outbound tissue loss is 0.75% of total body weight. Each is fed in an environment which affects neither intake nor feed efficiency.

3. Calves (<600 lb), short yearlings (600-749 lb), and yearlings (>749 lb) spent the first 60, 45, and 30 days, respectively, on the starter diet. Cattle then spent approximately one-half of total remaining days on feed on the grower diet and on the finisher diet except in the case of calf diet #2 when, due to the absence of a grower diet, calves spent the total remaining time on the finisher diet. All cattle on one of the 3 calf diets are considered with the 650 lb animals considered heavy calves rather than short yearlings.

4. Twenty-three percent calcium/eighteen percent potassium supplement was available, but was not required, to balance any diet under consideration.

5. Diet requirements were calculated under the assumption that requirements for that percent of feed no longer required due to death loss ceased on day 21 of days on feed (i.e. all death loss is assumed to have occurred on day 21). Death loss for animals entering the feedlot at 600 lbs or less, between 601 and 749 lb, and at 750 or more lb is 2.0, 1.5, and 0.75 percent, respectively.

6. Total kg feed does not represent that found by summing kg of each individual feeds listed (corn, corn silage, soybean meal, and urea). This is due, in small part, to rounding error. The largest portion of the difference is due to the absence, in calculating total requirements for each feed, of several additional feeds present in the ration (limestone, potassium chloride, and white salt).

of each feed per animal fed. Feed requirements determine required feed storage capacity, purchased feed, and corn and corn silage requirements.

4. Feed storage facilities

Due to their investment cost advantage over upright silos, bunker silos are used to store high moisture corn and corn silage[59]. Bunker silos are built which are sufficient to hold corn and corn silage requirements for a one year period, that lost in storage and feeding (15% of corn and of corn silage), and additional capacity (10%) for years in which crop yields exceed requirements by less than 10%. Any corn produced in excess of this level is, by assumption, sold. Separate bunker silos were built for corn and for corn silage. Total capacity required (cubic feet) was determined by multiplying weight (lb) of corn and of corn silage to be stored by their relative specific densities, 45 lb/ft^3 and 55.6 lb/ft^3, respectively. Least cost bunker silo dimensions with the required capacity were then determined. It was assumed that sufficient ground was available so that bunker silos could be built side by side, sharing one wall. Bunker silos of varying dimensions meeting required feed storage capacity for each production and marketing strategy where built. Bunker silos were costed for the 400 and 1200 head capacity feedlots under both capacity utilization strategies and the 3000 head capacity feedlot feeding one turn of cattle annually. Total cost of the bunker silos was calculated as shown in Equation 4.1.

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[59] No other feed storage facilities are utilized. Supplemental protein and minerals are assumed to be delivered frequently (at least once a month). Quite often on Michigan feedlots, as in this analysis, no additional storage is constructed for these purchased feedstuffs.

$$(4.1) \qquad TC = 10 * H * L + (1.50 * FLOOR)$$

Where:

TC	= total bunker silo investment cost
H	= height of sidewalls (ft)
L	= length of sidewalls (ft)
FLOOR	= bunker silo floor (sq ft)

Four decision rules were used to reduce the number of bunker silo dimension combinations considered. First, height, length, and width were defined in integral units of 10 ft and 5 ft, respectively. Second, the bunker silo was required to be long enough so that no less than four inches of feed was removed from the face surface daily. For example, under the continuous marketing strategies, if only one bunker silo was used, its minimum length was 122 ft (365 days * .3 ft). Minimum length requirements under the one turn system were shorter because the bunker is emptied in a fewer number of days. The use of multiple bunker silos for corn or for corn silage decreased minimum length. Third, bunker silo sidewall height was required to be between eight and fourteen feet. Fourth, the length of each bunker silo was limited to four times the width. The bunker silo combinations fitting each of these requirements were sorted by cost. Least cost silos were selected for corn and for corn silage such that the length of each was equivalent.

Capacity requirements were large for the 3000 head capacity feedlot operating year round and the 6000 head capacity feedlot. It was therefore necessary to consider multiple silos for corn and for corn silage. This increased the number of bunker silo combinations beyond that which could be easily handled using simple sorting and trial and error selection techniques. Therefore, to determine bunker silo investment cost for the remaining feedlot size and capacity utilization combinations, a model was estimated from least cost combinations determined using trial and error for the smaller feedlots. In the resulting model, bunker silo investment cost is described as a function of corn and corn silage capacity required, feedlot size, and feedlot capacity utilization. The best fit estimation is shown as Equation 4.2.

$$(4.2) \quad TC = 18{,}100 + .238(CAPCS) + .225(CAPCORN) + 12{,}857(CM400)$$

Where:

TC	=	total bunker silo investment cost
CAPCS	=	bunker silo capacity for corn silage (lb)
CAPCORN	=	bunker silo capacity for corn (lb)
CM400	=	dummy variable for the 400 head capacity feedlot marketing continuously

Due to the strong explanatory power of this estimation (adjusted $R^2 = .95$), bunker silo investment costs for each size feedlot were (re)estimated using this model. Annual use cost was then calculated using a interest rate of 10% and a bunker silo life of 15 years. Cost per head per day for the feed storage facility investment by feedlot size, capacity utilization, and diet is shown in Table 4.6.

5. Waste handling and manure nutrients

Manure produced by the feedlot enterprise is used to fertilize the soil on which the corn and corn silage used to feed the cattle are grown, thereby adding value to the crop enterprise. In this section, details on the determination of the nutrient value of manure for each size feedlot by production and marketing strategy are reported. The procedure used is described in more detail in Chapter 3. Assumptions and specific values used are reported here. Manure

Table 4.6 Bunker silo total investment cost and cost per head per day

Feedlot size (capacity)	Cost per head per day							
Diet and marketing weights	400	1200	3000	6000	400	1200	3000	6000
Y1 (600 - 1175 lb)	.048	.023	.023	.021	.054	.026	.022	.021
Y1 (750 - 1175 lb)	.058	.029	.025	.023	.055	.027	.023	.022
Y1 (750 - 1250 lb)	.052	.033	.024	.022	.055	.027	.023	.022
Y2 (600 - 1175 lb)	.049	.031	.028	.026	.060	.031	.027	.026
Y2 (750 - 1175 lb)	.058	.033	.030	.028	.061	.033	.029	.027
Y2 (750 - 1250 lb)	.053	.037	.030	.028	.061	.033	.029	.027
Y3 (750 - 1175 lb)	.058	.035	.027	.025	.058	.029	.025	.024
Y3 (750 - 1250 lb)	.052	.034	.026	.024	.058	.029	.025	.024
Y4 (750 - 1175 lb)	.044	.032	.027	.025	.058	.029	.025	.024
Y4 (750 - 1250 lb)	.051	.028	.026	.024	.058	.029	.025	.024
C1 (500 - 1175 lb)	.044	.031	.024	.022	.026	.028	.023	.022
C1 (650 - 1175 lb)	.051	.028	.026	.024	.035	.029	.025	.023
C2 (500 - 1175 lb)	.043	.032	.024	.022	.031	.034	.030	.029
C2 (650 - 1175 lb)	.048	.026	.026	.024	.025	.035	.031	.030
C3 (500 - 1175 lb)	.054	.032	.020	.019	.027	.034	.020	.018
C3 (650 - 1175 lb)	.055	.022	.022	.020	.023	.025	.021	.019

nutrient availability to the crop enterprise is first calculated as a function of number of animal days, animal type, storage and handling system, and land application technique[60]. For each storage, handling, and land application system considered, manure nutrient availability per animal per day is calculated for an average weight steer.

Available nitrogen as a percent of total nitrogen in the manure is estimated from a compilation of values taken from Midwest Plan Service (1985), Mackellar (1992), Michigan State University Beef Cattle Research Center data, and manure pit nutrient analyses collected during on farm interviews. Details are reported in Table 4.7.

Losses in available nitrogen due to handling and storage system and application technique are then calculated. Ranges of nitrogen lost during the transfer of the nutrients from the animal to the ground reported in Midwest Plan Service (1985) and the value used in the analysis are shown in Table 4.8. P_2O_5 and K_2O in manure are assumed to be 100% available to the soil. Values reflecting available nitrogen (ammonium nitrogen plus the mineralized portion of organic nitrogen) and that lost during storage, handling, and application are combined to determine daily recoverable nitrogen per animal unit by system (Table 4.9). Recoverable phosphate and potash are also reported. For the 400 head capacity feedlot, daily manure nutrient values per animal unit are those indicated for the solid manure daily scrape and haul system with broadcast application followed by immediate cultivation. For all other size feedlots, manure nutrient values are those indicated for liquid manure stored in an anaerobic pit and knifed in or broadcast with immediate cultivation.

[60] No allowance is made for differences in manure production or nutrient availability due to diet fed. The average animal is depicted as a 900 lb steer to calculate quantity of manure production over all ration and marketing scenarios. Animals purchased, but not sold (death loss) are assumed to produce manure equivalent in quantity to that produced by a 900 lb steer for 21 days.

Table 4.7 Available nitrogen as a percent of total nitrogen

Description of Source Use	System: Liquid — Anaerobic Liquid Pit 0.30*	Aerobic Lagoon 0.25*	Solid — Open Lot Concrete 0.25*	Open Lot Dirt 0.25*	Bedded Lot 0.30*	All 0.30*
Livestock Waste Facilities Handbook MWPS-18 (1985)						
■Table 10-6 Nutrients in Solid Manure			66.19	64.58	72.92	
■Table 10-7 Nutrients in Liquid Manure	82.50	73.43				
■Interpretation by Bruce Mackellar	80.09					
Beef Cattle Research Data (Collected by Bruce Mackeller)						
■BCRC Section of Summary of all farms	78.38					74.98
■BCRC Nutrient Content Table	80.96					
Michigan Producer (Washtenaw County)	77.33					
Value used in the Analysis	80.00		65.00			70.00

Where:

$$\text{Available Nitrogen} = \begin{matrix}\text{Ammonium}\\ \text{Nitrogen}\\ (NH_4)\end{matrix} + \left[\begin{matrix}\text{Organic}\\ \text{Nitrogen}\end{matrix} * \begin{matrix}\text{Minneralization}\\ \text{Factor}\end{matrix} * (1 + 0.5 + 0.25 + 0.125)\right]$$

* Mineralization Factors

Table 4.8 Nitrogen losses during handling, storage and land application[1]

Nitrogen Losses During Handling and Storage

System	Percent of Nitrogen Lost	Value Used in the Analysis
Solid		
■Daily scrape and haul	15-35	25
■Manure pack	20-40	N/A
■Open lot	40-60	50
Liquid		
■Anaerobic Pit	15-30	20
■Above ground storage	10-30	N/A
■Earth storage	20-40	N/A
■Lagoon	70-80	N/A

Nitrogen Losses During Land Application[2]

Application Method	Type of Waste	Percent Nitrogen Lost	Value Used in the Analysis
Broadcast	Solid	15-30	N/A
	Liquid	10-25	N/A
Broadcast with immediate cultivation	Solid	1-5	0[3]
	Liquid	1-5	0
Knifing	Liquid	0-2	N/A

Nitrogen Losses During Handling, Storage, and Land Application

	Storage and Handling	Application Method	Percent Nitrogen Lost	Value Used in the Analysis
Solid	Daily scrape and haul	Broadcast	28-55	N/A
		Broadcast with immediate cultivation	16-38	25
	Open lot	Broadcast	49-72	N/A
		Broadcast with immediate cultivation	40-62	N/A
Liquid	Anaerobic Pit	Broadcast	23-47	N/A
		Broadcast with immediate cultivation	16-33	20
		Knifing	15-31	N/A

[1] Adapted from Livestock Waste Facilities Handbook MWPS-18 (1985).
[2] Nitrogen lost during land application is stated as a percent of that recovered from handling and storage.
[3] The value of zero is used to simplify calculation and does not significantly change the calculated nitrogen availability value.

Table 4.9 Manure nutrient values per animal unit per day[1, 2, 3,]

System			Total Nitrogen (lb.)	Avail. Nitrogen (lb.)	Recoverable Nitrogen (lb.)[4]	P_2O_5[5] (lb.)	K_2O (lb.)
Solid	Daily scrape and haul	Broadcast	0.34	0.24	0.14	0.250	0.289
		Broadcast with immediate cultivation	0.34	0.24	0.18	0.250	0.289
	Open lot	Broadcast	0.34	0.22	0.09	0.250	0.289
		Broadcast with immediate cultivation	0.34	0.22	0.11	0.250	0.289
Liquid	Anaerobic Pit	Broadcast	0.34	0.27	0.18	0.250	0.289
		Broadcast with immediate cultivation	0.34	0.27	0.22	0.250	0.289
		Knifing	0.34	0.27	0.22	0.250	0.289

1 Adapted from Midwest Plan Service (1985).

2 An animal unit is equivalent to one 900 lb beef steer of medium frame.

3 No allowance is made for differences in manure production or nutrient availability due to differences in diet fed.

4 Recoverable nitrogen is calculated as available nitrogen less that lost during storage,handling, and application.

5 One hundred percent of P_2O_5 and K_2O produced by each animal unit is assumed to be available.

Using these values, total nutrients provided by the feedlot enterprise over the course of one year are calculated as

$$(4.3) \qquad \textit{Total quantity}_{nutrient} = (\textit{Nutrient per animal day} \times \textit{total number of animal days})$$

with total number of animal days as average days on feed for one animal times feedlot capacity for producers feeding one group of cattle per year and 80% of feedlot capacity times 365 days for producers feeding year round.

Total nutrient needs of the crop enterprise were then calculated by multiplying fertilizer requirements per bu corn or ton corn silage reported in Christenson, et al. (1992) times total quantity required of each feed (bu corn or ton corn silage) by the cattle enterprise. Due to multiyear mineralization of organic nitrogen and relatively large losses of ammonium during storage, handling, and land application, nitrogen required by the crop enterprise is larger than that provided by the feedlot enterprise. If manure was applied to satisfy the most limiting nutrient, all available manure would be applied. But, given that the system is modeled under steady state conditions and under current environmental legislation that limits phosphorous application to the amount necessary to replace that utilized by the crop grown, the amount of manure that can be applied is less than is available. Manure application rates are based on meeting the phosphorous requirements of the crop. Manure over that required to meet phosphorous replacement levels is assumed to be applied by the operator to neighboring land. The feedlot operator incurs a cost, but receives no income, for this application.

As in the crop budgets, the value of manure nutrients are priced at \$0.19, \$0.19, and \$0.11 per lb of N, P_2O_5 and K_2O, respectively. Cost of manure application is subtracted to determine the net value of the manure produced by the feedlot. Cost of application of \$25/load for a 3000 gallon tanker spreader or a 12 ton solid spreader was elicited from the Michigan State University farm manager (Darling, 1993). All activities associated with loading, hauling, and spreading manure are included in this cost with the exception of incorporating the manure. The cost of a disk harrow pass twice a year is included in the machinery budgets. For all feedlot sizes and under each production and marketing strategy combination, the net value to the use of manure in the crop enterprise (that is, value of the manure less costs of application) was positive and ranged from \$3.57 per head capacity for the 400 head capacity feedlot marketing one group of cattle per year to \$7.26 per head for the 6000 head capacity feedlot operating under a continuous system. Since nutrients provided per head per day were constant across systems (with the exception of the 400 head capacity feedlot) as were costs of disposal, differences in the value of manure per head are due only to varying number of animal days. Per head returns to manure for the 400 head capacity system were lower because of a higher cost associated with hauling and disposing of manure and greater nitrogen loss under the scrape and haul system.

6. Machinery, labor, and operating costs for the crop enterprise

Grown feed costs include those associated with investment in and use of machinery and labor and other operating costs. Corn and corn silage requirements adjusted for harvest, storage, and feeding loss are converted to acreage requirements where the land yields, on average, 120 lb of corn or 16 ton of corn silage per acre.

As described in Chapter 3, per acre operating costs are taken from Nott, et al. (1992) with modifications for a corn after corn rotation. These variable (cash) costs do not vary by acreage. Cost per acre for variable inputs are shown in Table 4.10.

Table 4.10. Variable per acre costs for the crop enterprise (in dollars)

Item	CORN cost per acre	CORN SILAGE cost per acre
seed	22.56	23.50
fertilizer		
N (ammonium nitrate, corn or urea, corn silage)	18.20	18.20
Phosphate	5.70	8.55
Potash	12.10	13.75
Lime	12.00	12.00
Herbicide	16.75	16.75
Insecticide	10.50	10.50

Least cost machinery capital, repair and maintenance, fuel, housing, interest, insurance, labor, and timeliness costs are calculated for crop systems defined by the ration needs for the 400 and 1200 head capacity feedlots, under both marketing strategies and the 3000 head feedlot for the one turn marketing strategy using MACHSEL. Field operations for corn and corn silage are shown in Table 4.11. Assumptions used are discussed in detail in Chapter 3.

Acres of corn and corn silage associated with the 3000 head capacity feedlot marketing continuously exceeded the capabilities of MACHSEL. Costs for these systems were therefore determined using a model which estimated total cost per acre as a function of total acres of corn and of corn silage, feedlot size, and capacity utilization strategy. Dummy variables were used for feedlot size and capacity utilization strategy. The best fit estimation had an adjusted R^2 of .92 (Equation 4.4).

$$(4.4) \qquad TC/acre = 102.30 + (45.23 \times 400\ OT) + (18.69 \times 400\ CM) - (.0087 \times CORN) - (.014 \times CS)$$

Where:

TC/acre	=	total cost per acre
400 OT	=	dummy variable for 400 head capacity feedlot operating one turn
400 CM	=	dummy variable for 400 head capacity feedlot operating continuously at 80% capacity
CORN	=	acres of corn
CS	=	acres of corn silage

Since the acreage required for the 6000 head feedlot facility was well outside the range for which this equation was estimated and because, at this size, cost per acre of corn and corn silage are approximately the same, a simple average of cost per acre for the crop enterprise associated with the 3000 head capacity feedlot marketing continuously and operating at 80% capacity, was used[61].

Since the corn and corn silage harvesting operations in MACHSEL do not include hauling and packing operations, costs associated with these activities were calculated separately. To calculate the per acre cost of hauling and packing corn silage, cost of corn silage chopping calculated by MACHSEL was subtracted from the custom hire cost for silo filling of corn silage, including field chopping, handling, and packing, reported by Schwab and Siles (1993). For the harvest corn activity, MACHSEL includes the labor associated with two, rather than one, men (man), but does not include costs associated with the power and equipment used to haul and push high moisture corn into the silo. Again, custom hire rates were utilized to assign a cost ($7.50/acre) to these activities.

[61] Economies of size in crop production, as well as all other economies of size in production cost, are nearly to fully exhausted by a 3000 head capacity feedlot.

Table 4.11 Dates for completing field operations for a corn-corn silage crop enterprise using a conventional planting and tillage system[1]

Field	Operation	Period During Which Each Operation Must Be Completed
Corn	Apply Manure[2]	March 19 - May 14
	Mobard/Chisel Plow	April 23 - May 14
	Disk Harrow	April 23 - May 14
	Field Cultivator	April 23 - May 14
	Row Planter	April 30 - May 14
	NH_3 Applicator	May 14 - June 25
	Sprayer (Broadcast pre-emergence herbicide)	May 14 - May 28 (within two weeks of planting)
	Row Cultivator	May 28 - June 25
	Combine	October 15 - November 19
	Apply Manure	October 15 - November 31
	Disk	October 15 - November 31
Corn Silage	Apply Manure	March 19 - May 14
	Mobard/Chisel Plow	April 23 - May 14
	Disk Harrow	April 23 - May 14
	Field Cultivator	April 23 - May 14
	Row Planter	April 30 - May 14
	NH_3 Applicator	May 14 - June 25
	Sprayer	May 14 - May 28
	Row Cultivator	May 28 - June 25
	Chopper[3]	Sept. 10 - Oct. 10
	Apply Manure	Sept. 10 - Nov. 31
	Disk	Sept. 10 - Nov. 31

[1] Feedlot interviews revealed that several, to many, of Michigan's feedlot operators with upper level management skills have gone to partial to mostly no-till planting systems. Although such systems may significantly lower machinery and, particularly, labor costs, they are not considered in this analysis. Type of tillage/planting system utilized may become increasingly important and should be included in future research efforts as systems and their associated costs and yields are refined in use and throughout the literature.

[2] Manure is applied using a honey wagon or solid spreader and is plowed under in the spring and disk in during the fall.

[3] The chopper is pull type or self-propelled, depending on farm size.

7. Other operating costs

Details and results of the calculation of other costs not included in the previous sections are presented here. These are labor cost, capital, maintenance, repair, and fuel costs associated with feeding equipment, materials used in processing feeder cattle (external parasite control, implants, and vaccinations), medicine and veterinary costs associated with morbidity, and purchased feed and bedding costs.

Labor wage used is $10.00 per hour and includes all costs incurred by the employer for the employ of one hours work. Although this wage rate is almost double that reported by Schwab and Siles (1993) for all farm workers, it is both in line with that elicited from feedlot interviews and consistent with the long term employ of skilled workers in Michigan. The annual salary reflecting a $10 per hour wage is $26,000 per FTE. Economies of size in labor use are assumed to exist between the 400 and 3000 head capacity feedlots, with the 400, 1200, 3000, and 6000 head capacity lots operating under continuous marketing requiring 0.5, 1, 2, and 4 FTE, respectively. Feedlots feeding only one group of cattle per year require a portion of this labor, prorated by number of animal days. All activities associated with the marketing and care of cattle are included (purchasing feeder cattle, marketing fed cattle, loading and unloading cattle, processing and treating cattle, sorting cattle upon entry and before marketing, walking pens, feeding cattle, and all associated managerial activities). Manure handling activities including cleaning pens or pumping the pit and hauling and spreading manure are not included in the FTE, but are rather included in the cost of applying manure in the crop budgets.

The cost associated with feeding equipment includes depreciation, repair, maintenance, housing, interest, insurance, and fuel cost. Cost of owning and operating feeding equipment was calculated using information elicited from producers during on farm interviews and an adapted version MCOST, a machinery costing program similar to MACHSEL, but which calculates annual use cost associated with the ownership and use of individual machines, rather than of those for a complete crop enterprise. Type, number, and size of machinery and equipment used to feed cattle as a function of feedlot size was elicited from producers. Producers interviewed used either a tractor pulling a feed wagon or a feed truck with a mounted mixer. Operational costs for each as calculated using MCOST were similar. An average cost of $6.50 per hour of operation was used to reflect the use of a feed wagon or truck. Number of hours per day required to collect and mix feed and feed by feedlot size was also elicited from producer interviews. Economies of size associated with feeding closely mimicked those found for labor use in general. Hours spend feeding are therefore modeled as a function of the number of FTE employed on the farm, with four hours per day allocated to feeding (feeding machinery and equipment operation) for each FTE employed on the farm.

Costs associated with processing feeder cattle are assigned on a per head basis and are dependent only on number of days on feed, and then only discretely. The per head charge for materials for vaccination ($1.50), external parasite control and deworming ($1.50), and a fly/identification tag ($1.00) is $4.00. Implant cost is $1.50/hd for cattle fed less than 200 days and is $2.00/hd for others. Total processing cost is therefore $5.50 per head for animals held less than 200 days and $6.00/hd for cattle held 200 days or longer. Labor and chute charges associated with processing feeder cattle are included in labor and facility cost, respectively.

Morbidity rates elicited from Michigan State University Beef Cattle Specialists and from producers during on farm interviews were found to be strongly related to death loss and, in the absence of widespread infection, related to the age at which the calf enters the feedlot. Morbidity incidence is assumed to be five times the rate of death loss. For example, if death loss is 2%, the morbidity rate, or the percent of cattle experiencing one bout of sickness, is 10%. Each bout of sickness is assumed to cost $5, including medicine and veterinary costs, but, again, not including charges associated with the use of facilities or labor. Total morbidity cost per head is $0.50, $0.38, and $0.19 when associated death loss is 2.00%, 1.50%, and 0.75% as cattle enter the feedlot at <650, 650-749 lb, and >749 lb, respectively.

Purchased feed costs are calculated using per animal feed requirements and average real prices of protein sources (soybean meal ($175 per ton) and urea ($250 per ton)) and minerals (limestone ($7.25 per cwt), potassium chloride ($10 per cwt), and white salt ($6.00 per cwt)). Total dry matter of each feed consumed per animal, as generated by BEEFSIM, was converted to an as fed basis and a cost per head was calculated. Purchased feed cost made up 6% of total cost averaged over the range of feedlot sizes and production and marketing strategies depicted.

A bedding cost of $7.00 per head capacity in concrete pens is used for feedlots operating year round. This is consistent with that experienced on Michigan feedlots with no farm produced source of bedding and with similar facilities to those considered in this analysis. A prorated figure is charged for farms feeding one group of cattle per year, depending on days on feed, so that the cost per head concrete pen capacity occupied per day is the same regardless of system.

PRODUCTION COST

In this section, cost of gain is presented for each of the production and marketing strategies considered. General results are then reported and discussed separately for calves and yearlings. The section concludes with a discussion of the affect of capacity utilization on cost of gain. Cost of gain for each production and marketing strategy is presented in Table 4.13. Average cost per cwt gain and cost per head per day for each feedlot size and capacity utilization strategy is shown in Table 4.12.

Table 4.12 Production cost by system (in dollars)

System	cost per cwt gain	cost per head per day
400 head, one turn, full capacity	54.7	1.36
400 head capacity, continuous marketing at 80% capacity utilization	48.5	1.23
1200 head, one turn, full capacity	48.4	1.22
1200 head capacity, continuous marketing at 80% capacity utilization	44.8	1.13
3000 head, one turn, full capacity	45.1	1.14
3000 head capacity, continuous marketing at 80% capacity utilization	42.2	1.07
6000 head, one turn, full capacity	44.3	1.12
6000 head capacity, continuous marketing at 80% capacity utilization	41.9	1.06

Table 4.13 Cost of gain (in dollars)

Marketing strategy	Diet	Purchase and sale weight	Cost of gain (per cwt)				Cost of gain (per day)			
	Size		400	1200	3000	6000	400	1200	3000	6000
One turn, full capacity utilization	Y1	600 - 1175	49.7	45.8	41.6	41.6	1.37	1.27	1.15	1.15
		750 - 1175	58.6	51.4	47.6	47.6	1.57	1.38	1.27	1.27
		750 - 1250	55.6	51.5	46.3	46.3	1.46	1.35	1.21	1.21
	Y2	600 - 1175	70.7	63.1	59.2	57.7	1.23	1.10	1.03	1.01
		750 - 1175	51.6	45.5	42.4	41.7	1.38	1.22	1.13	1.12
		750 - 1250	58.6	52.7	50.3	48.4	1.30	1.17	1.12	1.08
	Y3	750 - 1175	59.6	52.8	48.0	48.0	1.49	1.32	1.20	1.20
		750 - 1250	56.5	51.3	48.3	46.7	1.39	1.26	1.18	1.14
	Y4	750 - 1175	59.6	52.5	48.1	48.1	1.49	1.31	1.20	1.20
		750 - 1250	56.7	50.8	49.0	47.2	1.40	1.25	1.21	1.16
	C1	500 - 1175	46.3	42.2	40.6	39.2	1.21	1.11	1.06	1.03
		650 - 1175	53.3	47.4	44.4	43.3	1.36	1.21	1.14	1.11
	C2	500 - 1175	46.2	42.1	39.5	38.7	1.18	1.08	1.01	0.99
		650 - 1175	52.9	47.0	44.6	43.4	1.33	1.18	1.12	1.09
	C3	500 - 1175	45.3	41.3	39.1	38.4	1.32	1.20	1.14	1.12
		650 - 1175	53.9	47.4	43.1	42.5	1.53	1.34	1.22	1.21
Continuous marketing, 80% capacity utilization	Y1	600 - 1175	45.3	41.5	39.9	39.1	1.25	1.15	1.10	1.08
		750 - 1175	48.5	44.5	41.9	42.0	1.30	1.19	1.12	1.12
		750 - 1250	49.8	45.6	42.7	43.1	1.30	1.19	1.12	1.13
	Y2	600 - 1175	67.1	61.2	55.8	57.0	1.16	1.06	0.97	0.99
		750 - 1175	45.1	41.2	39.8	38.5	1.21	1.10	1.06	1.03
		750 - 1250	54.6	49.9	47.0	46.6	1.21	1.11	1.04	1.04
	Y3	750 - 1175	50.2	46.1	44.7	43.3	1.26	1.15	1.12	1.08
		750 - 1250	51.8	47.4	44.9	44.5	1.27	1.16	1.10	1.09
	Y4	750 - 1175	50.4	47.0	44.8	43.4	1.26	1.17	1.12	1.08
		750 - 1250	51.6	47.2	44.8	44.4	1.27	1.16	1.10	1.09
	C1	500 - 1175	44.0	41.2	38.4	38.5	1.15	1.08	1.00	1.01
		650 - 1175	47.3	43.9	41.4	41.2	1.21	1.13	1.06	1.06
	C2	500 - 1175	43.3	41.5	39.0	38.2	1.11	1.06	1.00	0.98
		650 - 1175	47.8	44.1	41.0	40.9	1.20	1.11	1.03	1.03
	C3	500 - 1175	42.7	39.7	37.6	36.9	1.24	1.15	1.09	1.07
		650 - 1175	45.5	42.6	39.4	39.6	1.29	1.21	1.12	1.12

Cost of gain, general results

Cost per cwt gain is the strongest indicator of overall production efficiency, although comparisons should be made across equivalent marketing, particularly purchase, weights[62]. Looking at the production costs of different size feedlots identified by capacity utilization strategy and averaged over all diets and purchase and sale weights, makes each system equivalent for comparison.

Overall cost per cwt gain, at $54.70, is the highest for the 400 head feedlot feeding one group per year. In fact, production cost per cwt gain for this system is $6.20 higher than for any other system. The 400 head capacity feedlot operating under continuous marketing and at 80% capacity and the 1200 head feedlot marketing one group of cattle per year have similar production costs of $48.50 and $48.40 per cwt, respectively, although their makeup is different. The 1200 head capacity feedlot has a higher facility cost when one group of cattle are fed per year than does the 400 head capacity feedlot operating continuously, due to both the additional cost per head capacity when the feedlot includes slatted floor pens and to lower capacity utilization. Conversely, feed, total operating, and labor costs are lower for the larger feedlot.

Overall production cost per cwt gain continues to decline by feedlot size and is always higher for an operation feeding one group of cattle per year than for that same size operation operating under a continuous marketing system. Production cost difference for the two strategies of capacity utilization drops to $2.40/cwt for the 6000 head capacity feedlot.

[62] For example, average cost/cwt gain is likely to be higher for yearlings versus calves, although this does not imply production inefficiency associated with feeding yearlings. Since they are typically more efficient over the time spent in the feedlot, purchase price for calves is higher.

Feed cost drops as number of acres required to produce feed grown on the farm increases. Initially, grown feed cost drops from $37.05 to $31.12 per cwt gain when feedlot size increases from 400 to 1200 head and one group of cattle are marketed per year. The decrease in grown feed cost thereafter slows as economies of size in the crop enterprise are reached. Operating costs decrease with feedlot size, with much of the decline due a decrease in labor cost. Facility cost as a percent of total cost is substantially higher for the feedlots feeding one group of cattle per year (22.1%) than for those marketing continuously (17.3%) (Figure 4.6) and for feedlot designs with one-third (1200 head capacity and larger) versus none (400 head capacity) of the pens having a slatted floor. Average production cost per cwt gain overall feedlot sizes and capacity utilization strategies is $46.23. Of this, 68%, 12.3% (6.5%), and 19.8% is feed, operating (labor alone), and facility costs, respectively (Figure 4.5).

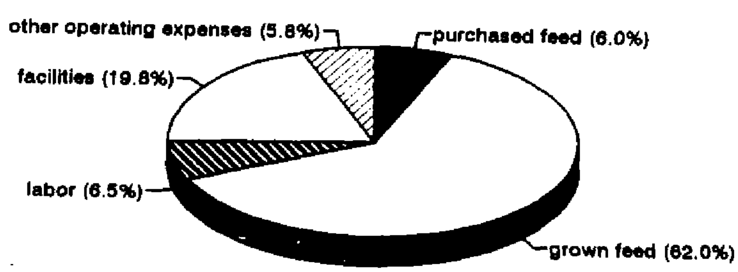
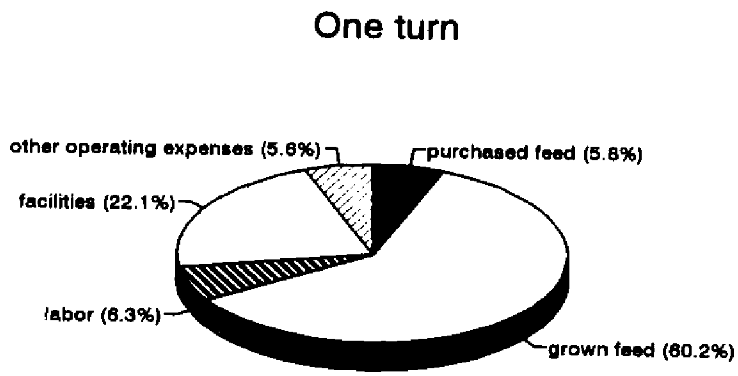


Figure 4.5 Makeup of total cost over all systems



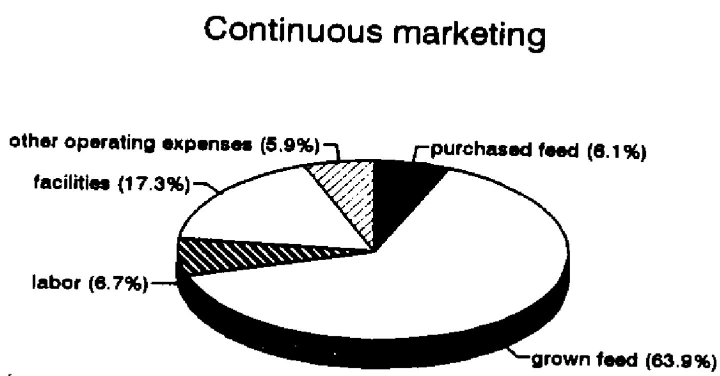


Figure 4.6 Comparison of makeup of total cost by capacity utilization strategy

Affect of production and marketing strategy on cost of gain

The affect of specific production and marketing strategy employed on cost of gain is reported and discussed. Unless specifically indicated, results are true across feedlot sizes and capacity utilization strategies. Cost of gain by production and marketing strategy is shown in Figure 4.7.

Calves fed from 500 to 1175 lb had the lowest per cwt cost of gain. Concentrate level of the diet for this weight range had little effect on cost of gain. Calves started on feed at 650 lb had a higher per cwt cost of gain than those starter lighter. This result is expected because, in general, animals put on feed at a lighter weight gain faster and are more feed efficient than those put on feed at a heavier weight.

In contrast, the diet fed to yearlings was an important determinant of cost of gain. Cost of gain was the highest for the least concentrated yearling diet (Y2) fed to yearlings from 600 to 1175 lb. Average daily gain under this low concentration ration, that used by the average Michigan feedlot operator, was much lower than for the highest concentration diet fed to yearlings over this weight range (2.42 versus 2.85). The cost of production is relatively low, however, for this low concentration diet when cattle are purchased heavy (750 lb) and sold light (1175 lb). This is true even for feedlots operating under a one turn system where increased feed efficiency as cattle spend less time on the starter ration and the lower death loss and incidence of morbidity for yearlings purchased at this heavier weight outweighs increased facility cost per cwt gain as animals spend less time on feed. The affect of start weight (600 versus 750 lb) on cost of gain for yearlings is, however, inconclusive under the one turn system when all diets are considered. Although heavier cattle have a lower death loss and spend less time on the starter ration as a percent of total time spent in the feedlot,

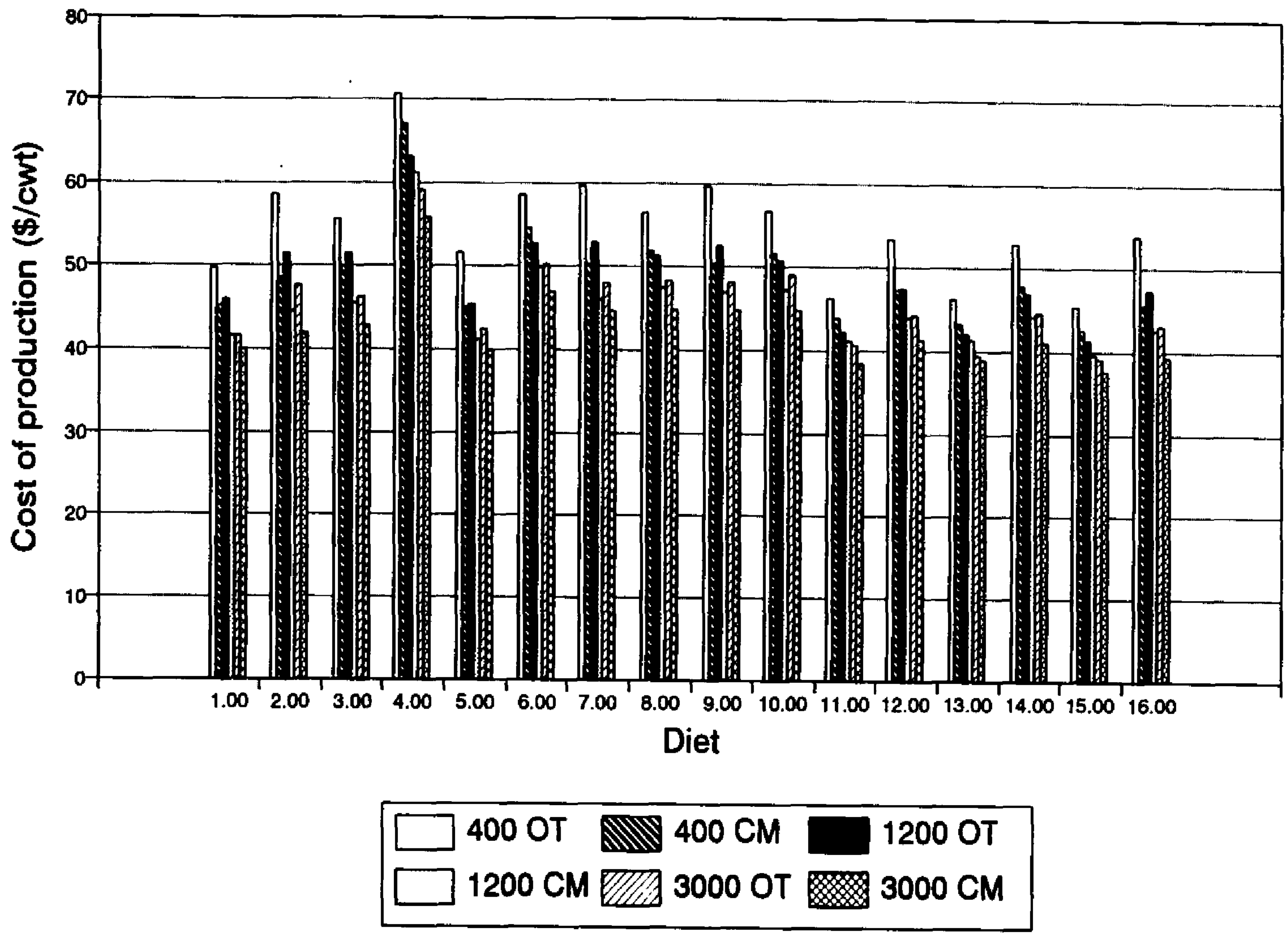


Figure 4.7 Cost of gain by production and marketing strategy

lighter cattle are more feed efficient and because they enter the feedlot at lighter weights, economies of size are greater and capacity utilization is higher. The cost of gain for yearlings fed Y2 from 750 to 1175 lb is, in fact, lower than that for equivalent animals fed a higher concentration ration. This is explained, in large part, by the lower grown feed cost per cwt gain as a result of the closer balance between corn and corn silage when a lower concentration diet is fed. In sum, cost of gain is lower for the more concentrated diet when yearlings are purchased at 600 lb and sold at 1175 lb and is lower for the less concentrated diet when yearlings are fed from 750 to 1175 lb.

In general, yearlings sold at 1250 lb have a slightly lower cost of gain than those sold at 1175 when only one group of cattle is marketed per year. This is particularly true for the 400 head capacity feedlot due to large economies of size in grown feed cost at that size. One exception is found. Yearlings fed the lowest concentration ration, Y2, to 1175 lb had a lower cost of gain than those fed to 1250 lb, presumably due to higher average daily gains and feed efficiency. Under a continuous marketing strategy, the cost of gain is always lower when animals are sold lighter.

Cost of gain is higher for the one turn versus continuous marketing systems. The average advantage over all feedlot sizes is $3.79 per cwt (Figure 4.8). The higher cost of gain for one turn systems is due to relatively higher facility charges resulting from a lower level of capacity utilization and from slight economies in grown feed cost. The advantage for the continuous marketing system is similar across different production and marketing strategies.

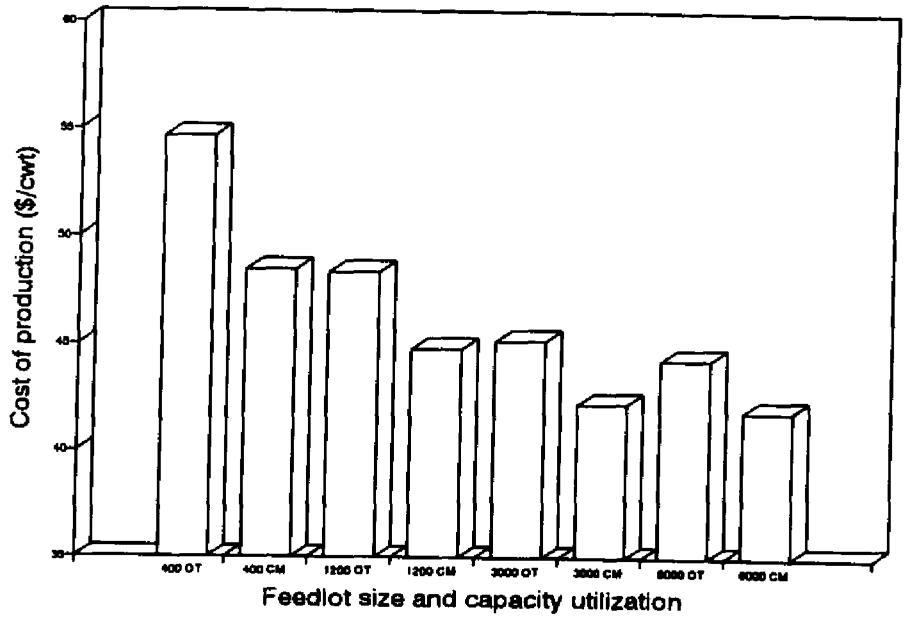


Figure 4.8 Cost of gain by capacity utilization strategy

CATTLE GROSS MARGINS

In this section, specifics on the calculation of gross margins are discussed. An inventory of available data series is presented and the use of selected series justified. Figures and summary statistics are presented to depict yearly and seasonal price trends and average prices. The procedure of and specifics associated with calculating gross margins are described. Resulting gross margins over a range of Michigan fed cattle systems are presented.

Price series utilized in the analysis include feeder and fed cattle prices from Michigan and Dodge City, Kansas and feeder cattle prices from Lexington, Kentucky. Price series are available from the author. Prices for fed cattle sold through Michigan Livestock Exchange were available from January 1978 to early 1993 and came from two sources. Michigan fed cattle prices from January, 1978 to September, 1986 are taken from Gwilliam (1988). Prices from January, 1985 to December, 1992 were provided by Michigan Livestock Exchange (Roberts, 1993). Both fed price series represent cattle sold through Michigan Livestock Exchange, a cooperative selling approximately eighty percent of all Michigan fed cattle (Reed, 1992). Both series represent monthly mid-range farm gate prices. To check the consistency and validity of the series, they were plotted together. As is evident from Figure 4.9, the series closely mimic one another, with differences likely due to rounding errors, frequency of data collection, and/or the use of different methods to represent a single price from a price range. Data from Gwilliam (1988) is used prior to January 1985 and from Roberts (1993) after September 1986. An average of the two series is used over the period during which data is available from both sources. In this analysis, Michigan fed cattle price is represented as the average real Michigan Livestock Exchange fed cattle farm gate price (using CPI as a deflator) from January 1984 to December 1992.

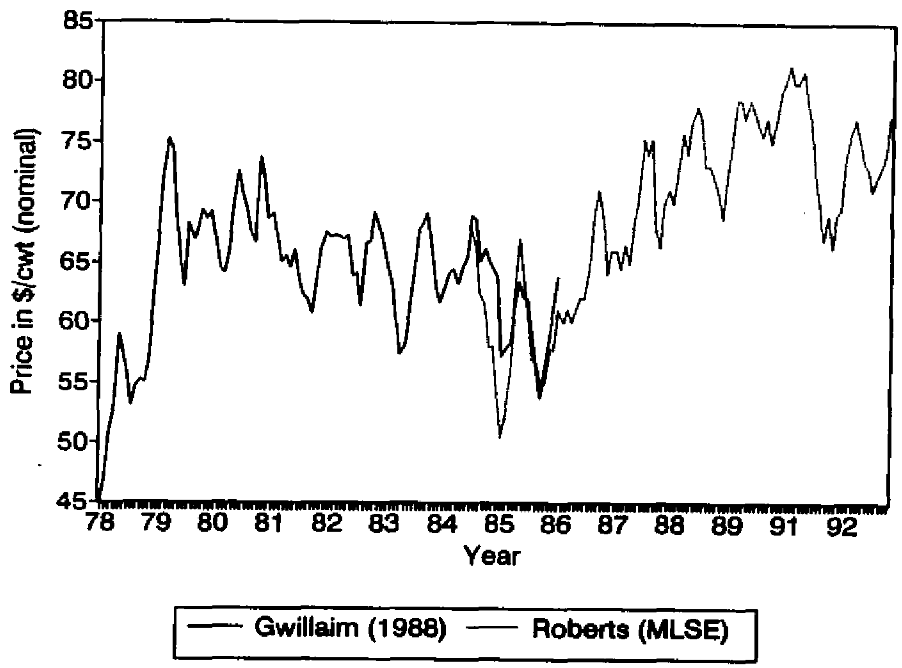


Figure 4.9 Michigan fed cattle price (choice steers FOB farm)

Feeder cattle prices paid by Michigan producers are represented by mean real Lexington auction prices from 1984 to 1992 for the weight class most closely reflecting that described by the marketing strategy under consideration. For example, the price of 600 lb feeder steer calves is depicted by the average price of 500 - 600 and 600 - 700 lb calves. Lexington, rather than Michigan, prices are used for two reasons. First, the majority of Michigan cattle feeders, particularly those feeding >500 head per year (87.7%), purchase cattle in the southeast. Very few of Michigan producers feeding >500 head per year (3.3%), however, feed Michigan raised calves. Secondly, Lexington price data available to the author had several advantages over available Michigan feeder cattle data. Data was available for a longer historical period and prices were reported by cwt classes rather than for all feeder cattle in aggregate.

From 1981 to 1992, the price of Lexington feeder cattle was, on average, $0.70/cwt less than that for those sold in Michigan. Since the transportation cost from Kentucky is approximately $1.40/cwt, under the assumption of pricing efficiency, differences in quality and other desirable market characteristics such as the availability of large groups and fewer health problems, made Kentucky feeder cattle worth, on average, $0.70/cwt more than their counterparts in Michigan. Michigan and Lexington feeder cattle prices are depicted in Figure 4.10.

Average real gross margins faced by producers operating under different production, marketing, and capacity utilization schemes were calculated using MLSE Michigan farm gate fed prices and Lexington feeder calf prices. Depending on the capacity utilization strategy, cattle were purchased and sold once per year or continuously throughout the year. When only one group of cattle is purchased a year, the historic average October feeder cattle price of the appropriate weight adjusted for inflation is used where (Equation 4.5):

$$(4.5)\quad \textit{Total price}_{feeders} = (\textit{Price}_{cwt} \times \textit{Weight}_{cwt}) - (\textit{transportation and commission cost per head})$$

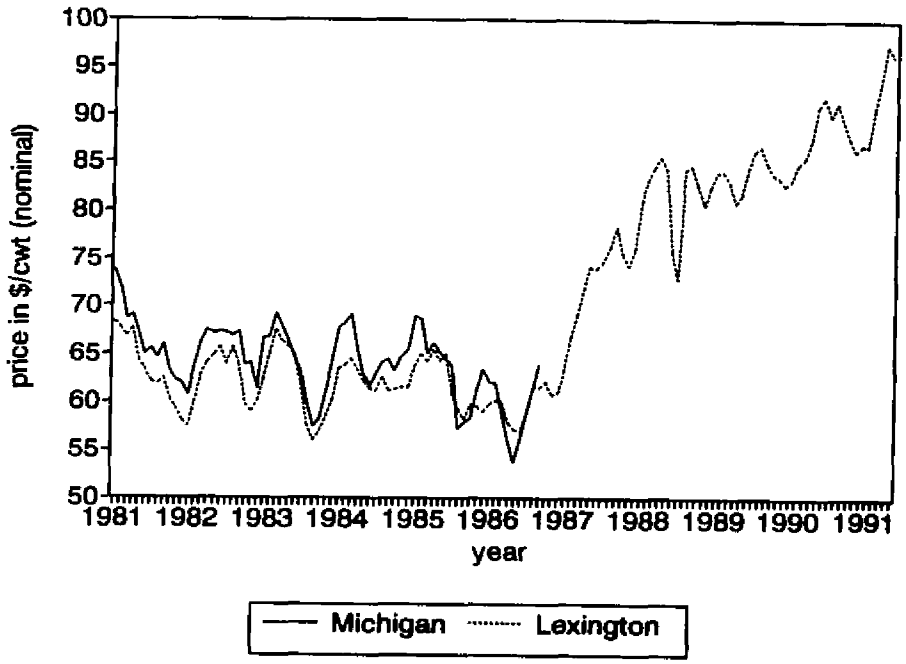


Figure 4.10 Michigan and Lexington, Kentucky feeder cattle prices; 500 to 800 lb steer calves

Fed cattle are sold at the historic average real price for the month in which they finish, as determined by days on feed. If cattle finish within the last or first 5 days of a month, an average of fed price from that month and the following or previous month is used, respectively (e.g. cattle sold on June 3 are sold at the historic average price for May and June). Days on feed and sale dates for each production and marketing strategy are shown in Table 4.15.

Table 4.13 Sale dates for one turn lots[63]

Ration	Purchase weight	Sale weight	Days on feed	Sale date
Y1	600	1175	208	May 13
Y1	750	1175	159	March 24
Y1	750	1250	191	April 24
Y2	600	1175	245	June 20
Y2	750	1175	187	April 20
Y2	750	1250	225	May 30
Y3	750	1175	170	April 5
Y3	750	1250	204	May 9
Y4	750	1175	170	April 5
Y4	750	1250	203	May 8
C1	500	1175	258	June 3
C1	650	1175	205	May 10
C2	500	1175	263	June 8
C2	650	1175	209	May 14
C3	500	1175	232	June 7
C3	650	1175	185	April 20

[63] All cattle are purchased on October fifteenth.

Gross margin is not adjusted for shrink because the weight at which feeder cattle enter the feedlot is only relevant for ration requirements and animal performance, both of which are adjusted for when determining ration requirements and days on feed. Number of cattle sold is decreased by the appropriate percent death loss. Transportation cost for inbound feeder cattle is $1.75 per cwt. Commission charges are $0.50 per cwt for feeder cattle. Deductions for fed cattle commission ($0.50 per cwt) and transportation charges ($1.50 per cwt) are included in farm gate price. An interest cost on feeder cattle of 7% is used to reflect the average of that for non-breeding livestock over the past decade.

The same assumptions are utilized for the continuous marketing strategy although, because cattle are purchased and sold throughout the year, the mean real price over the year for feeder cattle by weight category and for fed cattle is used under all management strategies. Gross margins by diet and marketing weights are reported in Tables 4.14 and 4.15 for feedlots operating under a one turn and continuous marketing strategy, respectively. Figure 4.11 depicts gross margins under each production and marketing strategy and capacity utilization level. Except for the calf diet where cattle are purchased at 500 lb and sold at 1175 lb, the per head gross margin for feedlots operating under a one turn system is higher than those marketing continuously.

Table 4.14 Gross margins for Michigan feedlots feeding one group of cattle per year

Ration	Marketing weights	Gross margin per head
Y1	600 - 1175	372.03
	750 - 1175	312.92
	750 - 1250	357.89
Y2	600 - 1175	355.33
	750 - 1175	305.47
	750 - 1250	337.68
Y3	750 - 1175	308.10
	750 - 1250	347.77
Y4	750 - 1175	308.10
	750 - 1250	347.89
C1	500 - 1175	423.72
	650 - 1175	350.00
C2	500 - 1175	419.70
	650 - 1175	349.57
C3	500 - 1175	422.52
	650 - 1175	369.17

Table 4.15 Gross margins for Michigan feedlots marketing continuously

Ration	Marketing weights	Gross margin per head
Y1	600 - 1175	346.96
	750 - 1175	270.74
	750 - 1250	326.78
Y2	600 - 1175	343.09
	750 - 1175	267.34
	750 - 1250	322.65
Y3	750 - 1175	269.41
	750 - 1250	325.20
Y4	750 - 1175	269.41
	750 - 1250	325.32
C1	500 - 1175	408.05
	650 - 1175	324.98
C2	500 - 1175	407.59
	650 - 1175	324.54
C3	500 - 1175	410.46
	650 - 1175	327.17

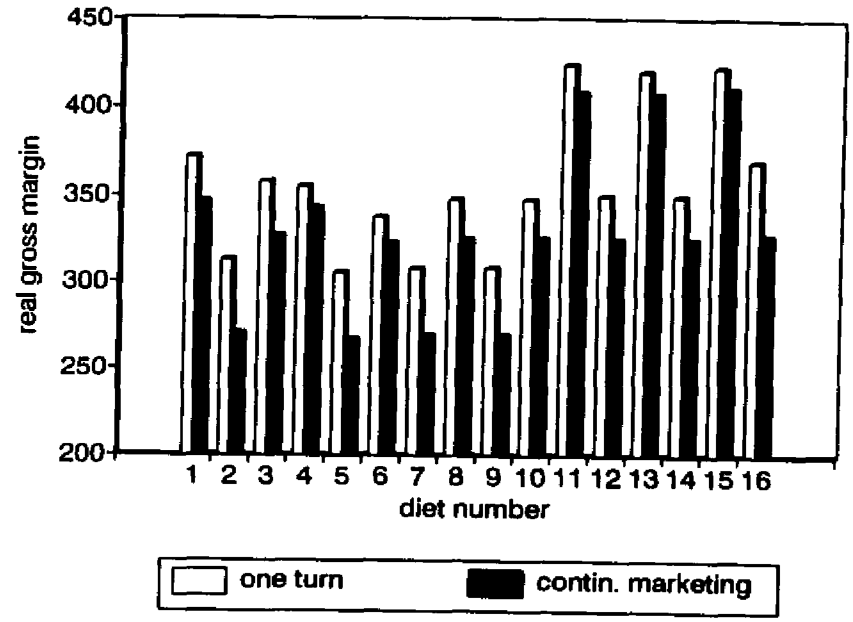


Figure 4.11 Gross margins for Michigan feedlots

Effect of production and marketing strategy on gross margin

Due to seasonality in cattle prices, production and marketing strategy utilized has an affect on gross margin when only one group of cattle is fed. Feeder cattle prices vary by season. The Lexington feeder cattle (5-800 lb) price is less (by $3.00 per cwt) in October when all feeder cattle for feedlots marketing only one group of cattle per year are purchased than the average price throughout the year (Figure 4.12). This is particularly true for 5-600 calves, for which the difference is $3.46/cwt, but is less true for heavier (7-800 lb) feeders, for which the difference is only $2.51 (Figures 4.13 and 4.14). Fed cattle prices also show considerable price seasonality. Michigan fed cattle price is highest from January to May, begins a sharp decline in May, bottoms out in September and October, and then begins to increase (Figure 4.15). Fed cattle prices are $3.10, $3.57, $2.88, and $1.44 higher than the year long average in March, April, May, and June, respectively. These are the months in which sale of cattle takes place in lots operating under a one turn system (Table 4.17). Both feeder and fed price seasonality favor the one turn systems, where feeder cattle are purchased in October, when feeder prices are low, and fed cattle are sold in the spring, when fed prices are high.

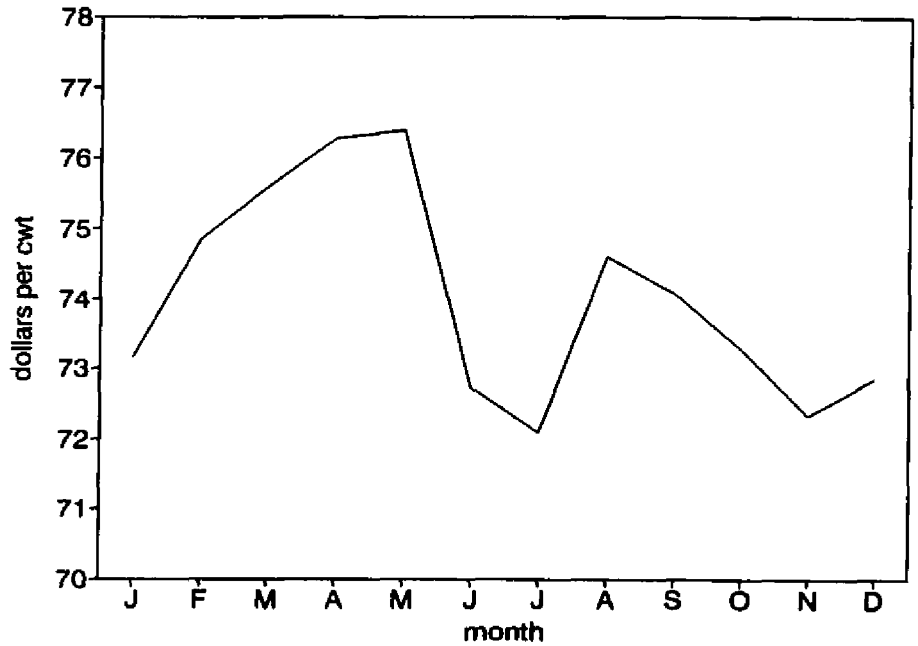


Figure 4.12 Seasonality of feeder cattle prices (500 to 800 lb steer calves)

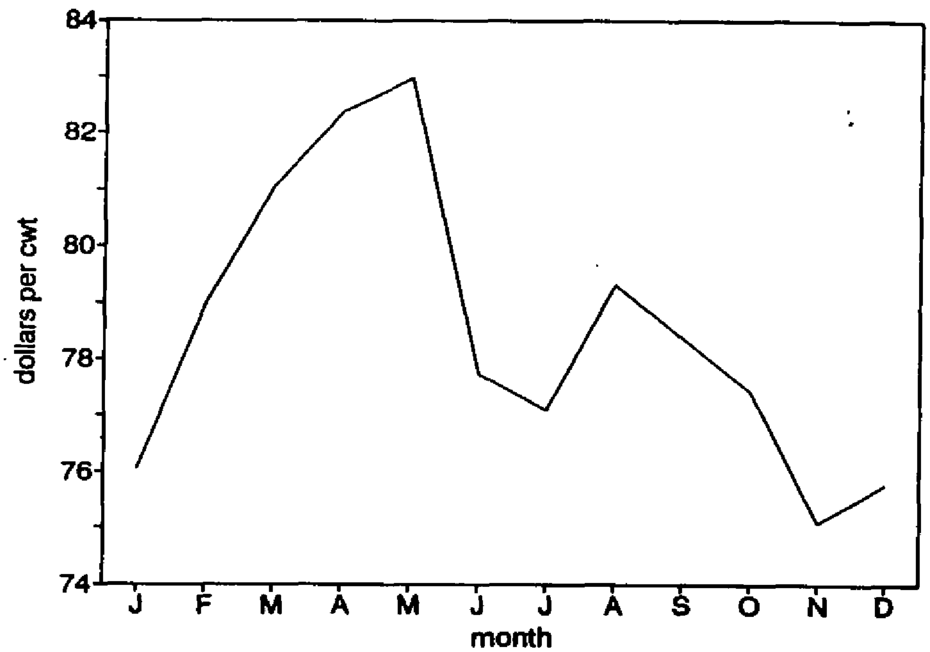


Figure 4.13 Seasonality of feeder cattle prices (500 to 600 lb steer calves)

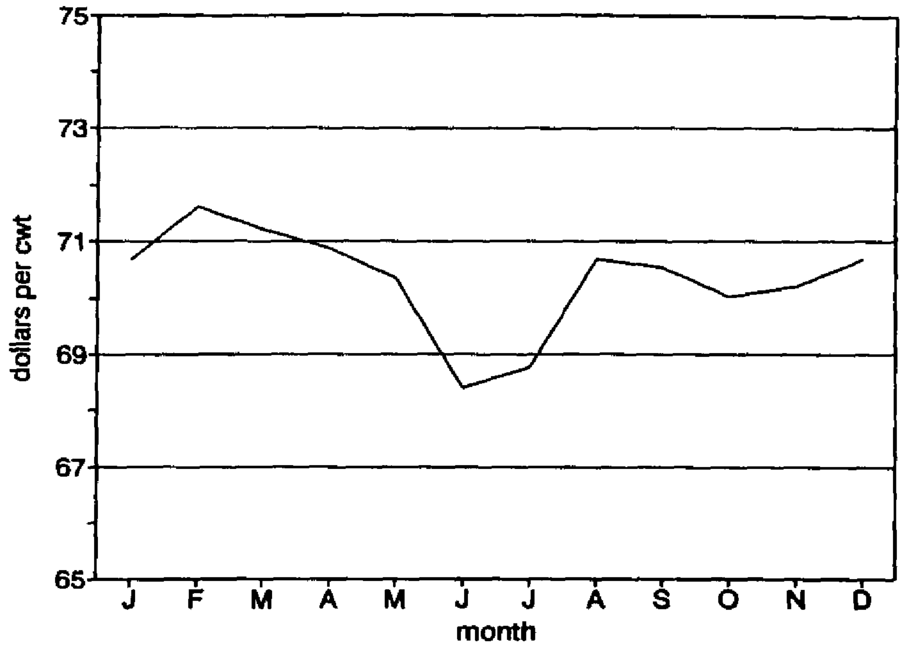


Figure 4.14 Seasonality of feeder cattle prices (700 to 800 lb steer calves)

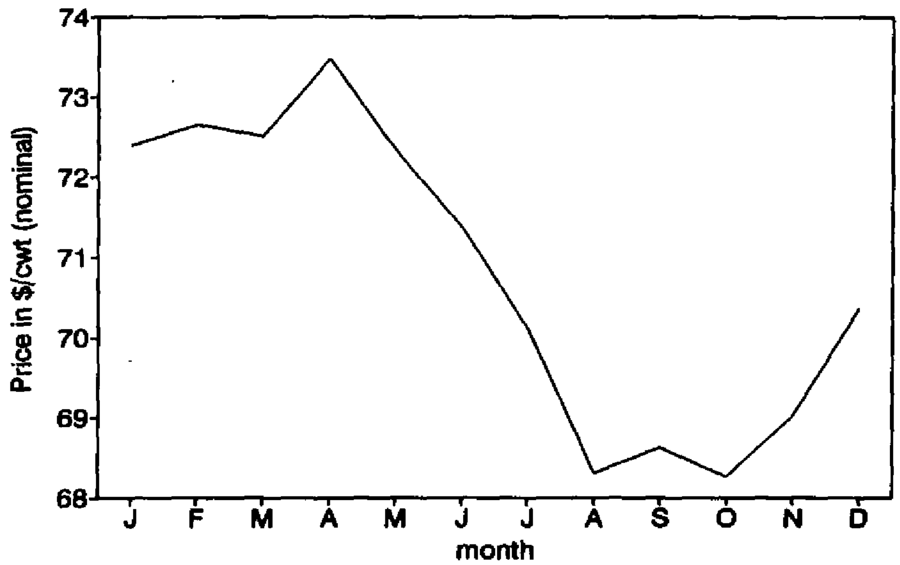


Figure 4.15 Seasonality of fed cattle prices (Michigan)

Other production and marketing strategies had similar affects on gross margin regardless of the capacity utilization strategy employed. However, the variability of gross margins due to different marketing and production strategies is lower when cattle are purchased only once a year than when they are marketed continuously. Since the gross margin is higher for cattle marketed under a one turn strategy, the difference is also lower as measured by percent change.

For both capacity utilization strategies, gross margin per head was found to be highly dependent on purchase and sale weight. For cattle marketed under a one turn strategy, gross margin per head is also highly dependent on the combined effect of the purchase and sale weight and on the concentration of the diet fed as it influences the time at which the animal is sold, and thereby sale price.

Gross margin per head is higher when calves are purchased at 500 lb than at 650 lb[64]. Gross margin for calves purchased at 500 lb is slightly higher for the most concentrated diet (C3) and is slightly lower for the least concentrated diet (C1). The affect of the concentration of the diet on gross margin is more pronounced for calves put on feed at 650 lb due to its importance on sale date and hence, sale price. Price per cwt for fed cattle peaks in April at $83.23/cwt and decreases into May and June at $81.81 and $80.69, respectively. Calves purchased at 650 lb and fed the most concentrated diet (C3) are sold in April, bringing a higher price than those fed the less concentrated diets (C1 and C2), which are sold in May. All calves put on feed at 500 lb are sold in June, regardless of diet concentration.

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[64] Although the lighter calves are more expensive on a per cwt basis, they cost less on a per head basis, hence a higher gross margin.

Purchase and sale weight also influence the per head gross margin of yearlings. Yearlings purchased lighter (600 versus 750 lb) and sold heavier (1250 versus 1175 lb) have a higher gross margin because they cost less and are sold for more on a per head basis, respectively. Concentration of the diet fed to yearlings affected gross margin under the one turn system by its influence on sale date of fed cattle. Yearlings fed a more concentrated diet (Y1) had a higher gross margin that yearlings purchased and sold at similar weights but fed a less concentrated diet (Y2, Y3, and Y4) over each weight range considered. This is because yearlings fed the more concentrated diet finished earlier in the spring, when the fed price was higher.

NET RETURN TO FED CATTLE PRODUCTION

The net return to the cattle operation (gross margin less production cost) is calculated for each production strategy as defined by ration, feedlot size, and capacity utilization[65]. Net return is reported per head and per cwt gain in Table 4.16[66]. Figures 4.16 through 4.19 highlight these results. Figure 4.16 shows average net return per head over all production and marketing strategies for each system. For each size feedlot and under each capacity utilization, net return was positive with the magnitude depending on diet fed and on marketing weights. Net return per cwt gain is highest for the one turn systems and increases with size. Figure 4.17 shows the highest and lowest net return for a given feedlot size and capacity utilization strategy utilized by Michigan feedlots.

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[65] Whether any of the systems is economically profitable requires that the associated opportunity costs of production are known. This is discussed in Chapter 5.

[66] Although return on investment is frequently reported as a measure of profitability, this value is less relevant for Michigan feedlots characterized by fixed land assets than is true for Kansas feed yards which often have outside capital investment.

Table 4.16 Net return to fed cattle production

Marketing strategy	Diet	Purchase and sale weight	Net return per head				Net return per acre			
	Size		400	1200	3000	6000	400	1200	3000	6000
One turn, full capacity utilization	Y1	600 - 1175	86.4	108.4	132.9	133.1	138.3	173.6	213.0	214.2
		750 - 1175	64.0	94.2	110.5	110.7	128.0	141.0	220.5	219.9
		750 - 1250	79.6	100.2	126.3	126.5	130.0	164.3	207.0	208.2
	Y2	600 - 1175	54.8	87.0	103.9	110.2	88.3	140.9	168.2	180.4
		750 - 1175	47.4	78.2	93.3	96.9	95.8	157.7	188.3	197.8
		750 - 1250	44.6	74.1	86.2	95.6	73.3	122.3	142.2	159.7
	Y3	750 - 1175	54.6	83.5	104.0	104.0	109.8	167.6	208.7	210.1
		750 - 1250	65.1	91.4	106.2	114.3	107.2	150.2	174.7	189.3
	Y4	750 - 1175	54.9	85.0	103.7	103.7	110.3	170.5	208.0	209.3
		750 - 1250	64.3	93.8	103.0	112.0	105.9	154.5	169.9	185.9
	C1	500 - 1175	111.4	138.5	149.6	158.9	162.0	201.3	217.5	232.8
		650 - 1175	70.3	101.1	117.1	122.9	121.2	174.6	202.4	213.2
	C2	500 - 1175	108.1	135.7	152.9	158.1	156.1	195.7	220.7	230.1
		650 - 1175	71.9	102.8	115.2	121.4	123.0	176.3	197.4	209.8
	C3	500 - 1175	116.4	143.7	158.7	163.0	166.9	206.5	228.1	235.1
		650 - 1175	86.2	120.6	142.7	95.8	140.7	205.2	242.9	249.1
Continuous marketing, 80% capacity utilization	Y1	600 - 1175	86.6	108.5	117.4	122.1	138.6	173.8	188.1	195.6
		750 - 1175	64.7	81.7	92.7	92.0	129.1	163.2	185.0	183.8
		750 - 1250	77.7	98.8	113.2	111.1	127.1	162.0	185.5	182.1
	Y2	600 - 1175	58.0	82.9	105.8	100.9	93.7	134.3	179.4	163.4
		750 - 1175	41.8	61.5	68.6	75.1	84.1	124.1	138.4	151.5
		750 - 1250	49.7	73.1	87.7	89.6	82.1	120.8	144.9	148.1
	Y3	750 - 1175	55.9	73.5	79.3	85.4	112.4	147.6	159.2	171.4
		750 - 1250	66.4	88.2	100.8	102.5	108.9	144.9	165.8	168.6
	Y4	750 - 1175	50.4	64.8	74.1	80.1	100.9	126.2	148.6	160.6
		750 - 1250	67.3	89.2	101.4	103.4	110.6	147.0	167.2	170.5
	C1	500 - 1175	110.8	130.1	148.8	148.5	160.8	189.2	275.3	215.6
		650 - 1175	76.5	94.3	107.8	108.5	132.1	163.1	186.5	187.6
	C2	500 - 1175	114.9	127.7	144.3	149.4	128.6	142.9	161.6	167.4
		650 - 1175	73.3	93.0	109.4	109.6	98.5	125.2	147.2	147.6
	C3	500 - 1175	122.4	142.7	156.6	161.5	176.1	205.0	225.1	232.2
		650 - 1175	88.0	103.6	120.5	119.3	149.8	175.5	205.9	203.3

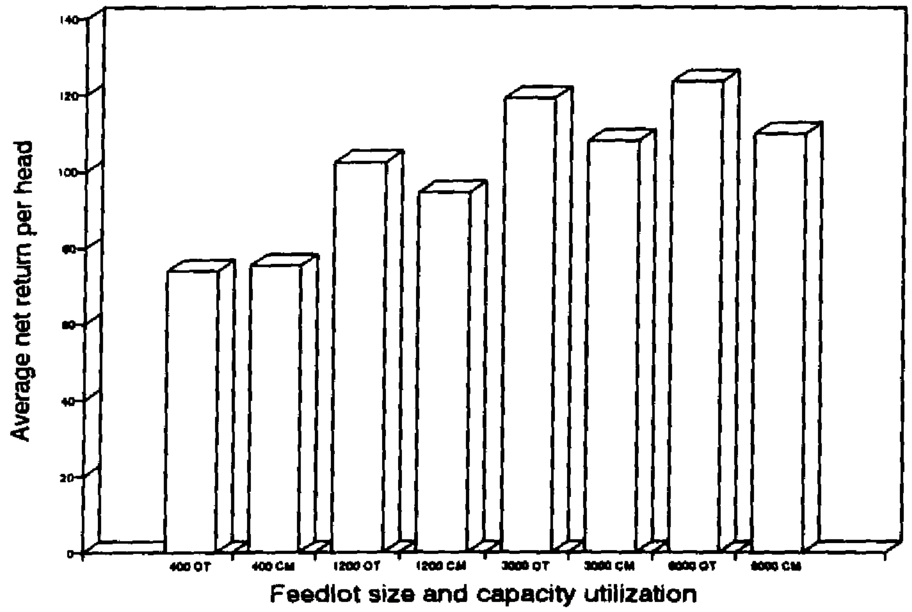

Figure 4.16 Net return per head

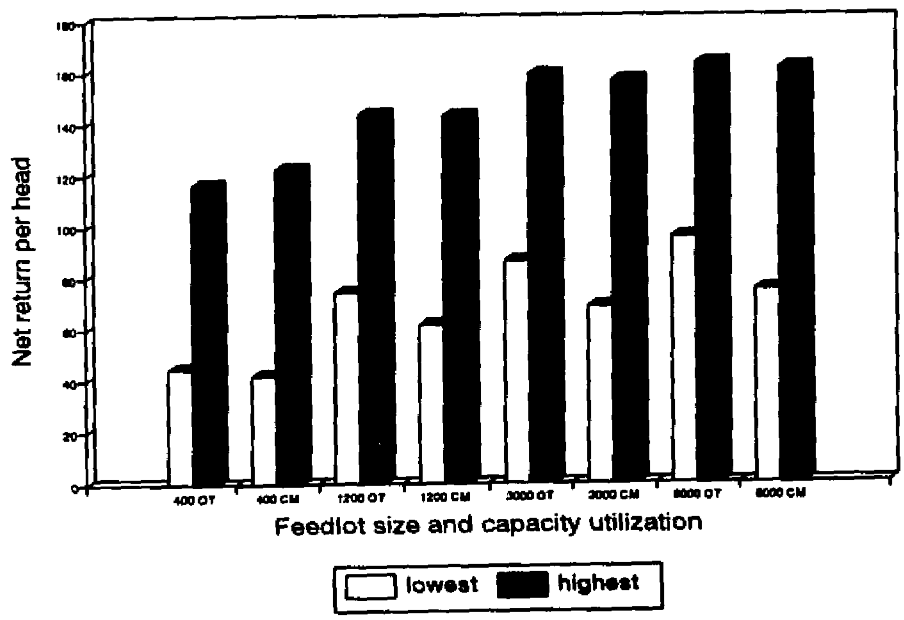

Figure 4.17 Per head return under the range of production and marketing strategies

Production implications

1. Capacity utilization

Two conclusions are clearly drawn from the information depicted in Figure 4.16. First, in most cases, for the same size feedlot and ration, net return is higher when the feedlot is operated under a one turn versus a continuous marketing strategy. This result is unexpected even under what appear to be relatively unconstraining assumptions regarding the production and marketing practices of Michigan cattle feeders. Cost per cwt gain is higher for the one turn, full capacity system than for feedlots marketing year round and operating at 80% of feedlot capacity. The higher gross margin per head found for feedlots feeding one group of cattle per year, as a result of both lower feeder cattle prices and a higher fed price, outweigh the higher production costs except when significant economies of size are gained from marketing continuously (i.e. for the 400 head capacity feedlot)[67].

From this surprising result came the hypothesis that the gross margin calculated for the system utilizing a strategy of continuous cattle purchase and sale was lower than that experienced in practice by Michigan cattle feeders. In the gross margin calculation, there is no adjustment for accelerated or delayed buying behavior as a result of current or expected market conditions. From follow-up phone interviews, the author learned that buyers will stay out of the market if the feeder cattle price is likely to decline within a period of up to a few months and/or will send fed cattle to market early or hold them longer if fed price is expected

[67] The exceptions are limited to the 400 head capacity feedlot. In twelve of sixteen production and marketing weight strategy combinations for the 400 head capacity feedlot, net return is higher under a continuous, rather than a one turn, capacity utilization strategy. Under these strategies, the advantage gained from a higher gross margin when marketing once a year is less than the disadvantage of higher per head facility and grown feed costs. Economies of size in grown feed cost are large for the 400 head capacity feedlot as the number of animal days increases when marketing is continuous rather than once a year. Returns are higher under a one turn capacity utilization strategy for the 400 head capacity feedlot when production and marketing strategies result in fed cattle being sold in April, when fed price is highest, or which result in a high number of days on feed, as is true when cattle are fed a high roughage diet over a larger weight range.

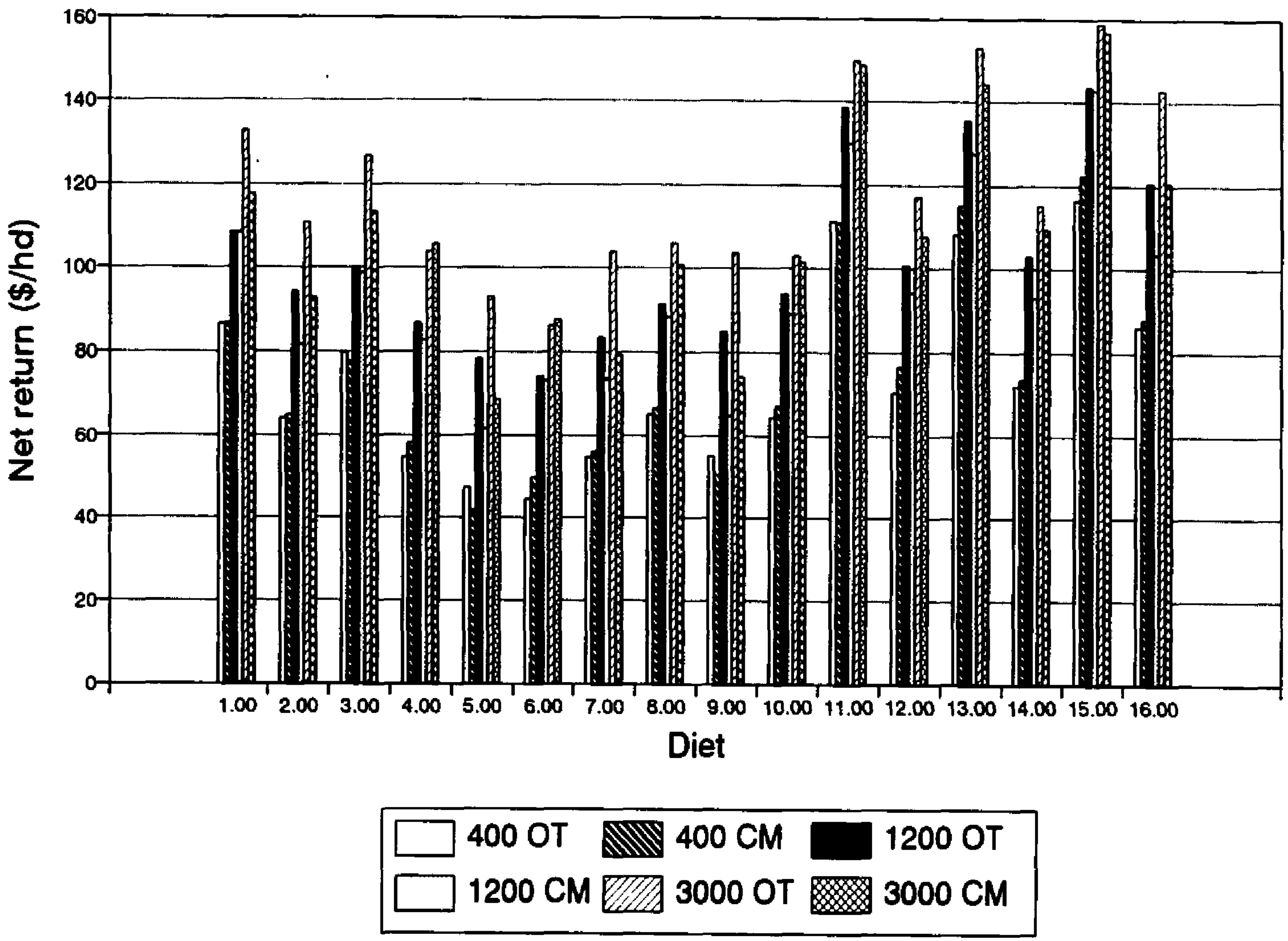

Figure 4.18 Net return per head by production and marketing strategy

to decrease or increase, respectively, within a couple of weeks[68]. Producer's responsiveness to market conditions is consistent with the level of management skill depicted in this analysis. It is also consistent with an 80% capacity utilization level. That is, the feedlot is empty or partially so when feeder or fed cattle prices are high, but expected to fall. This evidence, when combined with the fact that most producers interviewed could not identify specific months in which they do or do not market cattle, does not dispute the use of average historic prices as unbiased. It is not possible to model more flexible marketing behavior given the limited price data and lack of data on historic marketing behavior. There is a need for further research depicting both the current purchase and sale strategies of Michigan cattle feeders and towards defining best marketing practices for producers operating under continuous systems using various production practices.

2. Economies of size in fed cattle production

A second conclusion is that economies of size exist in fed cattle production in Michigan. The net return to farms with 400, 1200, 3000, and 6000 head capacity feedlots were calculated. Economies attributable to size were found over the range of feedlot sizes from 400 to 3000 head capacity. As feedlot capacity increases, cattle and feed storage facilities[69], labor requirements, and costs associated with the production of feed decrease.

[68] Since net return conclusions run counter to those expected and because, the assumption that marketing is continuous (so that purchase and sale price are the average price over the entire year) might not accurately reflect practices of skilled Michigan feedlot managers, feedlot owners/operators interviewed were presented, and asked to respond to, this conclusion. Although each was surprised, most reiterated that they purchase and sell cattle close to continuously to cut down on the number of cattle entering the feedlot during anyone month because of limited starting pen capacity and that they have not been successful in trying to catch the highs and lows of the market, even between months.

[69] Note that facility costs initially increase from the 400 to the 1200 head capacity feedlot size as the use of slatted floors is introduced.

Increased capacity utilization (from one turn to continuous marketing) has much the same affect as increasing feedlot size since, with both, the number of cattle marketed and total number of animal days per year are increased. With increased capacity utilization, economies of size in the crop enterprise and feed storage facilities are realized. Economies of size in annual average investment for the cattle facility are also found. As capacity utilization increases, number of cattle over which the fixed costs of depreciation and interest are spread increases. The net result is a lower production cost when year round marketing is practiced. Net return to these systems is lower when averaged over all production and marketing strategies considered, however, due to the lower gross margins realized from year round versus seasonal marketing.

Since the assumptions used in this analysis result in identical gross margins for feedlots of all sizes[70], economies due to size are realized only through reduced production costs. The cost per cwt gain decreases from \$54.35 for a 400 head capacity feedlot to \$44.30 for a 6000 head system (both feeding one group of cattle per year), a decrease of approximately \$0.18 per cwt for each additional 100 animals fed. Nearly all economies of size are exhausted by a 3000 head capacity feedlot. The same is true for feedlots marketing continuously and operating at 80% capacity, where cost per cwt gain decreases approximately \$0.12 per cwt per additional 100 animals fed from a 400 to a 3000 head capacity feedlot. The lack of significant economies of size beyond the 3000 head capacity feedlot is consistent with the absence of feedlots in Michigan with more than 10,000 head capacity. This lack of large feedlots in Michigan may further indicate that diseconomies of size may exist at some level.

[70] This assumption is not particularly limiting to the analysis since transportation, interest, and commission costs were found to be similar for feedlots of all sizes buying and selling cattle through Michigan Livestock Exchange.

Economies of size are found in grown feed, operating, and facility costs. Since feed cost makes up the majority of production cost, existing economies of size in feed cost have a relatively large influence on net return as farm size changes. Under the assumptions of this analysis, purchased feed costs are independent of feedlot size. Economies of size related to feed cost are therefore due only to cost of feed grown on the farm. Economies of size in feed cost were found to be large between the 400 and 1200 head capacity feedlots as per acre machinery and labor costs associated with the crop enterprise fell with increasing feedlot size. The crop enterprise required to grow corn and corn silage for the 400 head capacity feedlot does not fully utilize even the smallest available size of machinery. As the crop enterprise required to grow feed increases enough to justify larger machinery, labor costs per acre decline with machinery costs. As multiple power sources and implements are required in the crop enterprise, these effects disappear and cost per acre becomes nearly constant (Figure 4.19). Economies of size in grown feed cost for lots feeding only one group of cattle per year are greater than for those marketing continuously since the 400 head capacity one turn system represents the smallest crop enterprise and therefore, that with the highest feed cost per acre[71].

Economies of size also exist in operating cost (Figure 4.20), although their importance is relatively minor since operating cost makes up a relatively small part of total production cost. Operating costs include materials associated with processing cattle, materials and veterinary charges associated with morbidity, capital and other charges (other than labor) associated with feeding cattle, and labor. Per day operating costs for a feedlot of any size operating under a one turn strategy are defined as a fraction of that identified for a feedlot of the same size

[71] If it were not for the large diseconomies of crop production for this smaller feedlot, net returns would be equivalent to or higher than for the larger systems. Purchasing rather than growing feed would help reduce production cost for, but is not consistent with the weekly manure scrap and haul practiced in, the smaller feedlot system.

operating under continuous marketing. Operating cost per head is therefore not influenced by capacity utilization. Processing costs and costs associated with morbidity depend only on days on feed and death loss and, therefore, do not vary by feedlot size. Economies of size initially exist in bedding cost as the proportion of the feedlot utilizing bedding (that with concrete flooring) decreases as feedlot capacity increases from 400 to 1200 head capacity. Once feedlot capacity has reached 1200 head, all economies of size in bedding cost are exhausted because bedding requirements per animal day do not change as feedlot capacity increases. Economies of size associated with labor (Figure 4.21) and costs associated with feeding equipment investment and use are assumed to exist up to a 3000 head capacity feedlot. Labor requirements are identical for the 3000 and 6000 head capacity feedlots on a per animal basis. Manure application costs do not vary by feedlot size.

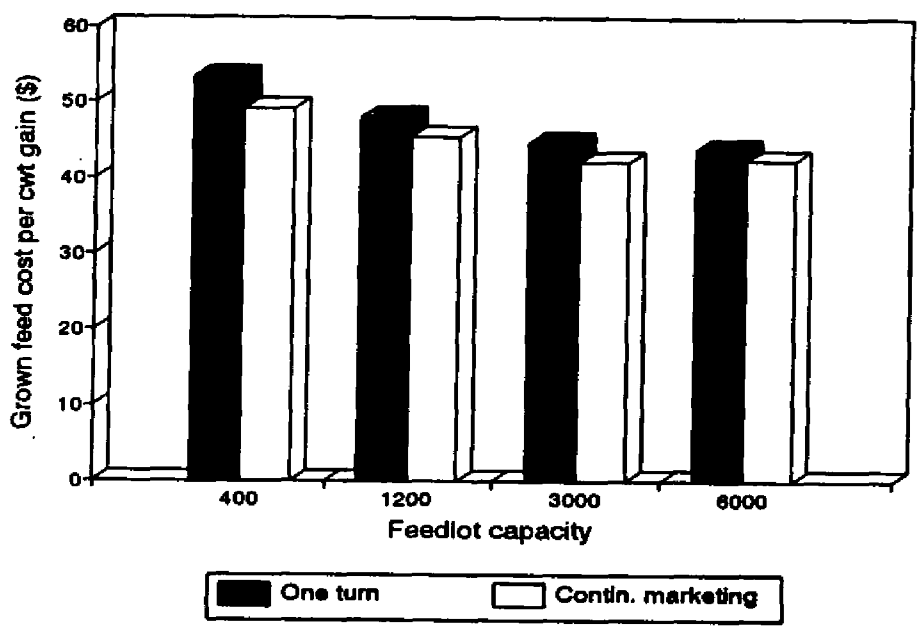

Figure 4.19 Economies of size in grown feed cost

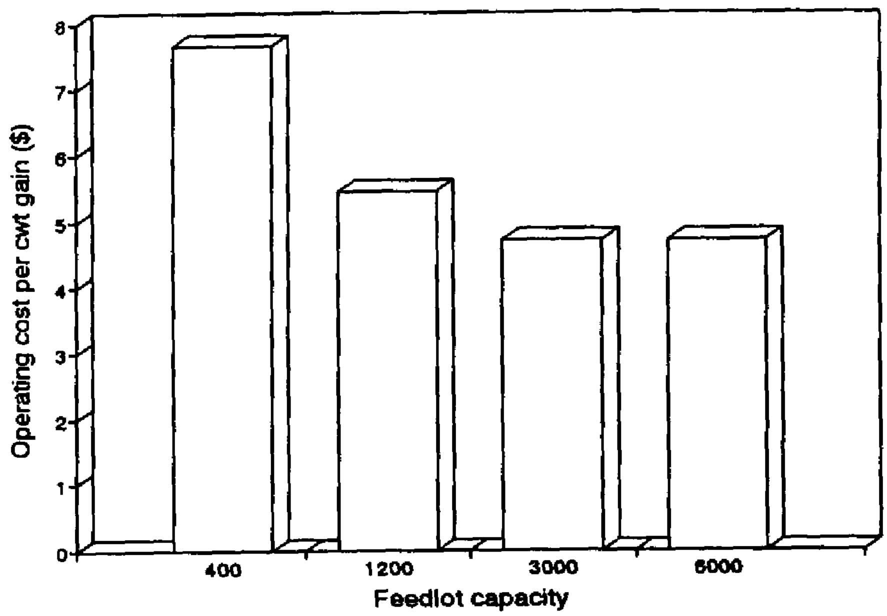

Figure 4.20 Economies of size in operating cost

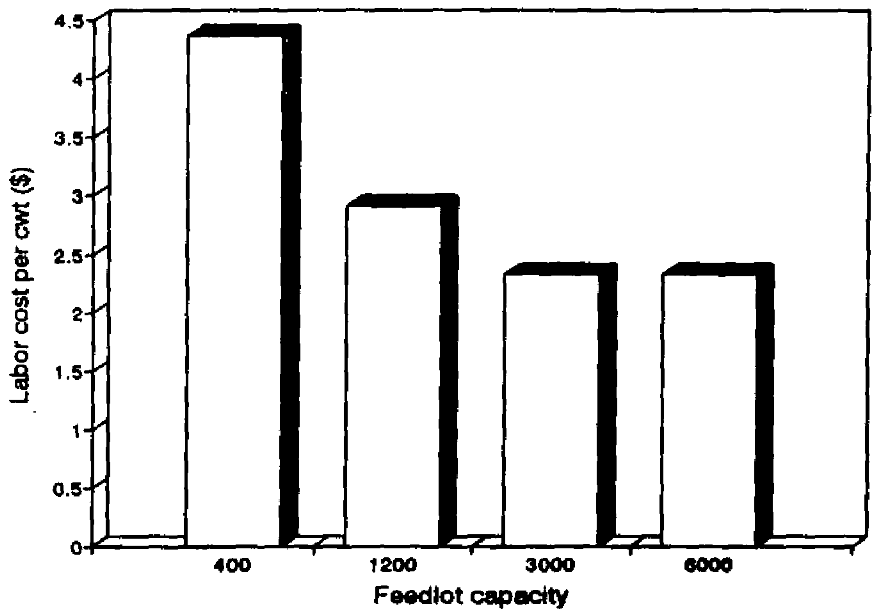

Figure 4.21 Economies of size in labor cost

Both diseconomies and economies of size are found for facility cost (Figure 4.22). Bunker silo costs decline as the number of cattle fed per year increases, rapidly between the 400 and 1200 capacity feedlots (Figure 4.23). The lower cattle facility cost associated with the 400 head capacity versus a larger feedlot more than compensates for the higher feed storage facility cost so that per head total facility costs are the lowest for the 400 head capacity feedlot. Cattle facility cost rises sharply as slatted floor pens are added to the facility design and thereafter, existing economies in cattle facility are quickly exhausted. Very slight advantages due to facility investments not dependent on feedlot size such as well drilling result in a slightly higher net return to the 6000 head capacity system than for the 3000 head capacity system.

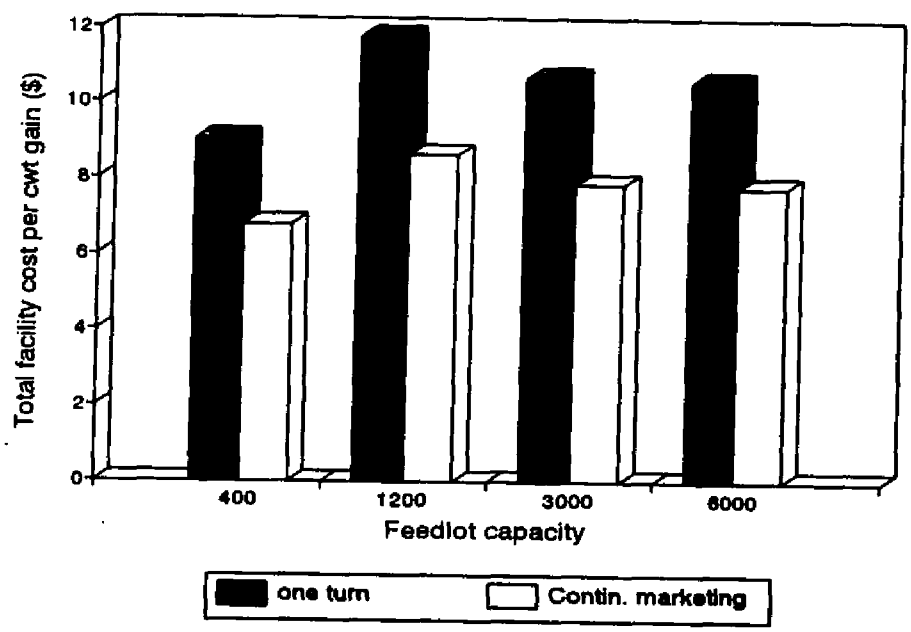

Figure 4.22 Economies of size in facility cost

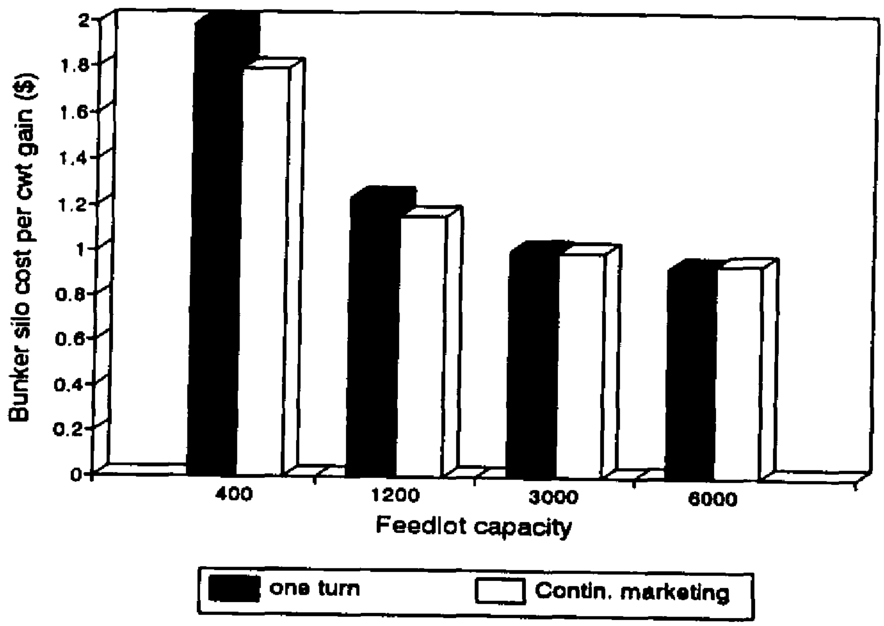

Figure 4.23 Economies of size in feed storage facility cost

The effect of diet fed and marketing weights on net return to fed cattle production

Two other practices which varied over the systems considered included diet fed, as defined by percent concentrate, and cattle purchase and sale weight. There may be significant confounding between the affects of diet and of purchase and sale weight. It is beyond the scope of this dissertation to statistically separate these affects. Rather, general observations are reported.

Four general conclusions can be made from visual observation of the net return per head under these different strategies[72]. Three conclusions regarding purchase and sale weights are (1) net returns to feeding calves is higher than to feeding yearlings, (2) net return to calves purchased at a lighter weight (500 lb) is higher than that for heavier calves (650 lb), and (3)

[72] The validity of these conclusions depend rather strongly on assumptions imposed, particularly death loss levels, and may not hold for individual producers.

holding yearlings to 1250 lb (versus 1175 lb) increases net return per head. A fourth conclusion is that, in general for both calves and yearlings, use of a more concentrated diet increases net return per head.

Both net return per head and net return per acre were considered. Net return per head is important under a one turn strategy because the return from each animal carries investment costs equivalent to the capacity required for one animal for the whole year. The value 'net return per head' is less meaningful when cattle are marketed continuously throughout the year. For example, under continuous marketing, cattle fed a less concentrated diet will spent more days on feed and therefore, must return more per head to produce an equivalent total net return to an operation as when cattle are fed a less concentrated ration. Net return per head is a useful measure when the net return to fed cattle production in Michigan is compared with that in Kansas. Net return per acre indicates the net return generated from the cattle operation per acre of land required to produce the corn and corn silage required by the feedlot enterprise. Whether it is considered on a per head or a per acre basis, net return across the various production, marketing, and capacity utilization strategies tells a similar story with a few exceptions. Net return to fed cattle production when animals are purchased as calves is first discussed. Net return to animals purchased as yearlings is then discussed. Finally, net return to animals purchased under a one turn versus a continuous marketing system are discussed.

Feeding calves from 500 to 1175 lb is the most profitable marketing strategy. Net return per head for this marketing strategy is much higher than for any other marketing strategy for calves or yearlings and ranges from $108.10 to $ 163.00 for the 400 and 6000 head capacity feedlots feeding one turn of cattle per year, respectively. Net return per acre is also highest for this marketing strategy, although the advantage for calves purchased at 500 lb over those purchased at 650 lb is relatively less than that found on a per head basis.

Net return per calf is slightly higher for the more concentrated diets. The net return per head for the most concentrated calf diet (C3) fed from 650 to 1175 lb is higher than for the less concentrated diets (C1 and C2) when the feedlot is operating under a one turn strategy. This is particularly true for feedlots of 1200 head capacity and larger. This is expected because, although cost of gain is similar for each diet, the gross margin from the most concentrated diet is higher as cattle are sold earlier in the spring, when the fed cattle price is the highest. The more concentrated calf diets also have a higher net return per acre than the less concentrated diets for the same reason.

The net return from feeding yearlings is dependent on both production and marketing strategy employed. The net return per head and per acre is higher when yearlings fed the most concentrated diet (Y1) are started at a lighter weight (600 versus 750 lb) or fed to a heavier weight (1175 versus 1250). The lowest net return per head results when the least concentrated diet (Y2) is fed[73]. The net return per head and per acre is the lowest of all marketing and production strategies when cattle are purchased at 750 lb and sold at 1175 and 1250 lb are fed Y2. This is true even though the average daily gain found for cattle purchased at 750 lb (2.38 and 2.31 for cattle sold at 1175 and 1250 lb, respectively) is not much less than that found when cattle are purchased at 600 lb and sold at 1175 lb (2.42 lb/day), when the net return is substantially higher.

[73] Recall that Y2 represents the average diet fed to yearling steers in Michigan in 1988 (Ritchie, et al., 1992).

For cattle fed a moderately concentrated diet (Y3 or Y4), fed weight (1175 versus 1250) has an affect on the net return per head. Slight advantages exist when cattle are held to 1250 lb due to economies of size and because there is no price discount for the heavier cattle. With one exception, this is true even though, for a feedlot operating under a one turn strategy, fed price is higher in April when fed cattle at 1175 lb are sold than in May when fed cattle at 1250 lb are sold. The exception is the 3000 head capacity feedlot operating under a one turn strategy, when animals sold at 1175 lb have a higher net return per acre than those sold at 1250 lb. Cattle sold at this lighter weight have a higher feed efficiency and average daily gain which results in them finishing when fed price is relatively high. The net return per head and per acre increases with the concentration of the yearling diet.

Net return per head and per acre also depends on the capacity utilization strategy employed. Net return per head is greater when the feedlot is operating under a one turn versus a continuous marketing strategy under nearly all production and marketing strategies for feedlots of 1200 head capacity or greater. For feedlots of 400 head capacity, results are mixed depending on the relative advantage for the one turn and continuous marketing system in gross margin and production cost of grown feed. At this size feedlot, there are still substantial economies of size found in the machinery and labor component of the crop enterprise realized when more than one turn of cattle is fed per year.

The advantage to the one-turn capacity utilization strategy is higher for yearlings fed from 750 to 1175 lb than for those purchased lighter or sold heavier. This is an unexpected result because these marketing weights result in the shortest number of days on feed. The higher net return for these yearlings comes from the higher gross margin resulting from a lower purchase price per cwt (than for the lighter yearlings) and a higher fed price. The higher fed price results from cattle being sold earlier in the spring. The one exception is under the most concentrated yearling diet when cattle are finished in late March, when per cwt price is approximately the same as in late April, when cattle held to 1250 lb are sold.

CHAPTER 5 ECONOMIC RETURN TO FED CATTLE PRODUCTION IN MICHIGAN

INTRODUCTION

The comparison of fed beef cattle production with other alternative resource uses in Michigan defines its comparative advantage within the state[74]. The assumption adopted in this analysis is that the Michigan producer owns or has a long term lease on farmland employed in production. The farmers alternatives are therefore limited to growing crops for feed or sale or renting out the land. Other livestock enterprises are not considered.

SYSTEM DEFINITION

Approximately 40% of Michigan's cash crop land is in a corn-soybean-wheat or corn-soybean rotation (Chase, et al., 1990). A corn-soybean-wheat rotation is used to represent an alternative land use to growing corn and corn silage to feed cattle. The number of acres defining the corn-soybean-wheat rotation is chosen to be that number required to grow corn and corn silage for a feedlot operating under the most profitable production and marketing

[74] Opportunity cost of production reveals the current economic stability of an enterprise, but does not offer extensive insight into the future of the industry under changing economic and competitive conditions. In Chapter 6, the net return to Kansas fed beef cattle production is compared with that found in Michigan. Depending on the marketing and production strategies employed in the future by Michigan cattle feeders and on the opportunity cost associated with the resources used in fed cattle production in Kansas, Kansas and other Central and Southern Plains states may or may not be able to bid feeder cattle away from Michigan producers. Opportunity cost of investment in the Kansas beef industry may require higher returns than for Michigan due to increased risk associated with purchasing more inputs and differing risk preferences by those investing. Two factors, changes in production or marketing costs or a large increase in cow numbers as the price of feeder calves is bid up, may slow or reverse any movement in feeder or fed cattle prices.

strategy for each size feedlot under each capacity utilization strategy[75]. An equal number of acres of each of corn, soybeans, and wheat is grown in the three crop enterprise. Total acres related to each feedlot size and capacity utilization strategy are shown in Table 5.1.

Table 5.1 Total acres for crop operations defined by feedlot size and capacity utilization strategy

Feedlot system	Total acres
400 OT	279
400 CM	350
1200 OT	828
1200 CM	1057
3000 OT	2087
3000 CM	2626
6000 OT	4160
6000 CM	5251

Operations performed throughout the year for each crop in the corn-soybean-wheat rotation are shown in Table 5.2.

[75] The use of acreage specified by only the most profitable fed cattle production strategy for each feedlot size and capacity utilization strategy may give a biased assessment of the comparative advantage of feeding cattle. The most profitable farms with a feedlot enterprise are those feeding relatively more concentrated rations and therefore, which require slightly more crop acres on which to grow required feed. The direction and magnitude by which these results may be biased by operations utilizing different rations and purchase and sale weights depend on the magnitude of economies of size in corn and corn silage production versus that found in the corn-soybean-wheat operation. If economies of size are relatively larger for a corn-soybean-wheat than for a corn-corn silage rotation, this analysis will be biased towards the corn-soybean-wheat rotation for less concentrated rations. This is particularly true for the smaller operations.

Table 5.2 Dates for completing field operations for a corn-soybean-wheat rotation using a conventional planting and tillage system[2]

Field	Operation[2,3]	Period During Which Each Operation Must Be Completed[4]
Corn following wheat	Combine (wheat)[5]	July 9 - July 23
	Custom Harvest Straw	July 9 - August 6
	Mobard/Chisel Plow	August 1 - October 1
	Disk Harrow	April 16 - May 14
	Field Cultivator	April 16 - May 14
	Row Planter (corn)	April 30 - May 14
	Sprayer (Broadcast pre-emergence herbicide)[6]	May 14 - May 28 (within two weeks of planting)
	Row Cultivator	May 28 - June 25
	NH_3 Applicator	May 14 - June 25
Soybeans following corn	Combine (corn)	October 15 - November 19
	Mobard/Chisel Plow	April 23 - May 21
	Disk Harrow	April 23 - May 14
	Field Cultivator	April 23 - May 14
	Grain Drill (soybeans)	May 7 - May 28
	Sprayer[7]	May 14 - June 5 (within two weeks of planting)
Wheat following soybeans	Combine (soybeans)	October 1 - October 22
	Disk Harrow	October 8 - October 29
	Grain Drill (wheat)	October 8 - October 29
	N Applicator (urea)	March 19 - April 23

1 Many Michigan farmers with upper level management skills have gone to partial to mostly no-till planting systems. Although such systems may significantly lower machinery and, particularly, labor costs, they are not considered in this analysis. Type of tillage/planting system utilized may become increasingly important and should be included in future research efforts as systems and their associated costs and yields are refined in use and throughout the literature.

2 Operations are listed in the order in which they are performed.

3 Operations are described by equipment used with the exception of custom hire of baling straw.

4 Period describes the period during which each operation must be completed without loss of yield.

5 The cost associated with custom harvesting straw is not included, nor is any revenue received from said straw, the assumption being that the two cancel one another out.

6 The sprayer operation in this system is a broadcasted pre-emergence herbicide application for corn. This operation must occur within 14 days of planting.

COST AND REVENUE DETAILS

Net return to a corn-soybean-wheat rotation is calculated as revenue from sale of crops less production costs. In this section, details of revenue and production cost calculation are discussed.

Revenue

Revenue from the crop operation is calculated as (Equation 5.1)

$$(5.1)\quad \textit{Total revenue} = ((Yield_{corn} \times Price_{corn}) + (Yield_{soybeans} \times Price_{soybeans}) + (Yield_{wheat} \times Price_{wheat}))$$

Corn yield is chosen to match that of the land used in fed cattle production (120 bu/acre). Wheat and soybean yields are consistent with soils producing a 120 bu of corn per acre. Wheat yield is 60 bu/acre. Soybean yield is 40 bu/acre. Corn ($2.66/bu) and soybean ($6.65/bu) prices are a historic average of Saginaw, Michigan prices, adjusted for inflation and technology as reported in Krause (1992)[76]. Wheat price ($3.70/bu) was determined by adjusting historic average Saginaw, Michigan wheat price for the average inflation and technology adjustments implicit in Krause (1992) for corn and soybean price.

Production cost

Production costs for the corn-soybean-wheat rotation are calculated as for the corn-corn silage rotation used to grow feed for fed cattle production. Costs include a land charge, variable cash costs, and costs associated with machinery and labor use. The land charge is $52.80 per acre, as it is for the corn and corn silage enterprises for the farm including a feedlot (Hanson,

[76] Prices were further adjusted slightly (downward) to reflect extremely high prices from 1972 to 1980.

et al., 1992). Variable cash costs are taken from Nott, et al. (1992) and are shown in Table 5.3[77].

Costs associated with machinery use, including those for machinery capital, repair, and maintenance, fuel, housing, interest, insurance, labor, and timeliness, are calculated using MACHSEL (see Chapter 3 for details on machinery selection and the assumptions used for this calculation). Machinery and associated costs per acre for each system are shown in Table 5.4. Economies of size in machinery and associated cost are exhausted by 2000 acres at $57.50 per acre. Figure 5.1 shows total cost per acre by system.

Table 5.3 Variable costs for a corn-soybean-wheat rotation

Item	CORN cost per acre	SOYBEAN cost per acre	WHEAT cost per acre
seed	$23.49	$14.40	$15.00
fertilizer			
N (ammonium nitrate, corn or urea, soybeans and wheat)	18.20	$3.80	17.10
Phosphate	6.20		15.20
Potash	12.10	$4.40	16.50
Lime	7.50	$7.50	7.50
Herbicide	$16.75	$27.30	$0.00

[77] No insecticide is used for the corn-soybean-wheat rotation.

Table 5.4 Per acre costs associated with the use of machinery

Feedlot system	Number of acres	Machinery and associated costs per acre
400 OT	279	$102.89
400 CM	350	$97.63
1200 OT	828	$65.56
1200 CM	1057	$61.48
3000 OT	2087	$57.50
3000 CM	2626	$57.50
6000 OT	4160	$57.50
6000 CM	5251	$57.50

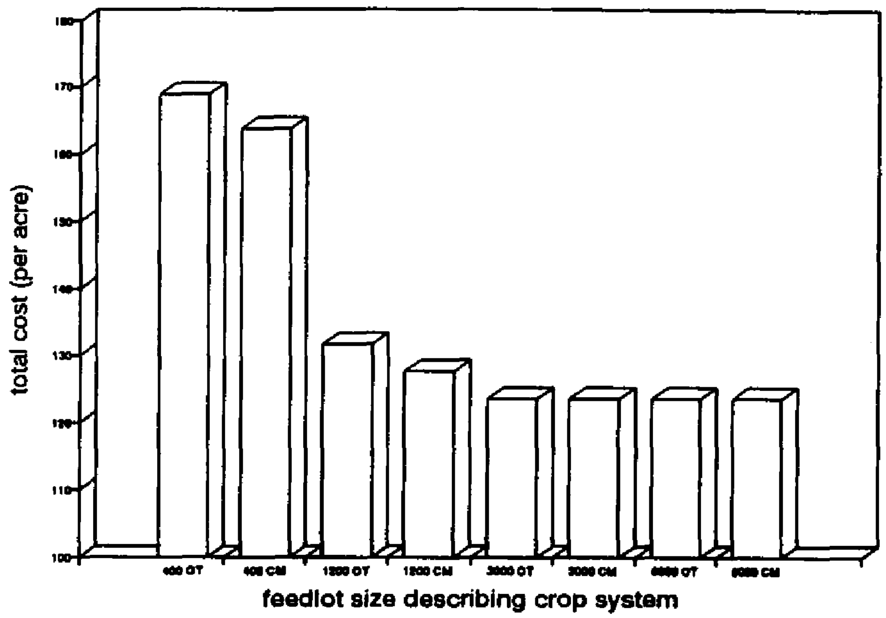

Figure 5.1 Cost per acre for a corn-soybean-wheat rotation

NET RETURNS TO THE CORN-SOYBEAN-WHEAT ENTERPRISES

Per acre net return for the three crop rotation enterprise is positive for each farm size and ranges from $47.31 for the 279 acre farm to $92.63 at 2000 acres, when all economies of size have been reached (Figure 5.2).

COMPARISON OF NET RETURN BETWEEN LAND USE ALTERNATIVES

Net return per acre for a farm with a feedlot enterprise under the production and marketing strategy offering the lowest, average, and highest net return per acre is shown along with the per acre net return for the analogous corn-soybean-wheat enterprise in Table 5.5. For each feedlot size and capacity utilization combination and under every production and marketing strategy, net return is higher for the farm with a feedlot enterprise than for the three rotation crop operation. The opportunity cost of utilizing the land to grown corn and corn silage for a feedlot enterprise is less than that which would discourage investment in feedlot facilities (i.e. the profitability of fed cattle production can fall substantially before feedlot operators will no longer rationally continue to invest in the feedlot)[78] Under the most profitable production and marketing strategy (feeding calves diet C3 from 500 to 1175 lb), the return per acre for the operation including a feedlot enterprise above that achieved with the three crop rotation ranges from $119.64 to $156.45 per acre for a farm size necessary for the 400 head capacity feedlot feeding one group of cattle per year to that defined by the 6000 head capacity feedlot also feeding one group of cattle per year, respectively (Figure 5.3). For an operation with land equivalent to that required for the 6000 head one turn system feeding calf diet C3 from 500 to 1175 lb, the cattle operation increases per acre net return over the corn-soybean-wheat rotation by 169%.

[78] Asset fixity, risk considerations, a strong preference for feeding cattle, or environmental characteristics other than those depicted in this analysis (such as availability of relatively cheap by product feeds,...) are reasons that a rational producer may not require resources to earn their full economic value, at least in the short to intermediate run.

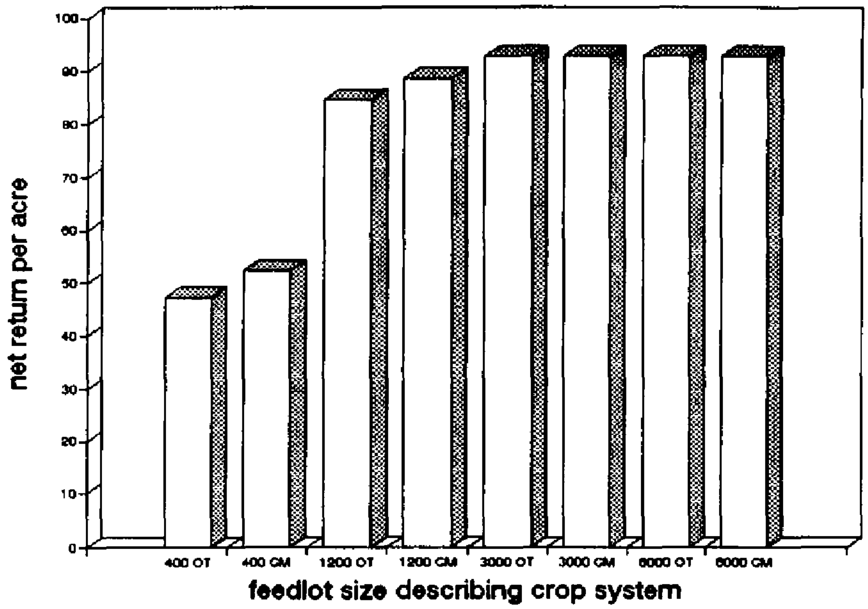

Figure 5.2 Net return per acre for a corn-soybean-wheat rotation

Table 5.5 Per acre net return for alternative land uses

Alternative	Corn-soybean-wheat rotation	Fed cattle production		
		low net return	average net return	high net return
Feedlot describing land acreage	net return per acre			
400 OT	$47.31	$ 73.35	$122.31	$166.95
400 CM	$52.52	$ 82.10	$120.84	$176.08
1200 OT	$84.59	$122.35	$168.90	$206.48
1200 CM	$88.67	$120.76	$152.81	$205.04
3000 OT	$92.65	$142.41	$200.62	$249.10
3000 CM	$92.65	$138.37	$175.26	$225.11
6000 OT	$92.65	$159.66	$209.05	$249.10
6000 CM	$92.65	$147.56	$178.09	$232.23

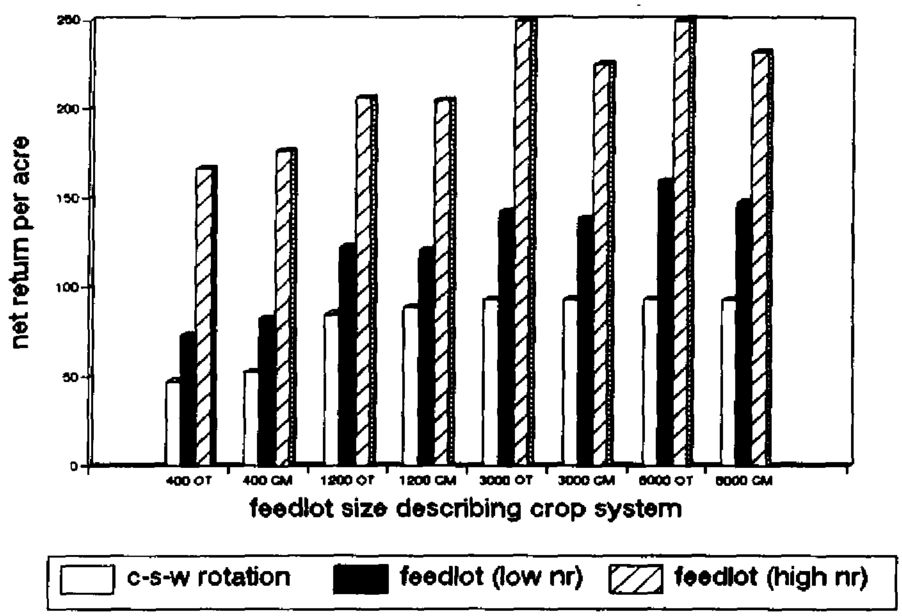

Figure 5.3 Net return to alternative land uses

The magnitude of the value added to the crop enterprise by the feedlot enterprise for farms of all sizes is particularly dependent upon diet fed. The more concentrated the diet used, the more crop acreage is required per animal fed. Increased farm size decreases per acre costs for the corn-soybean-wheat rotation and for the feedlot operation's crop enterprise up to the point at which economies of size in crop production are fully exhausted.

CHAPTER 6 REGIONAL COMPARATIVE ADVANTAGE IN THE FED BEEF CATTLE INDUSTRY

INTRODUCTION

This chapter addresses objective eight of this dissertation, to 'describe the costs and returns of feeding cattle in Kansas and compare returns to fed cattle production in Michigan with those in Kansas.' By doing so, the conviction of Hasbargen (1967) from nearly 3 decades ago is revisited:

> "Definition of existing locational economies and identification of the factors that have had and have the potential to change the profitability of cattle feeding with respect to alternative opportunities (both agricultural and non agricultural) that compete for the resources employed is important as an indicator of the likelihood of feedlot expansion and the development of the characteristics of feedlots within a given region over time."

From his research, Hasbargen concludes that locational factors are, perhaps, the most important long run determinants of industry location and that managerial expertise cannot overcome their influence. Sankey, et al. (1992) concur and argue that slow movements in the location of the U.S. cattle feeding industry are caused by relatively small differences in regional production costs. Sankey, et al. expand on Hasbargen's statement that locational differences will affect the characteristics of a regions' feedlots to include type of animal produced. How regional differences in production cost may create regional specialization within the fed beef industry, with regards to type of beef animal produced, is demonstrated. The authors show that regions with relatively low feed costs hold a comparative advantage in the production of highly marbled fed beef, such as that demanded by the increasingly visible Japanese market. Regions with relatively higher feed costs were shown to hold a comparative advantage in producing the leaner beef increasingly demanded by U.S. consumers. The analysis described in this chapter does not fully consider the changing role of the international market and of niche markets, although if Sankey, et al. are correct, analysis of Michigan's comparative advantage in producing particular types of beef for particular markets may provide important insight into the future of the industry in this state.

If locational factors provide other regions with economic advantages in cattle feeding not available to or that cannot be overcome by Michigan producers, the industry will continue to shift to these regions. If this is the case, these regions will be in a position to bid up the price of available feeder cattle and accept a lower fed cattle price, reducing returns for Michigan producers who compete with them in both markets[79]. A further shift of cattle production away from the Eastern Corn Belt will result if returns offered to fed cattle production in Michigan become lower than those offered by alternative resource uses. Contrarily, if the return on investment of fed cattle production approximates that offered by other investment opportunities of similar risk in each region, the market is said to be in equilibrium[80]. That is, the price of feeder and fed cattle are just adequate to keep resources employed in fed cattle production.

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[79] An increase in feeder cattle prices will, over time, lead to an increase in feeder cattle availability. The exit of marginal firms or those facing higher opportunity costs may not, therefore, be as extensive as suggested when feeder cattle availability is considered exogenous to the analysis.

[80] As is extensively considered in Chapter 5, the calculation of economic return must account for the opportunity cost of the resources used in production. Hasbargen (1967) noted that labor and land are often treated as fixed factors of production. As readily available markets exist for many crops which can be grown on land used to raise cattle feed and Michigan feedlots have increasingly begun to purchase much of their feed off the farm, it has become apparent that land and labor can no longer be treated as fixed factors of production.

FACTORS AFFECTING COMPARATIVE ADVANTAGE BETWEEN REGIONS

Introduction

It is evident from the regional shift of fed beef production from the Corn Belt to the Southern and, more recently, the Central, Plains that locational factors are an important determinant of economic return to beef production. Before regional comparative advantage is assessed, the general discussion of the influence of location on feedlot profitability contained in Chapter 2 is expanded to include more detail on the comparative advantage of the Michigan beef cattle industry relative to other regions in the U.S. Regional influence on the economic return to fed cattle production is considered in detail. Factors are identified which differ in presence or in affect between regions and the status of different regions in each of these factors and the resulting comparative advantage are discussed.

Production costs, production efficiencies, and cattle prices have been found to differ between regions. Hasbargen (1967) identified regional differences resulting from location, specialization, and management. Hasbargen and Kyle (1977) described regional differences due to location (including feeder cattle price and availability) and climate (and its affect on cattle performance and feed cost and availability). More recently, Krause (1991) identified regional differences in proximity to feeder cattle supplies and slaughtering plants and in access to financing. How regional differences interact to result in distinct regional (dis)advantages has not, however, been sufficiently studied.

As a precursor to comparing returns to fed cattle production in Michigan with those in Kansas, regional differences in feed cost, non-feed cost, opportunity cost, and production levels and efficiencies are identified and discussed in detail. Although they are discussed at length, sources of actual production cost differences between Michigan and the Southern and

Central Plains are not broken out in this dissertation. Production cost and performance efficiency advantages for the Plains are implicit in cost of gain values elicited from industry experts and the literature. The difference in economic return to fed cattle production between regions is later identified and discussed.

Regional differences in cost of and return to fed cattle production

1. Feed cost

Feed cost is an important component and generally makes up 60 to 65 percent of the total cost of fed beef production. The affect of the development and adoption of irrigation technology and of new grain varieties on feed cost in the Central and Southern Plains is often cited as instrumental in the shift of fed beef production to this region (Krause, 1991; Gwilliam, 1988; McCoy and Sarhan, 1988; Hasbargen, 1967).

In an early study of regional shifts in cattle feeding, Hasbargen (1967) found that the price of corn increased from the Central Plains to Michigan and concluded that the relatively low price of corn in Northeast Colorado, combined with readily available sorghum grain, resulted in relatively cheaper rations. As a result, high concentrate diets were found to be more profitable that rations with a higher percent corn silage in this region. Contrarily, high corn silage rations were more profitable in the Northern Corn Belt, particularly when only one turn of cattle was fed per year and if the corn price was high.

Today, high concentration rations are widely fed in the Southern and Central Plains, with many feedlots utilizing a ration consisting of over 90% concentrate. In Michigan, while the average diet contains a significantly lower percent concentrate, many of the larger feedlots, particularly those purchasing grain and byproducts and those feeding several turns per year, feed a highly concentrated ration. Several Michigan cattle feeders interviewed who have traditionally utilized farm produced feeds (Gwilliam, 1988) have begun to move towards purchasing grains and byproduct feeds off the farm to reduce feed cost.

Feedlots in Kansas purchase most to all of the feed grain utilized in their high concentrate ration. Feed costs are generally higher for Kansas feedlots than for those found in the Corn Belt, although the 18 cent per bushel average corn cost advantage for Michigan from 1981 to 1993 has narrowed to 4 cents per bushel when calculated from 1988 to 1993 (Figure 6.1). In addition to a decreasing corn price disadvantage, Kansas producers have an increasing number of viable feed grain alternatives to chose from as the market prices of feed grains move relative to one another. This evidence suggests that Kansas is no longer at a disadvantage in purchased feed cost relative to Michigan. Any feed cost advantage for Michigan producers must therefore come from cheaper and more available byproduct feeds or that gained from growing feed on the farm. Farm produced feed carries with it an additional advantage for Michigan producers, a market for manure produced on the feedlot. This is not nearly as important for the more arid regions of the country. In Chapter 4, credit was assigned to the feedlot for manure produced and utilized by the crop enterprise. The value of feedlot produced manure was priced at the value of the fertilizer it replaced. Although, in this analysis, manure is a valuable input to the crop operation and thereby reduces feed cost, it may, in actuality, be considered a liability to the extent that it limits the purchase of off farm feed as market prices become such that it would otherwise be economical to do so. It was for this reason and because on-farm production was the cheapest source of feed, that Hasbargen and Kyle (1977) concluded that investments in large scale lots were unlikely to occur independent of the land base in the Northern Corn Belt. The extent to which feedlots can expand independent of the land base in Michigan today will depend on Right to Farm legislation, price and availability of byproducts and other potential low cost feed sources, and existing alternatives for manure disposal.

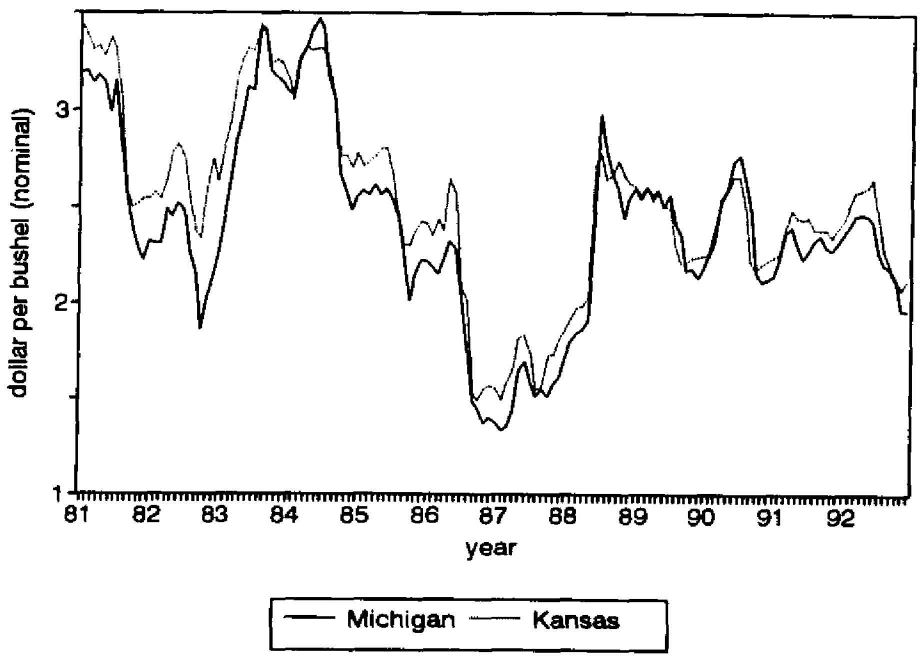

Figure 6.1. Corn price comparison; Michigan versus SW Kansas

2. Non-feed cost

Non-feed costs include those associated with cattle and feed storage facilities, equipment, labor, bedding, taxes, veterinary costs, and interest. Non-feed costs, particularly for facilities, are significantly higher for Michigan than for the arid Southern and Central Plains. Hasbargen and Kyle (1977) identified non-feed costs, particularly bedding, as the major locational disadvantage for the Northern Corn Belt. Due to Michigan's damp climate, investment requirements for cattle and feed storage facilities are higher than for the Plains States (Hasbargen, 1967; Hasbargen and Kyle, 1977; Loy, et al., 1986; Loy, et al, 1992). For example, while wooden or concrete horizontal silos are generally required in Michigan to avoid excessive feed spoilage and dry matter loss, lower cost earthen silos are adequate for feed storage in more arid regions such as the Central and Southern Plains.

Michigan cattle feeders also have higher costs, on a per head basis, for managerial activities such as buying feeder cattle and other inputs, selling fed cattle, and information gathering and analysis. Since economies of size associated with managerial specialization are less available to Michigan's feedlot operators, some of these services are hired out. For example, approximately 70% of Michigan feedlots purchase feeder cattle through an order buyer. This number increases to 83% when only farms marketing more than 500 head per year are included (Ritchie, et al., 1992).

Other non-feed costs are also higher for Michigan producers. The damp and cold climate make additional maintenance and operational activities such as snow and manure removal necessary. Additional labor and equipment is necessary to acquire, handle, and remove bedding. In addition to higher labor requirements, labor is more expensive in Michigan than for either the Southwest or the Northern Corn Belt due to heavy competition from industry. Interest rates do not differ substantially across regions (Sankey, 1992), although per head interest cost is higher in Michigan due to the relatively higher number of days on feed.

3. Opportunity cost

The opportunity cost of resources utilized in production is frequently ignored in economic comparisons between regions. Opportunity cost is that return which must be provided in order to keep a resource employed in its current use. In the longer run, opportunity cost represents the return to the next best alternative investment opportunity within a region, although it may be lower in the intermediate run because of asset fixity created by heavy investment in enterprise specific facilities and other factors. Asset fixity is particularly important for feedlots in the Corn Belt.

Opportunity cost of resources utilized in cattle production will differ depending on opportunities available to persons within and between regions. For example, cow/calf producers in the West, where grazing lands are an important resource, have fewer alternatives than fed beef cattle producers in the Corn Belt (Krause, 1991). The availability of slack labor may lower the opportunity cost for the Michigan farmer feeder.

Opportunity cost for Michigan cattle producers is depicted as the return from the sale of cash crops grown on land currently used to provide feed for the cattle operation (Chapter 5). The opportunity cost for fed cattle production in Kansas is, rather, identified as the rate of return available from financial investments with a similar level of risk, since a large proportion of capital investment in Kansas fed cattle is from outside investors or debt.

Performance differences

Cost of gain also differs between regions as a result of differences in animal performance. The tradeoff between facility costs and increased animal performance in a climate such as is found in Michigan was discussed extensively in Chapter 3. Benefits from the use of more extensive facilities include higher average daily gains and turnover rates and lower morbidity and mortality rates, resulting in lower fixed costs per unit gain, fewer lost days on feed due to sickness, and a lower death loss[81]. Higher feed efficiencies will reduce feed costs and may lead to higher average daily gains. Higher feed efficiencies in the Southwest as compared to the Northern Corn Belt have been found in past (Hasbargen, 1967) and more current (Loy, et al., 1992) research. This difference is generally attributed to climatic differences. Loy, et al. (1986) concluded that the prevalence of wet, muddy conditions in Iowa feedlots in the spring and severe winters affected average daily gain and feed efficiency, although the higher feed

[81] As discussed extensively in Chapter 3, in this analysis, facilities are designed such that climate has little to no affect on feed intake or performance. Animal performance is therefore simply a function of ration and animal type.

efficiencies found in Texas were attributed, in part, to the use of higher concentrated (and cost) rations. In contrast, Hasbargen found the affect of weather on feed efficiency negligible. He rather attributes better feed conversion to inaccurate estimates, differences in feed quality, or, (and most likely), quality and type of management. Feedlots in the Southwest were found to use higher concentration rations and more crossbreeds, had better animal health, purchased, rather than grew, feed, more accurately balanced rations, and marketed cattle at lighter weights.

Regional differences in cattle prices

Prices of feeder and fed cattle differ by region as influenced by their proximity to regions conducive to cow/calf and to feedlot production, and consumption markets (population centers). Loy, et al. (1986), compared feeder cattle prices paid by Iowa cattle feeders from 1975 to 1983 to those found in other regions. The relatively higher feeder cattle prices found in Iowa were attributed to the increased transportation costs required to obtain feeder cattle.

Loy, et al. (1986) and Loy, et al. (1992) found that fed price did not vary much between regions, although only Iowa/Southern Minnesota, Colorado, and Omaha were compared. In contrast, Gwilliam (1988) found that large cattle producing areas of the west tended to set the national price for fed beef. Results of his surveys showed that some Michigan fed cattle went west to Illinois and Wisconsin, adding transportation costs not experienced for feedlots closer to large packers. Gwilliam also found that eastern markets, including Pennsylvania and New York, generally offered higher prices than were found in the Midwest and therefore also drew cattle from Michigan, Indiana, Ohio, and Illinois. The Canadian market, which has traditionally offered Michigan feedlots a seasonal higher fed price, has declined in importance as the number of Canadian packers has decreased.

REPRESENTATION OF THE KANSAS BEEF INDUSTRY'S FEEDLOT SECTOR

The Kansas beef industry's feedlot sector as a comparative benchmark[82]

The Southern Plains states have the most favorable combination of locational advantages to fed cattle production in the U.S. Advancements in irrigation technology, improvements in crop (sorghum) varieties, an arid climate, and proximity to feeder cattle production have fueled this area's fed cattle market share growth. In addition, improvements in transportation and refrigeration technology and relatively recently, reduction in fuel prices and over the road truck taxes (Bowersox, 1992), have made cattle feeding and slaughter away from population centers more attractive. The High Plains currently has over 70% of the total feedlot capacity in the U.S.

The Kansas beef industry's feedlot sector was chosen to represent the growing cattle feeding sector in the Southern and Central Plains region. Kansas stands out among the High Plains states for two reasons. First, even though the state's marketings decreased slightly in 1990, Kansas had the fastest overall growth rate among the major cattle feeding states in the last decade (Dhuyvetter and Laudert, 1992). Kansas's share of U.S. fed beef production increased from 14.2% in 1980 to 18.7% in 1990. Second, rich data sets are available for feeder and fed cattle prices and for cost of gain in Kansas (Langemeier, 1993a; Langemeier, 1993b; Langemeier, et al., 1992; Minert, 1992; Focus on Feedlots, various years 1980 to 1992).

[82] Figures 6.2 to 6.5 are taken from Dhuyvetter, et al., 1992.

The Kansas beef industry

1. General trends in the industry

The number of cattle farms and ranches in Kansas decreased from 52,000 to 35,000 or 32.7% from 1981 to 1991 (Dhuyvetter, et al., 1992). Most of this decline took place from 1980 to 1986. While the number of feedlots has declined, number of cattle on feed has increased a dramatic 64% from slightly over 1.1 million head in 1982 to slightly over 1.8 million head in 1992 (Figure 6.2). The number of fed cattle marketed has increased an average of 120,000 head annually since 1960. Because the size of the cow herd has declined 25% from 1980 to 1990, the number of imported feeder cattle has increased from 1 million to 2.8 million, to approximately seventy-five percent of total fed cattle marketed (Figure 6.3).

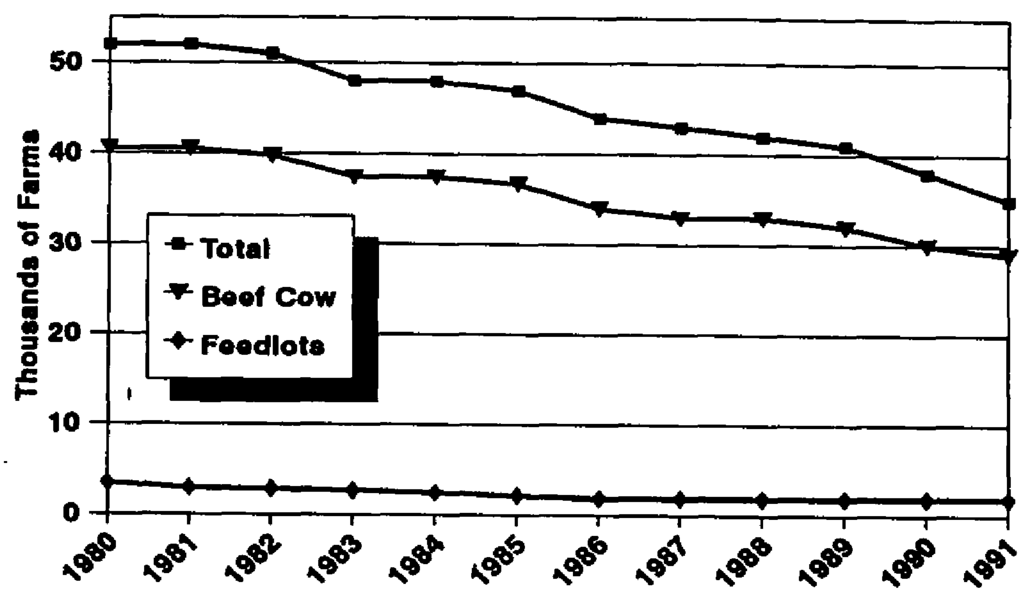

Figure 6.2. Number of cattle farms and ranches in Kansas (1980-1991)

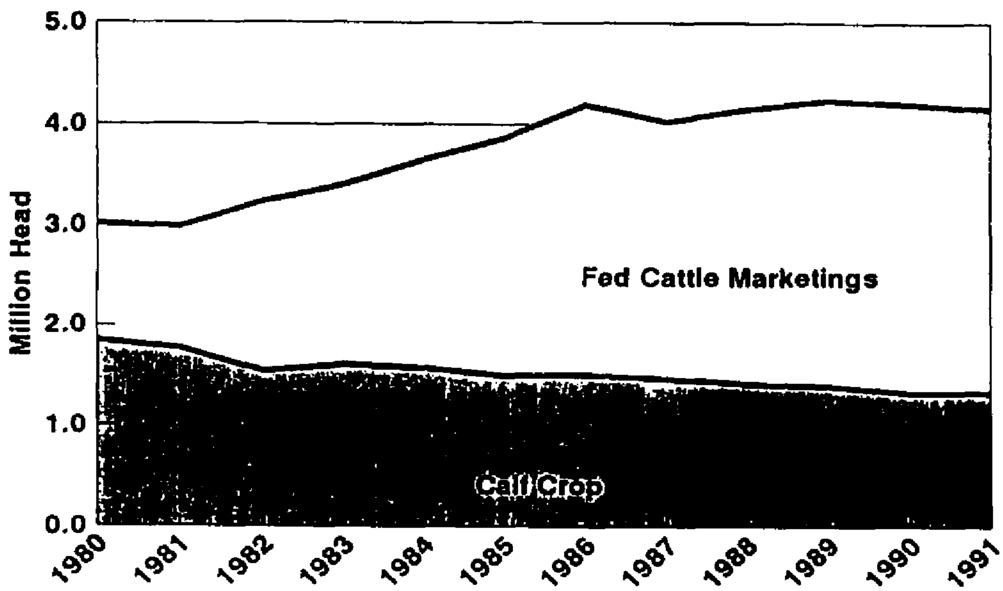

Figure 6.3. Kansas annual calf crop and fed cattle marketings

2. Fed cattle sector

Value of fed cattle marketings from Kansas rose 70.3%, from 2.1 to 3.63 billion dollars, from 1981 to 1991 as a result of the 39.4 % increase in fed cattle marketings, a 5.4% increase in average fed weight, and a 16% increase in fed price (Dhuyvetter, et al., 1992). Most of the approximately 1900 feedlots make a relatively small contribution to total fed cattle marketed (Figure 6.4). Feedlots marketing less than 2000 head of fed cattle per year make up 91% of all feedlots, but market less than 3% of all fed cattle. Feedlots marketing more than 16,000 head make up less than 3% of the feedlots, but market approximately 70% of all fed cattle. Most of the larger feedlots are custom feedyards which feed cattle for cow/calf producers and outside investors who retain or hold ownership on feeder or stocker cattle (Dhuyvetter, et al., 1992)[83]. Fed cattle from feedlots marketing less than 1000 head and between 4000 and 15,999 head have declined while those from feedlots marketing between 1000 and 3999 and over 16,000 head have increased. The largest drop in share of the Kansas fed cattle market has been among 4,000 to 7,999 head feedlots.

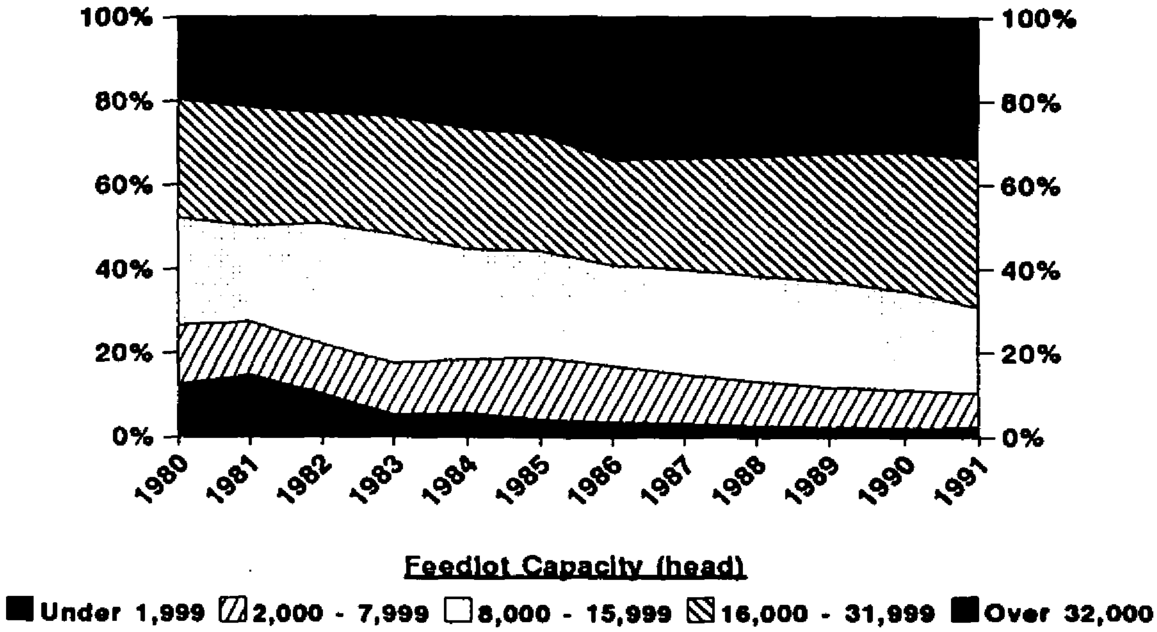

Figure 6.4. Percent of fed cattle marketed by feedlot size

Regionally, the fed cattle market in Kansas is very concentrated with the heaviest concentration in the southwest part of the state. The northwest and central regions also have a relatively large number of feedlots (Figure 6.5).

[83] This and other types of integration between the traditional cow/calf, stocker, and feedlot stages of beef production are a growing trend (Simms, 1991).

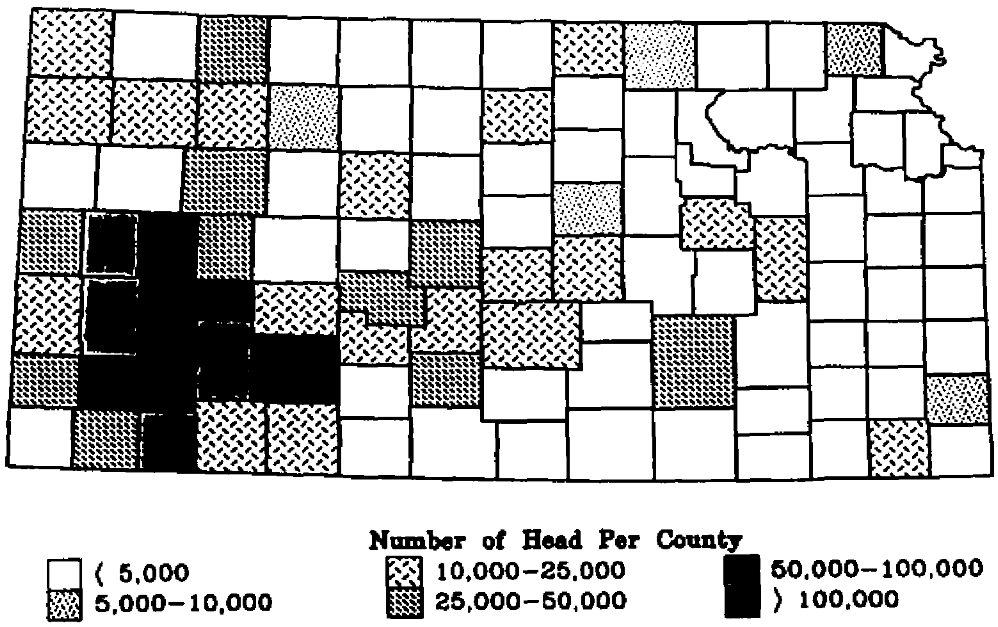

Figure 6.5. Geographic distribution of cattle on feed

3. Commercial slaughter

Currently, Kansas has the largest slaughter capacity and enjoys the fastest growth rate in number of cattle slaughtered of any state in the U.S. The Kansas share of U.S. slaughter increased from 10.4% to 18.4% from 1981 to 1991, when more than 6 million head of cattle were slaughtered in Kansas. The six major beef slaughter houses in Kansas have a combined daily slaughter capacity of 24,300 head (Dhuyvetter, et al., 1992). Almost 2 million head of cattle a year are imported for slaughter. Overtime, this excess slaughter capacity will act to increase the state's feedlot capacity.

4. Kansas crop production

The 64% increase in the number of cattle on feed in Kansas from January 1, 1982 to January 1, 1992 has generated some concern whether fed cattle production will remain profitable in this state as it becomes increasingly necessary to import feed to meet requirements. Currently, Kansas crop production greatly exceeds annual feedyard needs, although Kansas cattle feeders must compete with other livestock enterprises, both within the state and with other states (particularly Texas, Oklahoma, Colorado, Arizona, and New Mexico) for feed (Dhuyvetter, et al., 1992). Corn and milo are the most commonly used feed grains in Kansas, although wheat is used when its cost approaches 105 to 110% of the price of corn. Alfalfa, corn silage, and sorghum silage supply the majority of the forage used.

5. Data utilized to estimated Kansas cost of production and cattle prices

Representative cost of production and cattle price data for Kansas feedlots was obtained from Kansas State University researchers, fact sheets, industry newsletters, and research bulletins. Langemeier (1993b) and Langemeier, et al. (1992) report cost of gain for Kansas steers entering the feedlot at 7-800 lb from January, 1981 to December, 1992. This cost series is based on closeouts of two feedyards in Western Kansas. Cost of gain estimates include feed, yardage, processing, medication, and death loss, but do not include interest cost associated with purchasing and selling cattle or the cost of the feeder animal. Monthly cost of gain values were adjusted to real 1992 dollars using the Consumer Price Index. The monthly consumer price index is both readily available and is an appropriate adjustor for prices paid by agricultural producers[84]. Interest rates to calculate interest cost paid by Kansas producers were obtained from various issues of the Regional Economic Digest. Feeder and fed cattle

[84] Although separate indexes exist for prices paid by agricultural producers (see for example Index of Prices Paid by Farmers; Commodities and Services, Interest, Taxes, and Wage Rates), use of these indexes would not be consistent across the purchase of feeder calves and the sale of fed cattle (Ferris, 1993).

prices were estimated using Dodge City, Kansas feeder cattle auction summaries reported by the USDA.

Langemeier, et al. (1992) estimated average costs, returns, and performance by placement weight (6-700 lb, 7-800 lb, and 8-900 lb) for steers in western Kansas. Estimates were based on data provided by a western Kansas commercial yard. Quarterly returns are also provided for finishing 750 lb steers in Kansas. Focus on Feedlot newsletters provided information on cost of gain, estimated future cost of gain, days on feed, average daily gain, final weight, and feed efficiency for both steers and heifers and the price of corn, alfalfa hay, milo, and wheat in Kansas. This data was extensively reviewed for the period from late 1989 to early 1992. Summary graphs are shown in Figures 6.6 through 6.10. Additional Focus on Feedlots data was available to the author back to January, 1980. Due to the irregular publishing schedule of the newsletter prior to late 1989, this data was of limited use. Selected costs of Great Plains custom cattle feeding reported regularly in Livestock and Poultry Situation and Outlook Report (USDA, ERS, selected years) were used to check the validity of the cost of gain data obtained from Kansas State University.

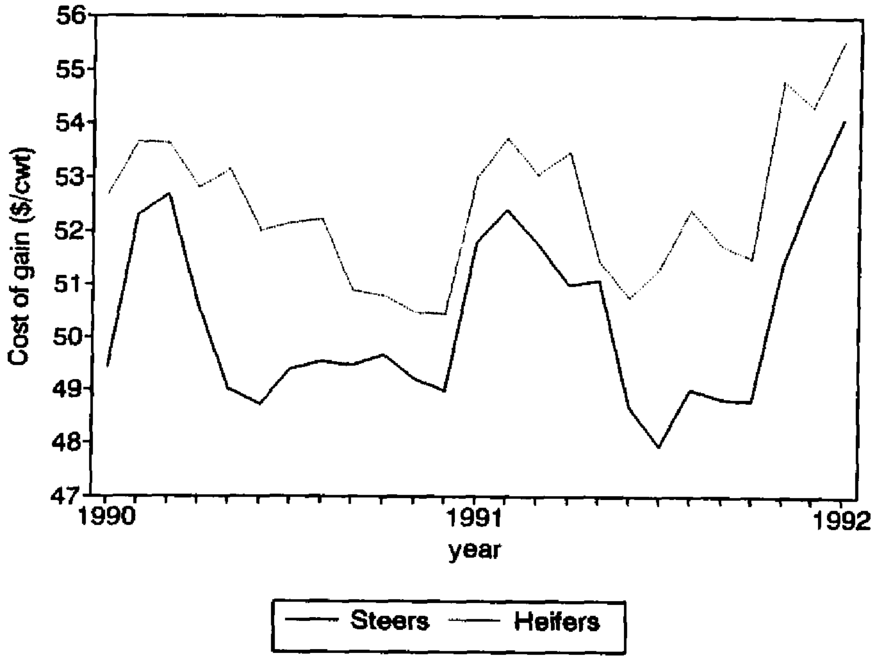

Figure 6.6 Cost of gain for Kansas feedlot steers

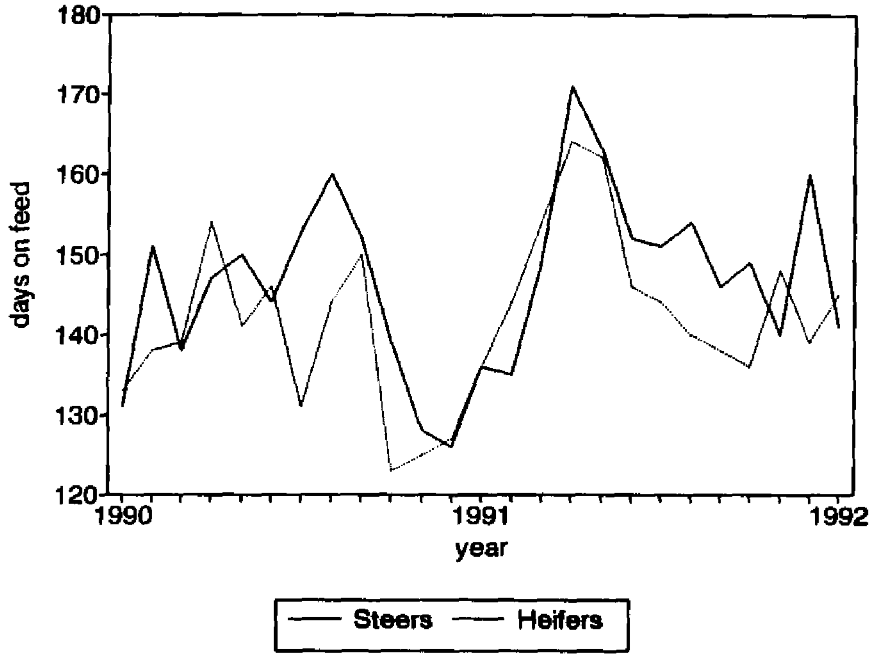

Figure 6.7 Days on feed for Kansas feedlot steers and heifers

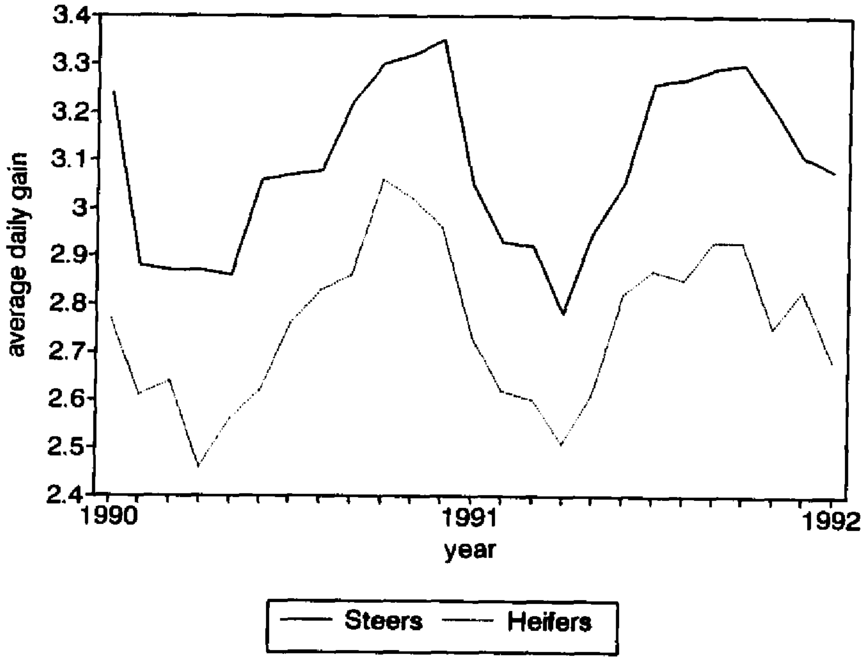

Figure 6.8. ADG for Kansas feedlot steers and heifers

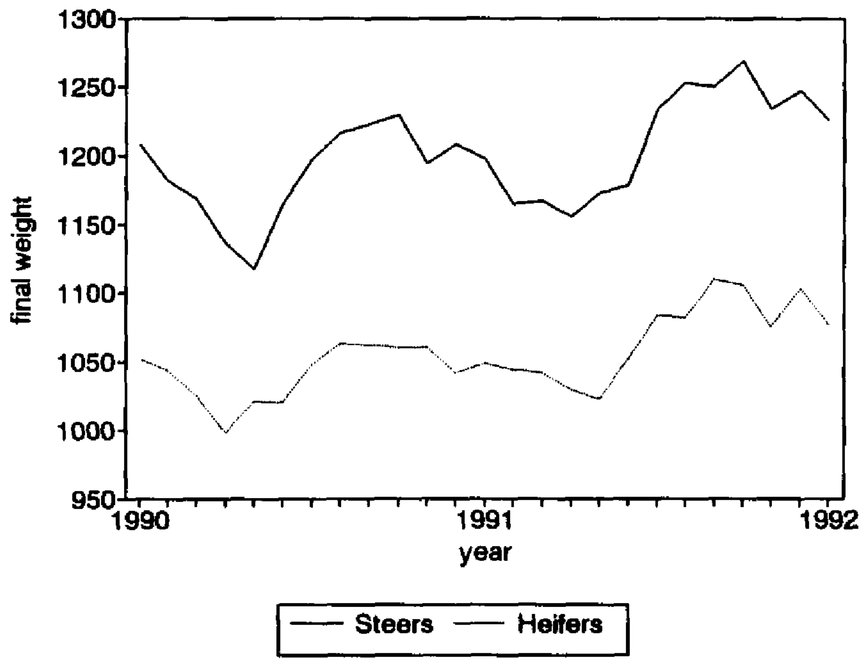

Figure 6.9. Final weight for Kansas steers and heifers

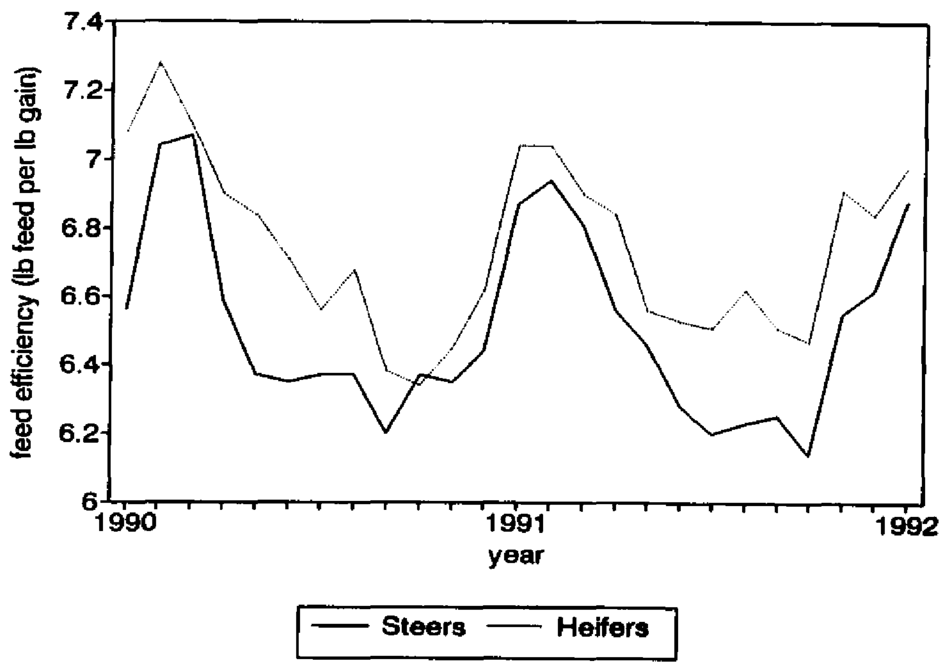

Figure 6.10. Feed efficiency for Kansas steers and heifers

Kansas cost of production

The real cost of gain in Kansas has decreased substantially from early 1981 to late 1992 (Figure 6.11). One Kansas State University beef cattle expert attributes the decline in cost of gain to technology improvements (Langemeier, 1993b). Improved technology is differentiated from feed prices, which also play an important role in cost of gain and to which much of the variance in cost of gain can be attributed[85]. The relationship between corn price and cost of gain is clearly shown by comparing cost of gain for Kansas steers with the corn price in Kansas (Figure 6.12). During periods of relatively high corn prices, cost of gain is above the linear path of decline while the opposite is true during periods of relatively low corn prices. This relationship is buffered somewhat by the substitutability of wheat and sorghum for corn

[85] Cost of gain was very volatile, ranging from $94 to $48 per cwt from early 1981 to late 1986.

when the price of corn exceeds that of other grains by a threshold amount. Corn prices tend to have less influence on profits as the weight at which animals enter the feedlot increases. Real cost of gain has been relatively stable, that is, the steady decline in cost of production has leveled off over the last six to seven years[86]. The data from 1987 through the end of 1992, converted to real 1992 dollars, is therefore used to represent the cost of feeding steers in Kansas. Mean real cost for this period is $57.33/cwt for feeder cattle entering the feedlot at 7-800 lb.

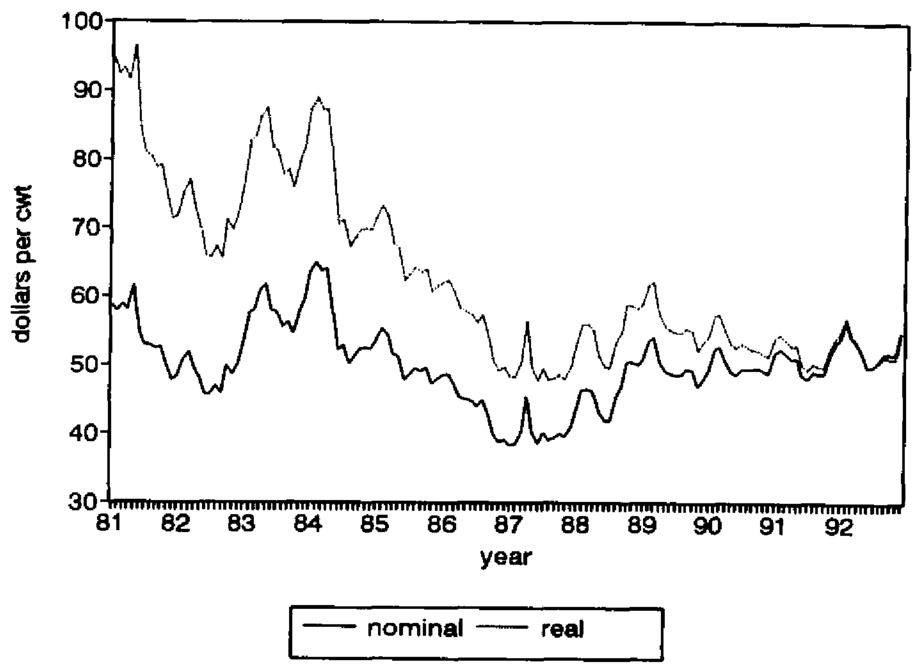

Figure 6.11. Cost of gain for Kansas steers and heifers (1981 to 1992)

[86] Any additional non-feed cost of gain decline experienced in 1991 and 1992 may have been buffered by the high grain prices due to poor crop performance in Kansas during these two years.

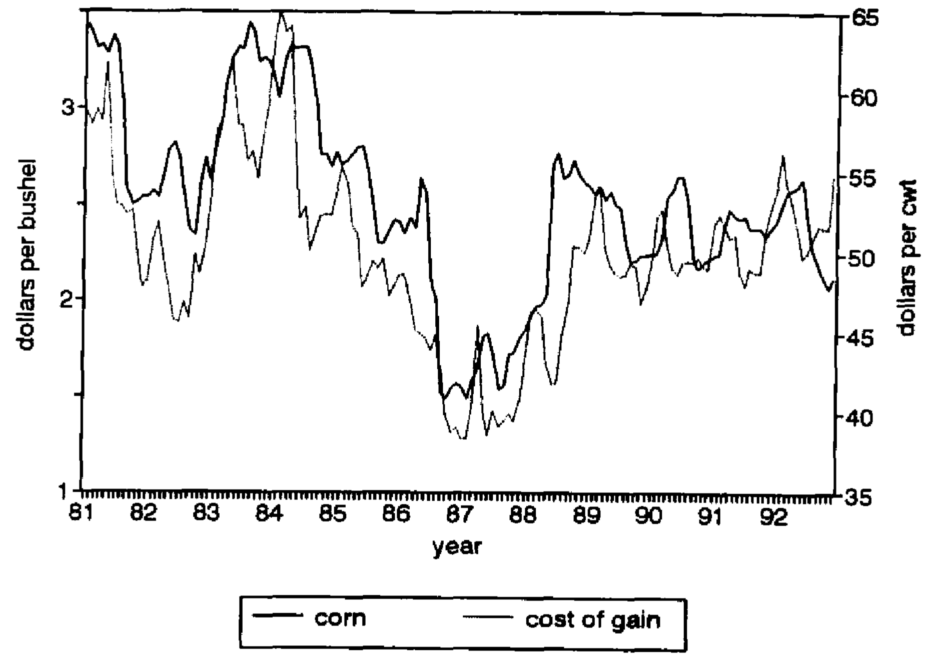

Figure 6.12. Feed cost of gain for Kansas steers and Kansas corn price (1981 to 1992)

Cattle prices

Gross margins faced by Kansas fed cattle producers were calculated using Dodge City, Kansas auction data made available by Kansas State University[87]. Due to higher transactions costs and to the tendency for cattle of lower quality (particularly fed cattle) to be sold through the auction, a lower gross margin is expected using this data than if a price series for the direct purchase and sale of cattle was available. While it is a reasonable assumption that feeder cattle are purchased through the auction, the assumption that fed cattle are sold through an

[87] Transportation costs from Lexington to Dodge City, Kansas are approximately $25.54 for a 750 lb steer. The price differential between the Dodge City auction and the Lexington auction for this animal is $40.95 (Dodge City more expensive), thereby making it economical for producers in Kansas to import feeder cattle from the Southeast.

auction or terminal market is less reasonable. Regardless of these limitations and because of their availability, auction fed prices are used to calculate revenue received for Kansas fed cattle.

Feeder cattle prices for 5-800 lb steer calves from Kansas auctions are, on average, $1.78/cwt and $1.00/cwt higher than those from auctions in Lexington, Kentucky and in Michigan, respectively (Figure 6.13). The high feeder cattle price is consistent with Kansas being a net importer of feeder cattle. Kansas fed cattle prices at Dodge City are $2.95/cwt greater, averaged over 1981 to 1992, than Michigan fed prices (Figure 6.14), although since Michigan fed prices are at the farm gate, reduction of transportation and other marketing costs and commission from the fed price paid in Kansas will reduce this advantage somewhat. The difference between Dodge City and Michigan fed cattle prices narrows to $0.47 when considered over the period from 1984 to 1992. The latter difference is in line with that suggested by Roberts (1993) and Bass (1993). For this reason and for consistency throughout the thesis, the 1984 to 1992 price series is therefore used.

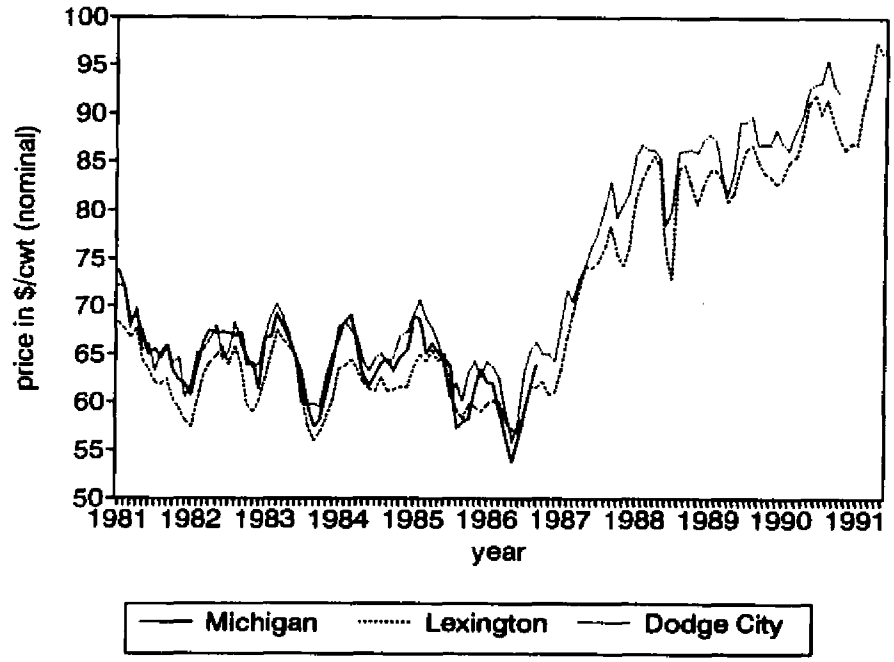

Figure 6.13 Real feeder cattle prices for Lexington (KY), Dodge City (KS), and Michigan

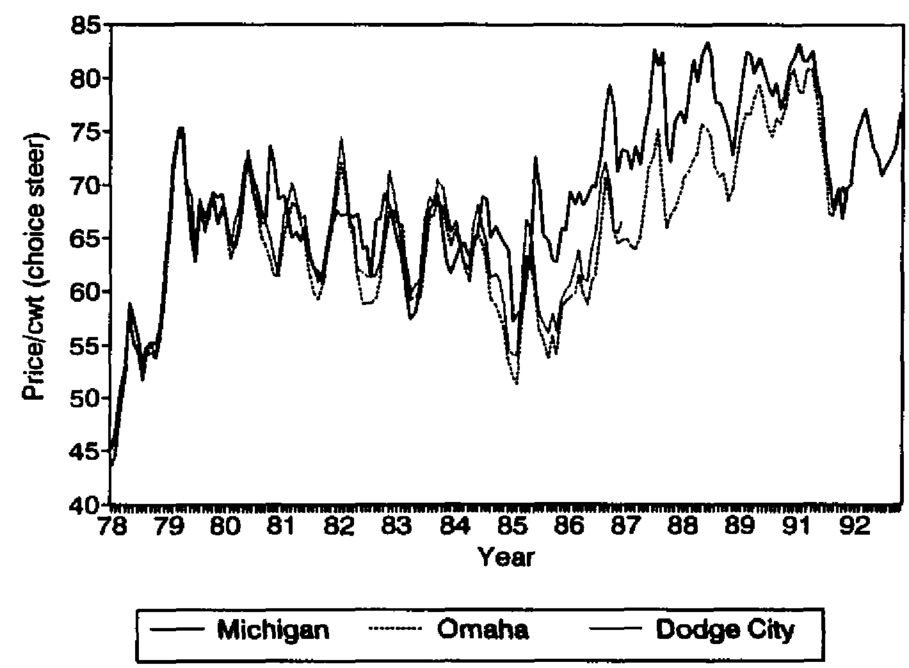

Figure 6.14 Real Fed cattle prices for Dodge City (KS), Michigan, and Omaha (NE)

Gross margins per head are calculated for Kansas fed cattle producers purchasing 750 lb feeder cattle[88]. Details regarding transportation and commissions are identical to those used to calculate gross margins for Michigan cattle feeders feeding on a continuous basis, although the distance feeder calves are hauled is much less[89]. Mean gross margin for Kansas fed steers as described above is \$325.50 per head, or \$7.69 per head higher than was found for a Michigan cattle feeder purchasing a 750 lb steer in Lexington and selling the fed animal FOB farm through MLSE.

Net returns to fed cattle production: Michigan versus Kansas

Net returns to unallocated resources for Kansas fed beef production is calculated as the gross margin less the cost of gain (Equation 6.1).

$$(6.1) \quad NE = GM_{hd} - (COG_{cwt} \times gain_{cwt}))$$
$$= (325.50 - (53.77 \times 4.5)) = \$67.52/hd$$

For the producer purchasing and selling a steer at 750 lb and 1200, respectively, net return is \$325.50 less \$257.98, or \$67.52 per head.

This is below the net return per head for the Michigan feedlot under most production and marketing strategies as represented in this analysis, but is above that experienced by each size (except 6000 head capacity) feedlot operating under at least one production and marketing

[88] Cost of gain/cwt data is for steers entering the feedlot at 7-800 lb and selling 1200 lb fed cattle, the approximate average fed weight for Kansas fed steers from 1987 to 1992.

[89] Fed cattle price was treated as FOB farm after transportation cost is subtracted. Fed cattle are assumed to be hauled 50 miles at \$1.80 per loaded mile, for a cost of \$2.25 per head. A commission of \$5.50 and transportation costs of \$2.62 for a haul of 100 miles are paid on Dodge City, Kansas purchased feeder cattle by Kansas producers. Interest rate on feeder cattle is assumed to be 7%.

strategy when cattle are bought and sold year round and for the 400 head capacity feedlot size when only one turn of cattle are bought per year (Figures 6.15 and 6.16).

If the return to fed cattle production in Kansas is just high enough, given the level of risk, to encourage investment at the present level (i.e. the Kansas feedlot industry is in equilibrium), returns are not inconsistent with the maintenance, and perhaps growth, of the Michigan fed cattle industry as fed cattle production compares favorably with alternative resource uses. If, on the other hand, and more likely as shown by the continued growth of fed cattle production in the High Plains, returns are higher than is necessary to maintain market share, the gross margins facing Michigan producers are likely to decline. The future of the Michigan cattle industry, in this case, depends on the willingness and ability of fed cattle producers to adopt the most profitable production and marketing strategies and size for their operation.

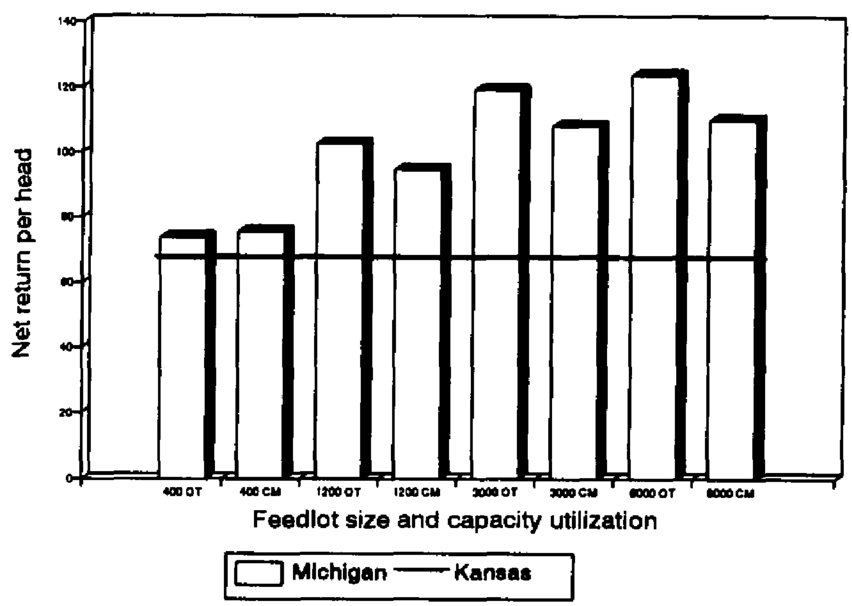

Figure 6.15 Net return to fed cattle production (Michigan versus Kansas)

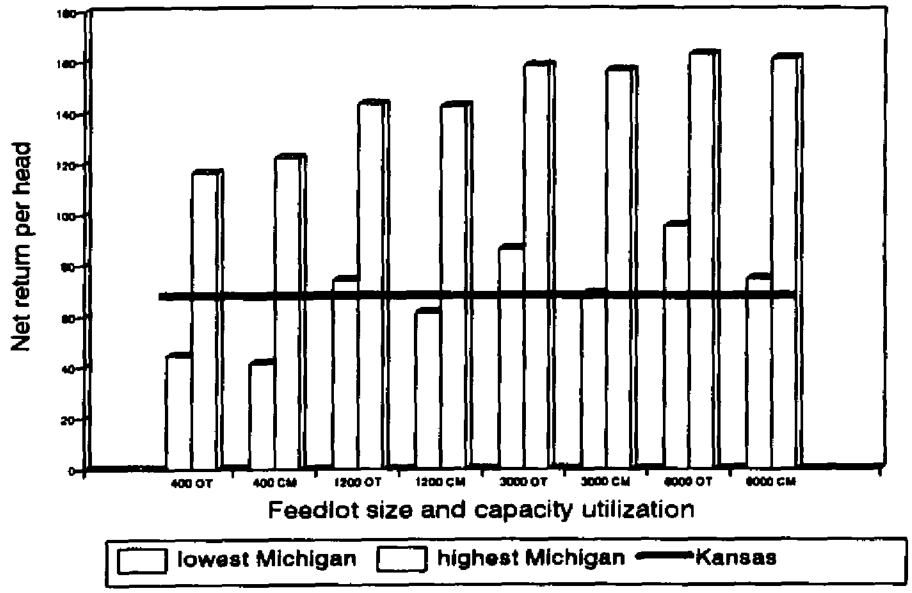

Figure 6.16 Net return to fed cattle production (lowest and highest Michigan versus Kansas)

CHAPTER 7 SUMMARY AND CONCLUSIONS

This chapter summarizes the objectives of this dissertation, details of the model used to meet these objectives, and the conclusions drawn from the analysis. Limitations of the analysis are discussed as they influence recommendations found within. Promising areas for future research to help overcome these limitations are suggested.

OBJECTIVES

The primary objective of this dissertation was to define the comparative position of the Michigan fed beef cattle industry to other viable uses of Michigan's agricultural land and to fed cattle production in the Central and Southern Plains. To achieve this objective, several specific objectives were addressed.

1. The net return to fed beef cattle production in Michigan under different production and marketing strategies was calculated by determining:

   a. the characteristics of Michigan cattle feeders,

   b. the cost of producing beef cattle in Michigan for farms of different sizes and operating under different production and marketing systems,

   c. gross margins faced by Michigan cattle feeders, and

   d. net return to fed cattle production.

2. The extent to which (dis)economies of size exist for Michigan fed beef cattle producers was determined.

3. The opportunity cost of growing feed for and raising fed cattle was determined for Michigan feedlots. Economic return to fed beef cattle production was then determined.

Returns from a corn-soybean-wheat rotation represent the opportunity cost of fed beef cattle production in Michigan.

4. The net return to fed cattle production in Kansas, a region with a growing fed cattle industry, was determined. This net return was compared with net returns to fed cattle production found in Michigan as a basis by which to predict the future locational evolution of the fed beef cattle industry.

METHODS

The net return to fed beef cattle production in Michigan under different production and marketing strategies and for different size farms was calculated as gross margin on the purchase and sale of cattle less production costs. Gross margins were calculated by subtracting the per head historic average price of feeder cattle in Lexington, Kentucky, transportation cost, commission, and death loss from the per head historical average farm gate Michigan fed cattle price. Gross margins were determined for feedlots feeding cattle with different purchase and sale weights and fed diets of differing concentrations under seasonal and year round marketing strategies. Production costs were determined for cattle entering and exiting the feedlot at different weights and fed diets differing levels of concentration, reflecting the range of production practices of existing Michigan feedlots.

A whole farm budget was created using a spreadsheet with details of, and costs for, separate components of the whole farm, including livestock and feed storage facilities, livestock rations, waste handling and manure nutrients, the crop enterprise, and other overhead and operating costs. Linear estimation, simulation modeling, and standard budgeting techniques were used to calculate the cost associated with each component and for the whole farm system. Net return was calculated under different production and marketing strategies, including differing levels of capacity utilization (one turn versus continuous marketing), diets of different concentrate levels, and differing purchase and sale weights. Management implications are drawn from these comparisons.

The highest net return to fed cattle production realized for each size feedlot and capacity utilization strategy was compared with that for a Michigan crop operation with a corn-soybean-wheat rotation and with net return to fed beef cattle production in Kansas. From the former comparison, the value added by using cattle to market grown crops was determined. From the latter, implications for the future locational evolution of fed cattle production in the U.S. are drawn. The net return to a Michigan farm producing a corn-soybean-wheat rotation was calculated as total revenue from the sale of the crops as based on historic average Saginaw, Michigan prices and yields comparable with land used to grow corn and corn silage in the feedlot operation less production costs. Machinery and labor and associated costs were calculated using a simulation model. Other variable costs are taken from Nott, et al., 1992. The net return to fed cattle production in Kansas was calculated as gross margin less production cost for steers entering the feedlot at 7-800 lb. Gross margins are calculated as historic average per head fed steer price at Dodge City, Kansas less transportation and commission costs, death loss, and historic average per head Dodge City feeder cattle price. Production cost per cwt gain is as reported in Langemeier, et al. (1992) and Langemeier (1993a, 1993b).

Net return to fed cattle production in Michigan under different production and marketing strategies, including differing levels of capacity utilization (one turn versus continuous marketing), diets of different concentrate levels, and differing purchase and sale weights are compared. From this comparison, best management practices are identified and described, although no further analysis is done to separate the specific affects of different influencers.

CONCLUSIONS

Net returns to fed beef production in Michigan were found to be highly dependent on production and, particularly marketing, strategies employed on the farm although positive net returns were found under all production and marketing strategies and for each size feedlot. Net return to feeding calves was, in general, higher than that for feeding yearlings. Purchase and sale weight affected net return. Yearlings and calves purchased at lighter weights had higher returns than those purchased at heavier weights. Net return increased as weight at which yearlings were sold increased from 1175 lb to 1250 lb.

Diet fed affected net return with more concentration rations, in general, resulting in higher net returns than less concentrated diets. Per head return was highest when feeding calves a very concentrated diet from 500 to 1175 lb and was lowest when feeding the least concentrated yearling ration, that representing the average diet fed to yearlings from 750 to 1250 lb by Michigan producers marketing more than 500 head of cattle annually in 1988.

The average net return over all production and marketing strategies was found to be higher under a one turn, full capacity utilization strategy than for a feedlot operating year round at 80% capacity for feedlots with 1200 head or more capacity. The higher gross margins found under the one turn strategy outweighed the higher production costs resulting from a lower annual level of capacity utilization.

Economies of size were found over the range of feedlot sizes considered[90]. In general, as feedlot size increased, economies of size were found for costs associated with cattle and feed

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[90] The source of all economies of size was from production cost because, due to the presence of Michigan Livestock Exchange and the tendency for Michigan producers to use order buyers to obtain feeder cattle, gross margin does not depend on feedlot size.

storage facilities, labor, bedding, feeding equipment, and grown feed. The cost associated with each declined as feedlot size increased except for the cost associated with cattle facility investment. This cost increased when the slatted floor pens were added as feedlot capacity increased from 400 to 1200 head and then declined with increasing feedlot size. Nearly all economies of size were exhausted by the 3000 head capacity feedlot size.

The comparison of net returns to a farm raising fed cattle on farm produced feeds to one with a similar land base operating a crop enterprise described as a corn-soybean-wheat rotation showed that fed cattle production, practiced under most production and marketing strategies, can add value to farm raised crops.

Net return to fed beef cattle production in Michigan was found to be higher than that for Kansas under most production and marketing strategies for all farm sizes considered. If the average production and marketing strategy considered is representative of those used in Michigan and if the fed beef cattle industry is in equilibrium, the Michigan fed cattle industry has strong potential for growth. Depending on the opportunity cost of capital invested in feedlots in the Central and Southern Plains, the profitability of feeding cattle in Michigan may diminish as feeder cattle are bid away from Michigan, and presumably, the rest of the Northern Corn Belt. If this is the case, as is hypothesized by observing the rapidly growing industry in the Central and Southern Plains states, which suggests that the U.S. fed beef cattle industry is not in equilibrium, the industry will continue to shift to the Southern and Central Plains. However, higher net returns found for Michigan under most production and marketing strategies than for Kansas feedlots indicates that Michigan feedlot operators can compete over the longer run with Kansas if cattle prices are in equilibrium.

LIMITATIONS

There are several limitations of this analysis which limit its applicability to determine optimal production and marketing strategies and to forecast the evolution of the Michigan and U.S. fed beef cattle industry. Each limitation is related either to the use of a simplifying (set of) assumption(s) or to assumptions made pending future research efforts.

Several assumptions used in this analysis were selected either for simplicity or because further data was not available to the author at the time of analysis.

1. The assumption that all investment decisions are made simultaneously is appropriate for questions of long run industry health. Although, under the dynamic conditions currently facing the fed beef cattle industry, it may limit the analysis in two ways. This assumption may overstate current production cost used in decision making. It does not include asset fixity in investment, labor, or other resources currently existing on Michigan cattle farms that may sustain an otherwise unprofitable operation until conditions change which make reinvestment in the industry a rationale economic choice. If conditions do not change or change in an unfavorable manner in future years, however, this assumption may understate production costs over time since agricultural producers rarely have the opportunity to design a comprehensive operation at one point in time. This is equally true for both the livestock and crop enterprises.
2. The net value of manure to each system was positive, thereby reducing production costs for the crop enterprise. While the assumption that manure nutrient credits are accounted for through decreased fertilizer use is consistent with increasing environmental accountability and good management, most Michigan cattle producers do not fully account for manure nutrients. Crop production cost may therefore be underestimated.
3. Although the livestock and feed storage facility designs modeled in this dissertation

follow recommendations put forth by industry specialists, they may be more elaborate than is necessary under current and potentially forthcoming environmental legislation and to minimize the effect of climate on animal performance. Fed cattle production cost may thereby be overestimated.

4. The assumption that fed cattle producers marketing year round realize average annual feeder and fed cattle prices limits the results of the analysis to feedlot operators marketing to achieve a particular capacity utilization level and may not fully represent operators who weigh the tradeoffs between cattle prices and capacity utilization when making purchasing decisions. It is clear from the analysis that gross margin is strongly influenced by timing of marketing. Follow-up calls made to feedlot operators to more accurately define the marketing practices of Michigan feedlot operators verified continuous marketing as representative of Michigan feedlot marketing practices.

This analysis could be expanded in several areas to better represent net returns realized by Michigan fed cattle producers or to explore the affect of different production and marketing strategies on net return to the operation.

1. Feeding of cattle types other than those defined as frame size 6 beef steers was not explored. The applicability of the analysis would be enriched by the consideration of heifers and animals of different frame sizes, particularly holsteins.

2. The definition of the operation as a feedlot enterprise plus that acreage required to provide the corn and corn silage used to feed the livestock limits the range of production strategies considered. For example, since large economies of size are available in the crop enterprise, a smaller feedlot size would be more economical, particularly in light of its relatively low cattle facility investment cost, if all feed for the livestock enterprise were purchased or the crop enterprise was enlarged to more fully realize economies of size. Additional corn could be sold as a cash crop. Byproduct feeds are widely utilized on

feedlots visited. Nutrient and price characteristics of these feeds, as well as potential for expansion in their availability to the feedlot enterprise is currently underexplored.

3. Because the study was limited to strong managers with adequate balance sheets, risk considerations were not explicitly incorporated into the analysis. If feedlot owners/operators are, on average, risk averse, the variability of returns to cattle feeding relative to alternative uses of available resources will influence the relative attractiveness of fed cattle production as an investment and land use choice.

FUTURE RESEARCH

Promising avenues for future research are easily identified from the limitations noted for this analysis.

1. New investment decisions made under conditions of different existing facilities and equipment would more accurately predict the evolutionary change for the fed cattle industry in Michigan.

2. Additional information should be elicited from Michigan cattlemen, beef cattle extension specialists, and industry representatives about the use of manure nutrients in the crop enterprise.

3. The effect of facilities on animal performance where the climate is unfavorable has been widely researched. Additional work is needed in assessing the economic viability of different flooring and manure systems and types of shelter. The environmental benefits of manure containment should also be estimated and included.

4. Gross margin is strongly influenced by timing of marketing. Alternative marketing strategies including weight of purchase and sale, and particularly, timing of cattle purchase and sale, should be further explored.

5. Feeding of cattle types other than those defined as frame size 6 beef steers, particularly

beef heifers and holsteins, should be explored.

6. The definition of the operation including a feedlot enterprise should be expanded to include operations with no additional land other than which is required for facilities and with additional land than is required to feed the livestock.

7. The use of alternative resources such as byproduct feeds should be explored to identify their economic worthiness for fed beef cattle production.

8. The influence of risk on the attractiveness of fed cattle production for Michigan producers, as well as those in other regions of the U.S., may be significant. This may be particularly true for the larger Central and Southern Plains feedlots whose investment is largely capital tied up in cattle. The inclusion of risk into the analysis would solidify the result that the U.S. beef industry is not in equilibrium and help predict its evolutionary path.

APPENDICES

APPENDIX 1 BEEF CATTLE FEEDLOT INTERVIEW QUESTIONS

I. Farm operator

II. Description of farm enterprises -- feedlot enterprise

A. Facilities

1. Description of facilities (including one time capacity, housing type and seasonal limitations, watering system used, feeding system, and facilities for the treatment and/or housing of sick or incoming cattle)
2. Operator impression of how current feedlot facilities differ from "ideal" facilities
3. Recent plan for or actual change in type or size of facilities. Description of what conditions would or have influence(d) a change in size
4. Yardage per head per day (facility charges including cost of facilities (depreciation and interest) and cost of operating (electricity, maintenance, and repair)

B. Animal description

1. Types of animals fed (frame size, weight when placed on feed, age, sex, weight when sold, and quality and yield grade and dressing percentage realized).
2. Decision rules used for type and weight of cattle fed (strategies for feeder cattle purchase and factors influencing these strategies)

C. Characteristics of operation and factors influencing these characteristics

1. Animal numbers (turnover per year, fill rate)
2. Seasonality of feeder cattle purchases and fed cattle sales
3. Animal performance (Average daily gain, feed efficiency, morbidity, mortality)
4. Production practices (number of full-time equivalent employees for the livestock enterprise and for the overall operation and time required for various operating and managerial tasks (purchasing supplies, feed, supplement, and feeder cattle, selling fed cattle, enterprise and whole farm record keeping and analysis, tax preparation, and securing financing)
5. Purchase of cattle (purchasing method (self, order buyer, cooperative, other), use of break-even calculations, information sources, location from which cattle are purchased)
6. Sale of cattle (sale method (terminal or auction market, other intermediary; direct versus grade and yield), decision rules for choice of market outlet and for timing of sale, how finishing weight varies with market opportunities, use of risk reduction techniques (forward contracts, futures contracts, other), and participation in marketing groups)
7. Financing availability and cost
8. Purchase and sale prices (consistency between purchase and sale price, given feed prices), estimation of long-run (expected) price relationships where the prices of corn and of feeder cattle are the key prices in the system
   a. Estimation of short and intermediate run feeder cattle prices (for well defined type, weight, time of year, and market) including expectation of the price of corn
   b. Estimation of short and intermediate run feeder and fed cattle prices for a Michigan farmer implied by grain and supplement prices. Estimation of basis relationships between base point and prices paid and received by Michigan feeders (basis relationships defined in terms of well defined feeder types and times of year)
9. Transportation/marketing costs for feeder and for fed cattle (charges per unit, commissions, timeliness,shrink)

10. Medical practices (death loss, mortality, morbidity (frequency, decision rules regarding treatment, cost of treatment and chute charges, duration of treatment, how the frequency of morbidity or mortality varies by type and weight of animal purchased, seasonal affect, veterinary costs))
11. Processing practices (use and price of growth stimulants, ionophores, frequency, chute charges, and labor involved)
12. Labor use (overall per head and per head capacity and by task (including monitoring of cattle)

D. Manure
1. Manure facilities, storage system(s)
2. Type, source, and amount of bedding used
3. Production type and volume as manure comes out of storage (includes manure analysis values, effect of ration)
4. Description of manure handling and application practices (machinery and labor used, number of times manure is applied per year, application windows, restrictions on application times and techniques). Size (capacity) of manure spreader(s), honey wagon(s), and manure pit pump and agitator
5. Description of factors affecting location of manure application (replacement method, soil test, guess, field closest to barn)
6. Estimation of the value of manure as a fertilizer versus costs in equipment and man hours to store, haul, and spread
7. How actual or anticipated environmental regulations have changed manure management practices

E. Ration and feeding
1. Rations (number of rations used, actual rations used, how ration is influenced by crop enterprises and yields, level of crude protein ration is balanced for)
2. Feed disappearance
3. Feeding practices (number of times per day)
4. Labor and machinery requirements for feeding cattle (including operating, maintenance, and repair costs)
5. Purchased feeds (type and volume used, availability of byproduct and other feeds, decision rules on type and volume)
6. Discount in feed cost arising from growing feed on farm (premium obtained on corn by selling it through the livestock)
7. Feed storage (type, capacity, cost (depreciation, maintenance, and repair))

III. Descriptions of crop enterprises
   A. Acreage
      1. Tillable
      2. Pasture
         a. improved
         b. unimproved
   B. Description of crops grown (for cash sale and for feed, number of acres, average and other percentile yields for grain, hay, and silage ,and description of animal performance per acre for grazed pasture)
   C. Crop rotations in use/under consideration and rules which govern corn variety choice and which corn is cut for grain versus silage
   D. Soils
      1. Type(s) (texture, natural drainage, topography, restrictions on land use)
      2. Tiling and man made drainage
   E. Climatic Influences
      1. Moisture (median by month)
      2. Average minimum and maximum temperatures by month
      3. 80th percentile last frost in spring, 20th percentile first frost in fall
      4. Weather conditions which have particular bearing on cattle performance
      5. Weather conditions which have particular bearing on crop production
      6. Weather conditions which have a particular bearing on field operations (e.g. weed control as a function of weather sequence)
      7. Weather conditions which have a particular bearing on manure disposal
   F. Crop budgets (in context of crop sequence; including set-aside acres and field operation methods). Cost per acre by crop
   G. Field operations
      1. Timing of field operations
      2. Machinery and equipment used (type, cost (depreciation, operating, maintenance, and repair costs), labor use, associated building use)
   H. Processing and storage considerations (activities as based on type of crop (high moisture versus dry, silage storage) and associated costs)

IV. Evaluate possibilities for improvements in the representative farm
   A. Adoption of superior technologies, impacts of emerging technologies
   B. Adoption of improved information and decision support systems (including better rules of thumb, monitoring, and control)
   C. Research needs to facilitate improvements that would increase comparative advantage of Michigan farms and which have a reasonable probability of being achieved

APPENDIX 2 BALANCING NUTRIENT AVAILABILITY WITH NUTRIENT NEED - A CASE EXAMPLE

An example of balancing nutrient availability with nutrient need is shown using the procedure described in Chapter 3. This Appendix shows the steps which are otherwise accomplished through the use of a spreadsheet. A 1200 hd capacity feedlot with an 80% average fill rate, resulting in a one time occupancy of 960 animals is used. A concentrated diet is fed. In the case feedlot, animals enter the system at 650 lb and exit at 1150 lb. For simplicity, average daily gain is assumed to be the same over the entire period in the feedlot so the average weight of all steers in the feedlot for the year is 900 lb. The quantity of nutrients provided from the manure in this example is calculated using values from Midwest Plan Service (1985), although more specific estimates are utilized in this dissertation to calculate values reported in Chapter 4.

The total nutrients provided by manure from the above case farm are 107,520 lb of nitrogen (N), 78,720 lb of phosphate (P_2O_5), and 92,160 lb of potash (K_2O) as calculated using Midwest Plan Service guidelines. These values are calculated by taking total nutrient production per head per day times the number of animal days (average occupancy times number of days in the year) in the system (Equation A2.1). In this example, total manure production per day for a 900 lb animal is taken times 350,400 (total animal days). The total manure production for the system is expressed as 18,921,600 lb per yr, 315,360 ft^3 per yr, or 2,361,696 gallons per yr.

*(A2.1) Total nutrients = nutrient provided (lb per year per animal) * average number of animals*

The nutrients required in the crop enterprise are then calculated. Soil type in this example is consistent with average yields of 130 bu per acre of corn or 18.75 ton per acre of corn silage. The appropriate nutrient requirements for crop production are found in Christenson et al.

(1992). They are 117 lb N, 45.5 lb P_2O_5, and 35.1 lb K_2O per acre for corn and 176.25 lb N, 67.5 lb P_2O_5, and 146.25 lb K_2O per acre for corn silage.

In order to calculate total nutrient requirements for the crop enterprises, it is necessary to determine the number of acres of corn and of corn silage necessary to support the cattle fed. In this case, 664 acres of corn and 129.28 acres of corn silage are required to support the corn and corn silage needs of the 1200 head feedlot. While the animal diet requirements have determined the crop acreage, the associated animal manure output will provide an input to these crop enterprises in the form of fertilizer. The purpose of the remainder of this section is to work through the step by step procedure necessary to define this balance. Due to the relative complexity of nitrogen balancing, nitrogen will be used as the balancing nutrient in this example. In general, the system will be balanced using the least limiting nutrient to maximize use of manure nutrients and to reduce environmental pressures. The nutrient on which each system was balanced will be indicated along with the results of said balance in Chapter 4.

The first step is to calculate nutrient availability in the manure. The nutrients provided per 1000 gallons unit of manure will depend on the system (Midwest Plan Service, 1985). This system has a liquid pit which stores manure from the entire 1200 capacity feedlot. Table A2.1 shows the available nutrients per 1000 gallons of manure stored in an anaerobic liquid system.

Table A2.1 Nutrient availability of manure stored anaerobically in a liquid form

Composition	pound per 1000 gallon unit of manure
Total Nitrogen	40
Ammonium Nitrogen	24
Nitrate Nitrogen	0
P_2O_5	27
K_2O	34

If the system is balancing on nitrogen, as in this example, the second step is to calculate nitrogen available to the plant per 1000 gallon unit of manure applied[91]. This calculation consists of calculating three values:

(1) the amount of organic manure available is calculated as:

$$(A2.2)\quad \textit{total lb N} - (\textit{ammonium N (lb)} + \textit{nitrate N (lb)})$$

In this example:

$$\textit{Organic manure (per 1000 gal unit)} = 40\ \textit{lb} - (24\ \textit{lb} + 0\ \textit{lb}) = 16\ \textit{lb}$$

(2) the amount of this total organic nitrogen which is released in the first year is calculated as:

$$(A2.3)\quad \textit{Organic N available this year (per 1000 gal unit)} = \textit{Organic N} \times \textit{mineralization factor}$$

In this example:

$$\textit{Organic N available this year (per 1000 gallon unit)} = 16\ \textit{lb} * 0.3 = 4.8\ \textit{lb}$$

[91] For simplicity, discussion of the source of nutrient losses associated with the storage, handling, and application of manure is ignored in this example, but are incorporated in the analysis and results presented both in this example and in Chapter 4.

(3) The amount of plant available nitrogen in the manure is calculated (depending on application technique employed) as:

(a) If incorporated:

(*A2.4*) *Plant available N = available organic N + ammonium N + nitrate N =*

In this example:

Plant available N (per 1000 *gallon unit)* = 4.8 *lb* + 24 *lb* + 0 *lb* = 28.8 *lb*

(b) If surface application:

(A2.5) Plant avail. N (per* 1000 *gal unit) + avail. organic N + (ammonium N * 0.66) + nitrate N

In this example:

Plant available N (per 1000 *gallon unit)* = 4.8 *lb* + (24 *lb* * 0.66) + 0 = 20.8 *lb*

The third step is to adjust the nitrogen fertilizer recommendation to account for residual N from manure applied in the previous 3 years. In this study, since it is assumed that the operation is in steady state equilibrium, nitrogen made available from manure applied in each of the last three years will be added with the assumption that both quantity and quality is the same as that applied this year. The additional N released is calculated as shown in equation A2.6

This amount will be added to available organic nitrogen calculated to calculate total nitrogen available in the manure. In this example:

$(A2.6)$ $\textit{Total organic N avail. (per 1000 gal unit)} = ((0.3 + 0.5625) * 16\ lb) = 9.0\ lb$

The amount of plant available N in manure is recalculated with this new value of available organic nitrogen.

(a) If incorporated:

$$(A2.7)\quad \textit{Plant available N} = \textit{available organic N} + \textit{ammonium N} + \textit{nitrate N}$$

In this example:

$$\textit{Plant available N (per 1000 gallon unit)} = 9.0\ lb + 24\ lb + 0\ lb = 33.0\ lb$$

(b) If surface application:

$$(A2.8)\quad \textit{Plant avail. N (per 1000 gal unit)} + \textit{avail. organic N} + (\textit{ammonium N} * 0.66) + \textit{nitrate N}$$

In this example:

$$\textit{Plant available N (per 1000 gallon unit)} = 9.0\ lb + (24\ lb * 0.66) + 0 = 25.0\ lb$$

The fourth step is to calculate the nutrient needs of the crop. Nutrient needs of the crop are based on replacement values (to replace those nutrients utilized, but not returned, by the previous crop) found in Christenson et al. (1992).

Table A2.2 Nutrient requirements of corn and corn silage

	Corn	Corn Silage
Expected yield per acre	130 bu	18.75 ton
Nitrogen required per acre (lb)	175	142
P_2O_5 required per acre (lb)	72	51
K_2O required per acre (lb)	120	135

If manure application is made to meet the nitrogen needs of the crop:

$$\textit{total N required (lb)} = (175\ lb/acre\ *\ 663.75\ acre\ corn) + (142.07\ lb/acre\ *\ 129.28\ acre\ corn\ silage) = 134{,}523\ lb$$

The number of gallons of manure necessary to satisfy this requirement can be calculated as:

$$(A2.9)\qquad \left[\frac{N\ requirement/acre\ corn}{N\ available/1000\ gal\ unit} * (acres\ corn)\right] + \left[\frac{N\ requirement/acre\ corn\ silage}{N\ available/1000\ gal\ unit} * (acres\ corn\ silage)\right]$$

In this example:

(a) If incorporated:

$$Manure\ needed\ (gallons) = \left[\frac{175\ lb}{.033\ lb\ per\ gallon\ unit} * 664\ acres\right] + \left[\frac{142\ lb}{.033\ lb\ per\ gallon\ unit} * 129\ acres\right] = 4{,}075{,}072$$

(b) If surface applied:

$$\textit{Manure needed (gallons)} = \left[\frac{175\ lb}{.025\ lb\ per\ gal.\ unit} * 664\ acres\right] + \left[\frac{142\ lb}{.025\ lb\ per\ gal.\ unit} * 129\ acres\right] = 5{,}380{,}560$$

Manure application is increasingly limited by phosphorous application limits. The 1990 Right to Farm Bill limits phosphorous application to that removed by the crop if soil phosphorous levels exceed 150 lb/acre. If manure application is made to meet the P_2O_5 needs of the crop, gallons of manure required are calculated as:

$$\textit{Manure needed (gallons)} = \left[\frac{72\ lb}{27\ lb\ per\ 1000\ gallon\ unit} * 664\ acres\right] + \left[\frac{51\ lb}{27\ lb\ per\ 1000\ gallon\ unit} * 129\ acres\right] = 2{,}016{,}552$$

Annual manure application is rarely based on the amount of K_2O required (cite).

The fifth step is to calculate additional fertilizer requirements for the crop. Additional N required is calculated as follows:

$$(A2.10)\quad \textit{Additional N required} = \textit{N requirement} - \textit{lb N applied}$$

Where:

$$\textit{applied N (lb)} = (1000\ \textit{gallon units manure applied/acre} * \textit{lb available N per } 1000\ \textit{gallon unit})$$

The final step is to calculate the additional land necessary to apply the remainder of the manure produced, which provides nitrogen or phosphorous which exceeds that needed for crop replacement. In this dissertation, the assumption is made that land is available under these circumstances and manure can be disposed by the operator at the cost of disposal.

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