A SIMULATION MODEL FOR EXAMINING PROFIT VOLATILITY IN THE CATTLE FEEDING INDUSTRY

By

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Bachelor of Science

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Canyon, Texas

1986

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1988

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ACKNOWLEDGMENTS

I would like to thank all the people who have encouraged me in my academic experience. Thanks to the instructors and administrators in the Department of Agricultural Economics at Oklahoma State University for their part in what I feel is an excellent education. I would like to thank my major advisor, Dr. James N. Trapp, for his continuing help, understanding, and support throughout my Master's program. Special thanks are due my committee members: Dr. Francis M. Epplin and Dr. Joe E. Williams for their advice and help throughout the program. My deepest appreciation goes to my family for their continued support, encouragement and understanding.

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CHAPTER I

THE RESEARCH PROBLEM

Cattle feeding is an enterprise in which net returns tend to be relatively volatile and small. The competitive nature of cattle feeding tends to drive average profits very close to break-even. Profit volatility arises from the fact that industry participants are faced not only with unpredictable physical performance of feedlot cattle, but also with price uncertainty. Price uncertainty exists for both input prices and output prices. All these factors combine to make cattle feeding a risky business.

Theory indicates there is generally a direct relationship between the level of exposure to risk and the potential profits to the enterprise. The higher the risk, the higher the average expected return. Effective management requires that exposure to risk be controlled and maintained within acceptable bounds. When the potential returns do not justify the level of risk exposure, the economic viability of the firm is jeopardized. For the cattle feeding industry to attract and maintain investment, volatility in net returns must be controlled at acceptable levels relative to the profit potential.

Economics tends to label volatility as bad, arguing that it causes unnecessary adjustments. These adjustments involve moving resources out of production and decreasing supply. For example, many firms can not cope with excessive risk and must cease operation or reduce their size. Alternatively, volatility creates the need for insurance, in the form of buffer stocks or cash reserves. Resources devoted to these reserves generate no economic utility except to sustain the firm through periods of financial hardship. Specifically, cattle feeders have been forced to have ample risk capital, referred to as operating margins, available in times of low net returns. Through such reserves, short-run adjustments are avoided, but the economic cost of volatility is not avoided.

Volatility in cattle feeding net returns has also made financing cattle on feed difficult, as well as costly. Lenders are reluctant to venture into such a volatile industry where the risks often exceed the returns. Thus, the cost of doing business in the cattle feeding industry increases with exposure to risk.

Holthausen (1979) concluded that the existence of opportunities to transfer price risk will generally induce a firm to produce greater output than it otherwise would. This risk averse behavior is indicative of a need for improved risk management techniques. Holthausen (1979) referred to forward contracting as a method of shifting price risk. A related measure would be the use of the futures market in hedging against adverse price fluctuations. Of course, an even better alternative would be to find production and marketing systems that reduce or eliminate risk, versus just shifting risk to others more capable of managing it.

The Problem Statement

According to J. Bruce Bullock (1986), uncertainty exists because the decision maker is unable to determine with certainty the outcome that will be realized from the action being initiated. (Bullock, 1986) Cattle feeders face uncertainty because of uncertain biological and economic factors which combine to determine net returns. The ability of the decision maker to determine the outcome of each of these factors, let alone their combined effect, is limited.

Cattle feeding may also be considered a risky business, with risk being defined as the probability that the outcome of the selected action will fall in the subset of possible outcomes defined as undesirable by the decision maker (Bullock, 1986). The risk associated with cattle feeding net returns is substantial. The high volatility of profits coupled with the relatively low net returns makes the probability of economic loss greater for cattle feeders than for investors in relatively less volatile enterprises, such as certificates of deposit or savings bonds.

Even though net return volatility is apparent in the cattle feeding industry, there is little previous study describing and documenting the nature of profit volatility in the industry. Most of the previous studies of profit volatility deal with highly aggregated industry data. For example, the United States Department of Agriculture reports industry average net returns. However, little attention has been given to individual lots of cattle and the components forming net return figures. Use of aggregate data to quantify risk would appear to be a questionable procedure.

Research involving the analysis of net return volatility in the cattle feeding industry has primarily dealt with price risk. Hedging and marketing strategies developed to help manage erratic price behavior have virtually ignored the existence of physical volatility. Furthermore, these studies tend to use secondary aggregate data such as average prices received, average cost of gain, etc., which likely misrepresent the individual pen volatilities. Perhaps the most plausible explanation of this shortcoming stems from a limited supply of recorded data available at the firm (pen) level for analyzing the volatility involved in beef production.

Purpose of the Study

The purpose of this study is to develop a better understanding of the sources of profit volatility in the cattle feeding industry at the micro level and to utilize this knowledge to develop methods for coping with uncertainty and managing associated risk. Specifically, the three primary objectives are:

1. To determine the sources of the volatility seen in cattle feeding net returns at the pen level.
2. To determine how these sources of volatility are related.
3. To examine ways of controlling the volatility seen in cattle feeding net returns.

Procedure

Records for individual lots of cattle were utilized in this study. The data were used to develop a simulation program to analyze both the physical and price volatility forming the components of net returns to cattle feeding.

To describe the relationships between the variables obtained from the data set, several regression equations were estimated describing the basic structural relations between key physical and economic factors determining cattle feeding profits. These equations were made stochastic with the addition of a random variable. The magnitude of these random variables was determined from the error terms of the estimated structural equations or directly from the collected data. The equations forming the components of cattle feeding net returns were then stochastically simulated using a microcomputer spreadsheet program. The resulting mean and variance estimates were compared to those from the original data set to determine the validity of the model. Sensitivity tests were then conducted with the model to determine the relative importance of various sources of profit volatility. Finally, ways of controlling these sources of volatility were analyzed in an effort to determine strategies for reducing the risk faced by the cattle feeding industry.

CHAPTER II

RELATED LITERATURE AND PREVIOUS STUDIES

Risk exists in all phases of agricultural production. Much of the economic literature regarding producer decisionmaking has attempted to explore the concept of risk. However, controversy exists as to the definition of risk and its relationship to uncertainty.

The literature reviewed in this study proceeded in three steps. First, literature was reviewed that examined concepts of risk, and alternative definitions of risk. An attempt was made to categorize the types of risk faced by cattle feeders in hopes of finding better ways of describing and managing this risk. Secondly, procedures for stochastic simulation modelling were examined for their potential usefulness in analyzing the cattle feeding industry. Lastly, earlier studies of feedlot profit volatility were reviewed.

Concepts of Risk and Uncertainty

Bullock (1986) contends that the failure to distinguish between the terms risk and uncertainty is a flaw in much of the economic literature. The interchangeable use of these words has resulted in some inappropriate terms like "risky markets." Bullock submits that there are no risky markets, only risky decisions involved in operating in markets with uncertain prices. Thus, risk exists because of the decision maker's inability to predict future outcomes with perfect certainty.

Uncertainty exists because 1) there is more than one possible outcome associated with an action, 2) the decision maker does not have complete control of the process that determines the outcome of a particular action, and 3) each of the possible outcomes has some non-zero probability of occurring (Bullock, 1986). Decision makers in the cattle feeding industry are faced with much uncertainty for all three of these reasons. Numerous uncontrollable factors enter into the production process which can alter the outcome of the actions taken by the cattle feeder. Among the most obvious factors are market prices. Feeder cattle prices, slaughter cattle prices, and feed prices are all determined in their respective markets. Even though producers may have a vast knowledge concerning the characteristics of these markets, there still exists uncertainty because this knowledge is not perfect. Decisions are based on the information available at the time the decision is made. Because the cattle feeding production process takes place through time, market prices at the end of the production period may differ from those expected by the producer at the time his initial production decision was made.

Biological or technical factors may also alter the outcome of the actions taken by cattle feeders. The cattle selected may exhibit poorer performance than the producer expected at the time the production process was initiated. Reasons for this range from weather conditions to individual physical characteristics of the cattle. Because cattle feeders are unable to accurately predict these factors, uncertainty exists.

Like Bullock, Knight (1921) distinguished between risk and uncertainty. He defined a decision under risk as one in which the probability of occurrence can be assigned to states of nature or outcomes. Alternatively, a decision is made under uncertainty, when the decision maker is unable to assign probabilities to the possible outcomes. Since decision makers can typically assign subjective probabilities, even in situations with little or no prior information, Knight's distinction is considered unnecessary. Risk and uncertainty, by these definitions, are synonymous. Therefore, Bullock's definition of uncertainty is believed to provide a more suitable framework for the analysis of this study.

Risk is typically defined in agricultural economics literature in one of two ways. The first definition, and the most common, defines risk as variability, where variability is measured by variance or standard deviation. In this context, risk is increased by a change in the distribution of the random outcome which keeps the mean constant and moves the probability away from the center to the tails of the distribution (Walker and Nelson, 1977). Secondly, risk is defined as "chance of loss," or the probability that net income will fail to meet a specified disaster level of income.

Defining risk as variability is useful for analyzing the cattle feeding industry. Profit volatility, as well as variability of economic and biological factors forming the cost and return components of profit, can be measured in terms of variance and standard deviation. Industry data indicate that tremendous "risk" exist in cattle feeding for both of the concepts of risk given above. Average net returns and their associated variance and standard deviations for two different data periods are reported in Table I. A standard deviation of $53 to $61 is indicative of substantial variability and substantial risk, where risk is defined as the chance of a loss. The latter concept of risk is especially the case with relatively low average net returns. However, even with highly profitable net returns of $56.32, a standard deviation that approximately equals the mean substantiates the contention that feeding cattle is a risky business.

TABLE I

EXAMPLES OF FEEDLOT PROFIT VOLATILITY

PRIVATE INDUSTRY DATA (9/78 - 7/85)[1]

Mean	Variance	Standard Deviation
-$6.75	3724	$61.02

PRIVATE INDUSTRY DATA (5/86 - 4/87)[2]

Mean	Variance	Standard Deviation
$56.32	2798	$52.90

[1]Trapp and Webb, 1986
[2]Individual pen data collected in this study.

[1] Trapp and Webb. 1986.

[2] Individual pen data collected in this study.

Types of Risk

Boehlje and Eidman (1984) divide the risks faced by producers into two broad types, business and financial. Business risk is defined as the inherent uncertainty in the firm, independent of the way it is financed. The major sources of business risk are price and production risk. Price or market risk is the result of factors that lead to unpredictable shifts in supply and demand of inputs and products. Seasonal, cyclical, and trendular patterns of prices are predictable to some extent. But the inability to predict prices with a high degree of accuracy is the source of price risk. In the cattle feeding industry, price or market variation includes volatility in feeder cattle prices, slaughter cattle prices, and feed prices.

Production risk, the second source of business risk, is the result of factors affecting the production level that are beyond producer control. They include weather, changes in governmental policies, and, to some extent, disease and insect damage (Boehlje and Eidman, 1984). In the case of feedlots, production risk is reflected in volatility in such variables as feed conversion efficiency, rate of gain, and death loss percentage.

A third type of risk is financial risk. It is defined as the added variability of net returns to equity that result from the financial obligation associated with debt financing (Boehlje and Eidman, 1984). Financial risk also includes uncertain loan availability and fluctuating interest rates, which reflect the price of debt capital. It deals primarily with the firm's ability to meet long-term claims and the increasing likelihood of that inability as leverage increases (Barry, Hopkin and Baker, 1979). Leverage, which is measured by the ratio of debt to equity, multiplies the potential financial return or loss that will be generated with different production and price levels.

Managing Risk

Traditional Agricultural Economics literature contains very little information about the production, marketing, and financial risks of cattle feeding. This is especially true for micro level data. Furthermore, no study appears to have been made of the interaction between these three sources of risk. They may act independently or may combine for compounding or offsetting effects. It is hypothesized here that utilizing ways of controlling the volatility of some factors can help in controlling other factors, thus decreasing the overall volatility associated with cattle feeding net returns both directly and indirectly. Some of these control mechanisms may include using the futures market to hedge against input and output price fluctuations, purchasing specific types of cattle, controlling the length of time the cattle remain on feed by adjusting placement weights, or changing the level of equity used to finance the operation. Also, it is hypothesized that seasonality has a dramatic effect on biological factors concerning feedlot cattle performance and thus may have an impact on risk.

Modelling Risk

Simulation is an analytical technique that models the reality of a system of relationships. It is a flexible technique that can incorporate stochastic variables within a system of equations. Thus, simulation is an appropriate tool for analyzing net returns realized from feeding cattle. The first step in constructing a computer simulation model is to develop a flow chart of the structure of the system to be modeled. Equations must then be used to represent this structure and a computer program developed to solve the equations.

Six ordinary least squares regression equations were estimated for incorporation into the simulation model developed here. The implicit error term associated with the dependent variable predictions of each of those equations was added to each equation, making the model stochastic. Pindyck and Rubinfeld (1981) discuss the rationale for stochastic simulation of OLS estimated systems. The procedures they outline were the ones used in developing the basic structural model used in this study.

Naylor, et al. (1986), in "Computer Simulation Techniques," discuss the concept of random number generation. Also, guidelines for making decisions concerning the distribution of each random error term were provided by Naylor, et al. Because the variables being analyzed in the study were found to be correlated, a procedure was incorporated into the simulation model which correlates the stochastic error terms being generated. The publication "A Procedure For Correlating Events in Farm Firm Simulation Models," by Clements, Mapp and Eidmann (1971), provided the methodological framework for correlating the randomly generated error terms. Finally, a forthcoming publication by Trapp provided the necessary modelling techniques for incorporating the above mentioned elements of stochastic simulation into a LOTUS 1-2-3 Spreadsheet Program. Techniques for calculating mean and variance estimates within a spreadsheet program are also discussed by Trapp.

Previous Studies of Feedlot Profit Volatility

Purcell and Ginn (1987) developed a conceptual framework to facilitate an examination of the implications of exposure to price risk in the livestock industry. They contend that the cost of the product is inflated due to needless exposure to price risk. The availability of investment funds is affected because funds will not be offered by the potential investor unless there is a return commensurate with the risk of the investment. The cost of doing business in a risky arena will be greater because it will cost more to attract and keep the investment funds needed to run a business.

In addition to having an impact on the cost of getting and keeping investment capital, there is increasing evidence that exposure to price risk inflates operating margins. Cattle feeders try to buy feeder cattle so that, given their expectation for the price of fed cattle coming out of the lot, some gross margin or profit margin will be realized. In an analysis by Ginn (1986), the feeding margins for a western Kansas custom feeding program were estimated across the period December 1978 - December 1987. The average margin for the time period was about -$7 per head. The variance was 4624 and the standard deviation was $68, which means that two-thirds of the future profit margin observations would be expected to fall between -$75 and +$61 per head. Ginn contends that it is difficult to visualize a business operating successfully when exposed to that level of risk.

Figure 1 provides a schematic picture of the highly variable pattern of average feeding profits for Southern Plains cattle feeding operations. There is a cost involved in being able to absorb the periodic losses from price decreases and still be able to operate the feedlot enterprise (Purcell and Ginn, 1987). This cost is partially passed back to the producer of feeder cattle in the short run in the form of lower bid prices on feeder cattle. In a longer run context, this results in fewer cattle and reduced per capita supplies of beef.

Ginn (1986) contends that the variation in profit margins evolves from the derived demand for feeder cattle. Cattle feeders base their bids for feeder cattle on such factors as recent prices of slaughter cattle and the recent profit experiences of cattle coming off feed. Periods of profitability are usually associated with higher slaughter cattle prices. These profits can increase the

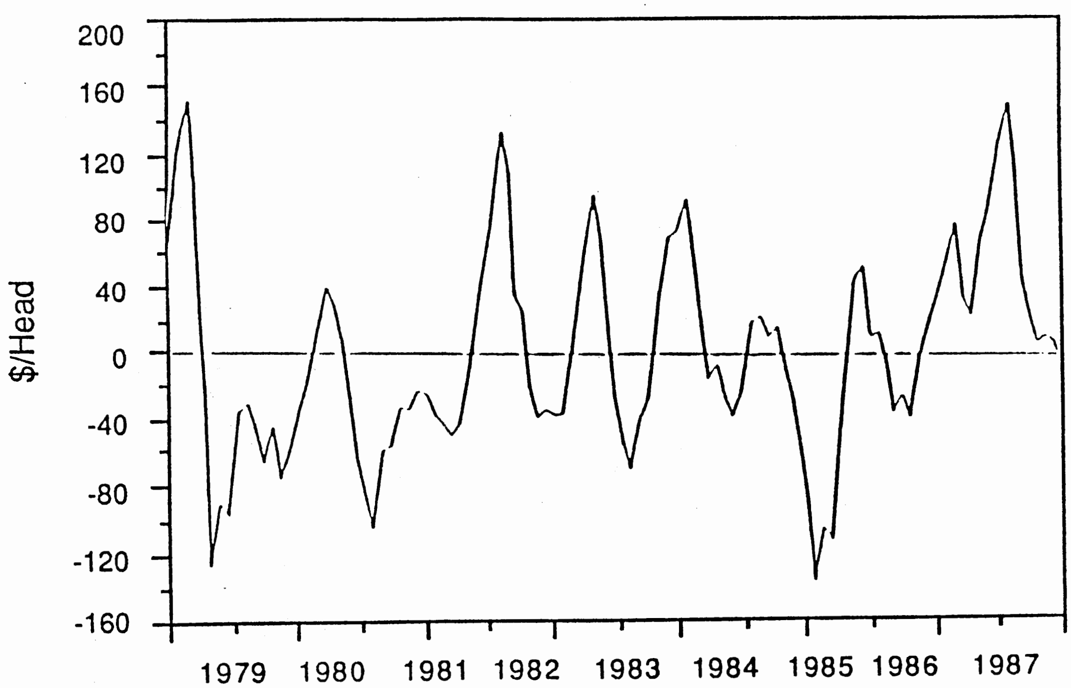

Figure 1. Profitability of Southern Plains Cattle Feeding, 1979-1987 (Ginn, 1986)

demand for feeder cattle and raise their prices. However, by the time these cattle are sold, the realization that feeder cattle purchased some months before were priced too high comes too late to allow losses to be avoided. Cattle feeding profitability is thus highly variable, partially because of the tendency to bid up feeder cattle prices and increase placements when slaughter cattle prices are high. This substantiates the assertion that the competitive nature of the cattle feeding industry tends to keep profits low, usually around the break-even point.

Ginn (1986) indicates that the variability in feeding margins is a measure of risk. The distribution of cattle feeding returns for the 1979 through 1987 period approximated a normal distribution (Figure 2). With no risk management in a constant program of placing and marketing cattle, the odds of making $50 per head were about the same as the odds of losing $50 per head throughout this time period.

To summarize the findings of Gin and Purcell (1987), it appears that feedlot profit volatility can be analyzed using variance or standard deviation measures. Since the volatility in key variables comprising cattle feeding cost and return figures can be similarly estimated, it seems that the most volatile factors causing profit volatility can be identified. Efforts can then be directed at the volatile factors to decrease the overall risk the cattle feeding industry faces.

In a study conducted by Trapp and Webb (1986), cattle feeding profit variance indicated by private versus public data were compared. The public data were obtained from the cattle feeding budgets published by the USDA and the private data were obtained from a feedlot consulting firm. The private firm data consisted of 82 months of average monthly prices, quantities and technical coefficients for approximately 110 feedyards. Since the public data assumed a given feeding system and a constant set of physical characteristics, the variation

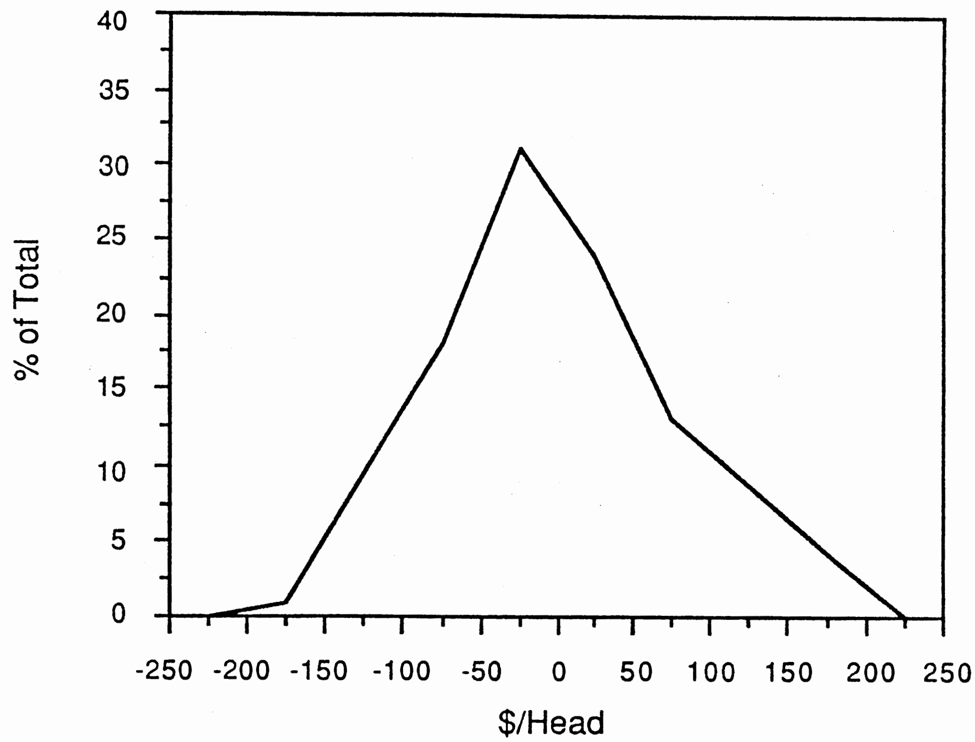

Figure 2. Frequency Distribution of Monthly Cattle Feeding Profitability, 1979-1987 (Ginn, 1986)

in net returns reflected in these budgets was subject to question. Production volatility, which along with price/market volatility contributes to profit variation, was ignored by the USDA. Trapp and Webb attempted to determine the appropriate volatility to inject into the technical/quantity coefficients of the USDA budgets to reflect the "actual" variance of net returns from production risk associated with cattle feeding.

Statistical tests were conducted to determine which of the means and variances reported by the USDA and the private consulting firm were significantly different. The means and variances of the price series used by the USDA and the industry series were statistically equal, except in the case of interest rates, where the USDA series was more volatile and had a lower average. Key physical parameter averages and their variances for the industry data were compared to the constant physical coefficients assumed by the USDA. In general, the industry data were found to be significantly different in magnitude than the USDA data. Specifically, the industry data indicated cattle were fed for shorter time periods, and gained less total weight than assumed by the USDA. The difference in total pounds gained was due to the industry placing cattle approximately 100 pounds heavier than the USDA assumed and slaughtering them only about 50 pounds heavier than the USDA assumed. Average daily gain estimates were greater for industry estimates than for USDA assumptions, but not significantly greater. Significant volatility was shown to exist in the private sector data for key physical parameters. However, physical volatility was not found to be as great as price/market volatility.

Surprisingly, the total profit variance reported by the two sources was found to be statistically equal. This can be attributed to several stabilizing interrelationships found in the private sector data between the components creating production and market volatility. The first stabilizing relationship found stems from the fact that cattle feeding revenues and costs are derived as products of price and quantity. The correlation found between these prices and quantities was negative in every case, except for interest rates and financed capital. Negative correlation between the components of a product reduces the variance of the product. Thus, in this case, the variance of the costs and revenues forming net profit is reduced. Secondly, stabilizing interaction was found because of positive correlation between total costs and total revenue for the industry data. This resulted in the variance of their difference, i.e. net returns, being reduced. Thus, while the industry data contained more sources of variation than the USDA data, the interrelationships found between production and marketing risk offset these additional sources of variation.

Conclusions and Implications

Trapp and Webb (1986) made use of highly aggregated industry data in their study of feedlot profit volatility. As in previous studies, (Ginn,1986), these data indicated that substantial volatility exists in cattle feeding net returns. However, the basis for this study stems from the questionable use of aggregated data. A follow-up to the Trapp and Webb study was incorporated into this research. It was hypothesized that the use of individual pen data from representative feedyards, rather than aggregate industry data, could help to identify major sources of volatility in cattle feeding profits. The volatility seen in the key economic and biological factors associated with individual pens of cattle was used as a measure of risk. The study was also utilized to determine the probability of certain outcomes under differing cattle feeding scenarios. The procedures for this analysis are discussed in Chapter III.

CHAPTER III

MODEL DEVELOPMENT

A simulation modeling approach was taken in this study. Simulation is an analytical technique that models the reality of a system of relationships. In agriculture, simulation analysis has been used to model many subjects, including plant and animal growth processes, growth and intergenerational transfers of the farm firm, risk and survival projects, supply and demand relationships, multi-objective decision processes, etc (Anderson, 1974).

Because few relationships are known with certainty in economic analysis, simulation is utilized as a flexible technique that can easily incorporate stochastic variables. Among the many attributes of a simulation model are:

1. it may be deterministic or stochastic;
2. it may involve single or multi-period events;
3. it may be programmed to maximize or minimize a linear or nonlinear objective function, search for an optimal solution, or be nonoptimizing;
4. it may represent part or all of a complex process; and
5. it may be behavioral or mathematical (Mapp and Helmers, 1984).

The steps in constructing a simulation model are:

1. model formulation,
2. synthesis,
3. verification/ validation, and
4. experimentation.

In the first stage, the problem is identified and research hypotheses are formulated. The model's structure is determined, including information flows, decision rules, feedback loops, and input-output requirements. Stochastic variables must be identified and incorporated for risk analysis. The model's output should be designed to yield the key measures needed for analytical analysis of the system's performance.

In the synthesis step, the model is specified in detail, including the stochastic variables, the choice of distributions, collection of data, examination of serial dependence, and estimation of covariance. The verification/validation step considers the model's technical accuracy and realistic portrayal of stochastic events. One common validity test is to compare the model's results with observed behavior. Finally, the experimentation stage consists of making simulations with the model over a range of values for the key variables.

Data Collection

Records of a private feedlot consulting firm were utilized to develop a micro level data set of the key variables forming net profit. Monthly pen closeout sheets for individual lots of cattle sold were recorded from four custom feedyards. The four lots were located in a geographic region spanning from the southern Texas Panhandle into southwestern Kansas. This area encompasses a large portion of the cattle feeding industry. Approximately ten closeout sheets per feedyard per month were recorded over the time period, ranging from May, 1986 through April, 1987. A total of 479 observations were collected, one less than the anticipated 480. The reason for this discrepancy is a lack of reported closeout sheets. Each feedyard did not necessarily report ten or more lots sold in every month. Whenever possible, a lack of data from one feedyard was compensated for by the addition of data from another in order to obtain 40 total observations per month. In one case this was not possible.

Table II shows a typical format of a pen closeout sheet. As the name implies, this sheet provides a summary of facts related to a specific pen of cattle at the time the lot is closed and the cattle are sold. More specifically, it includes price and technical coefficients. The price variables include feeder cattle price, slaughter cattle price, and feed price. Technical coefficients reported include placement weight, slaughter weight, feed conversion rate, number of days on feed, total pounds of gain, average daily gain, pounds of feed consumed, and death loss percentage. These variables are thus used to derive total revenue and total cost comprising net returns for each lot of cattle.

The closeout sheet data were entered into a microcomputer spreadsheet using the LOTUS 1-2-3 Spreadsheet Program. The following variables were recorded: the specific feedyard; the lot number used by the feedyard to identify each individual lot of cattle; the day, month, and year the cattle were placed on feed; the number of head placed on feed; the average weight of the cattle going into the feedyard (placement weight); the average price paid for the cattle (feeder price); the total cost of the lot of cattle; the day, month, and year the cattle were taken off feed to be slaughtered; the number of head sold; the total and average weight of the slaughter cattle; the total value of the lot of cattle; the associated feedlot charge; the total number of pounds gained while on feed; the total number of days the cattle were in the feedyard; the total amount of feed consumed; the total cost of the feed; the conversion rate (pounds of feed required per pound of gain); the percent dry matter of the feed, where dry matter is defined as pounds of feed less water content; the interest charge for the cattle; the interest charge for the feed; and net return per head. Care was taken in collecting the data to check for data entry errors. Numerous identities exist in

TABLE II

CLOSEOUT SHEET EXAMPLE

REVENUE	
(SLAUGHTER WEIGHT * SLAUGHTER PRICE)	
(1145 * .60)	$687.00
FEEDER COST	
(PLACEMENT WEIGHT * FEEDER PRICE)	
(739 * .59)	$436.00
COST OF GAIN[1]	
(FEED PRICE * POUNDS OF FEED)	
(.05 * 3520)	$176.00
(Assuming lot charges are incorporated into feed price)	
INTEREST ON CATTLE	
(FEEDER COST * INTEREST RATE * DAYS ON FEED/365 * % FINANCED)	
(436 * .11 * 164/365 * .75)	$ 16.00
INTEREST ON FEED	
(FEED COST * INTEREST RATE * DAYS ON FEED/365 * % FINANCED)	
(176 * .11 * 164/365 * .35)	$ 3.00
NET RETURN PER HEAD	
(REVENUE - FEEDER COST - COST OF GAIN - INTEREST ON CATTLE - INTEREST ON FEED)	
($687.00 - $436.00 - $176.00 - $16.00 - $3.00)	$ 56.00

[1]Pounds of Feed = Dependent on pounds gained and conversion rate (pounds of feed required per pound of gain).
Pounds Gained = Slaughter Weight - Placement Weight.
Average Daily Gain = Pounds Gained/Days on Feed.

the data that should hold if the data are entered correctly. For example, slaughter weight should equal placement weight plus pounds gained. These identities were programmed into the computer to conduct data entry error checks.

This data set was somewhat incomplete due to a lack of reported information in some of the above categories. One of the feedyards did not report feed cost separately from feedlot charges. Only one feedyard separated interest charges for cattle and feed, and two of the yards failed to report any interest charges. Although these pieces of information were missing, it was possible to use the available subsets of data to calculate mean and variance values for the variables analyzed in this study.

After entering the pen data into the spreadsheet, the total data set was used to calculate average per head values for selected variables. The variance and standard deviation for each variable was also computed (Table III).

Statistical Tests of the Data

An initial hypothesis of the study was that the data collected from the four feedlots could be considered to be from one population and thus could be combined. To test this hypothesis, Bartlett's Chi-square test for equality of variance (Fryer, 1966) and an F-test for equality of means (Fryer, 1966) were used. The computed Chi-square value was less than the tabular Chi-square value, at the 5% level of significance. Therefore, the hypothesis of equal variances among the four representative feedyard data sets could not be rejected. Failure to reject the hypothesis that the four feedyards had statistically equal variances led to the F-test to determine if the means among the four lots were equal. The hypothesis that all the means were equal was rejected at the 5% level of significance but could not be rejected at the 1% significance level. It

TABLE III

ESTIMATED MEAN, VARIANCE, AND STANDARD DEVIATION OF INDIVIDUAL PEN DATA VARIABLES

VARIABLE	MEAN	VARIANCE	STANDARD DEVIATION
Feeder Price (¢/lb)	$0.59	.00268	$0.0517
Slaughter Weight (lbs)	1146.15	6531.501	80.8177
Conversion Rate (lbs)	8.2957	0.5815	0.7625
Days on Feed (days)	137.68	1794.52	42.3617
Slaughter Price (¢/lb)	$0.6043	0.00158	$0.03982
Feed Price (¢/lb)	$0.0511	0.000011	$0.00345
Placement Weight (lbs)	728.578	11091.358	105.3155
Interest Rate ($)	$0.1202	0.000018	$0.00427
Average Industry Feed Price (¢/lb)	$0.0669	0.000015	$0.00387
Pounds of Gain (lbs)	419.4474	4163.6836	64.5266
Average Daily Gain (lbs)	3.2073	0.2650	0.51479
Pounds of Gain (lbs)	3397.3044	200473.284	447.7423
Death Loss Percentage(%)	.006920	.000116	.010791
Revenue ($)	$685.558	4112.4701	$64.1285
Feeder Cost ($)	$434.2895	3649.2758	$60.4092
Feed Cost ($)	$175.3796	645.5927	$25.4085
Interest on Cattle ($)	$16.4559	17.9341	$4.2348
Interest on Feed ($)	$3.3504	1.7890	$1.3375
Net Return ($)	$56.3189	2798.6474	$52.9022

was therefore concluded that the four individual sets of data could be combined into one data set for use in the study.

Further statistical analysis was made following the creation of the combined data set. The hypothesis that the variances of each set of forty monthly net returns were equal was tested using Bartlett's Chi-square test. The hypothesis could not be accepted at the 5% level of significance, indicating monthly variances among net returns were not equal. It was determined, through the use of an F-test, that the hypothesis of equal means among monthly net returns could not be accepted at the 5% level of significance either. This result indicated that the average net return per head was significantly different from month to month in the year from which the data was derived.

Table IV shows the mean and variance in net returns for the twelve months being analyzed. For this particular time period, average net returns ranged from a low of -$33.69 in June, 1986, to a high of $117.24 in April, 1987. The variance in net returns ranged from 391.87 in June, 1986, to 1573.84 in April, 1987. There seems to be a general tendency in both the net return mean and variance to increase from the lows in June, 1986 through September, 1986. They then begin to decline through January, 1987 before again increasing to the maximum values in April, 1987. The fact that there is only one year of data available makes it impossible to draw any definite conclusions concerning the effects of seasonality on cattle feeding net returns.

Model Structure

The simulation model of the cattle feeding process was constructed using a LOTUS 1-2-3 Spreadsheet Program on a microcomputer. The model is designed to portray the interconnected components which form net returns. Figure 3 is a graphical representation of the model's structure. Ordinary least

TABLE IV

MONTHLY NET RETURN MEAN AND VARIANCE

MONTH	MEAN	VARIANCE
May, 1986	-$12.43	538.62
June, 1986	-$33.69	391.87
July, 1986	$17.74	985.64
August, 1986	$56.34	1251.32
September, 1986	$97.38	866.44
October, 1986	$96.90	529.48
November, 1986	$84.80	1253.78
December, 1986	$61.76	1161.35
January, 1987	$42.28	702.82
February, 1987	$67.14	399.37
March, 1987	$82.38	748.69
April, 1987	$117.24	1573.84

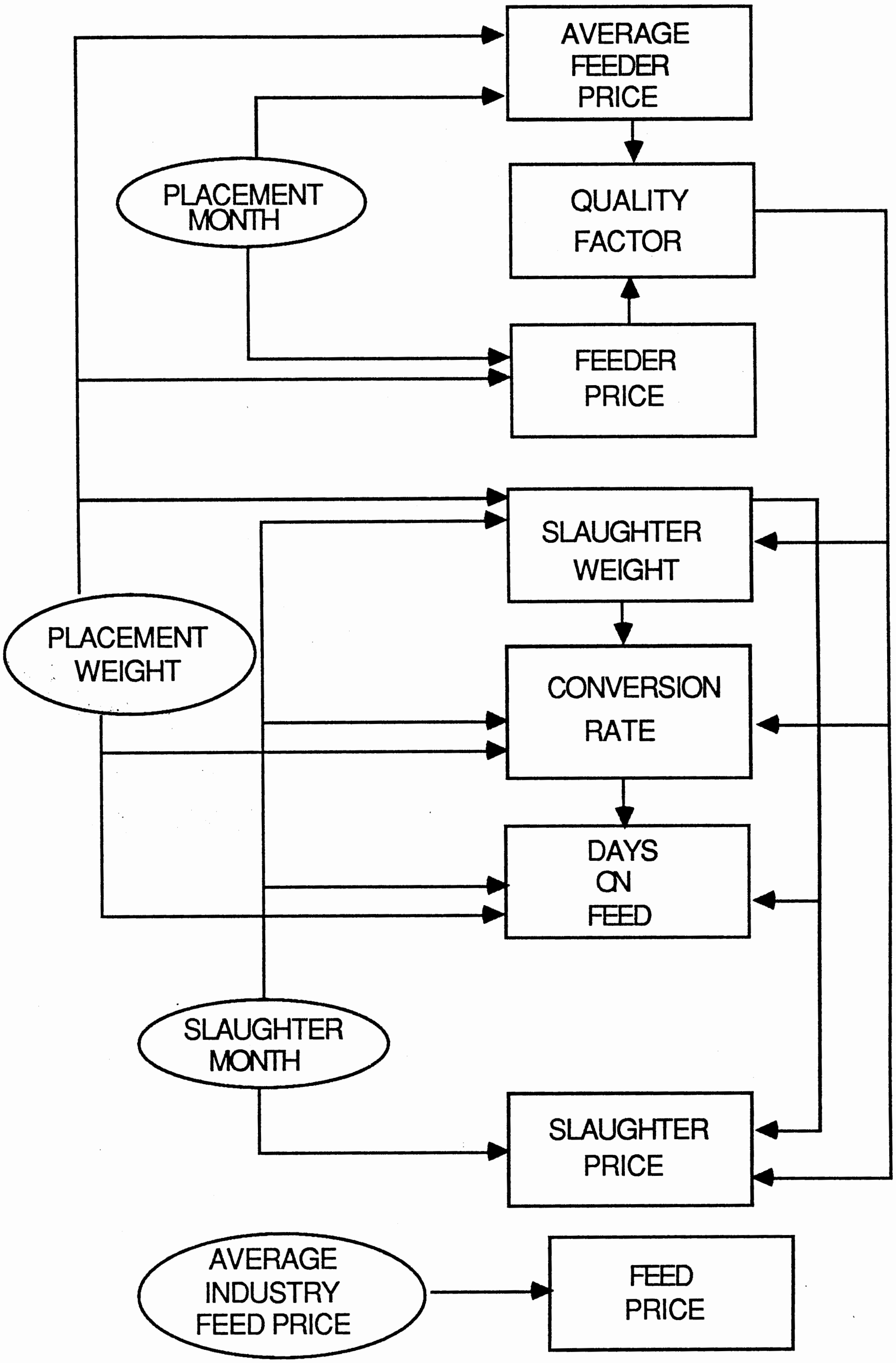

Figure 3. Flowchart Representation of Regression Equations

squares regression analysis was used to estimate six equations to represent the structure based on the data collected. The six equations estimated include: 1) feeder price, 2) slaughter weight, 3) conversion rate, 4) days on feed, 5) feed price, and 6) slaughter price.

As is evidenced in the flow diagram, the structure of the model is such that the six equations can be calculated in a sequential order beginning with feeder price. This framework allows for the use of some dependent variables as independent variables in following equations.

The logic of the flow chart in Figure 3 flows from top to bottom. Two feeder cattle price values are modeled. The logic of having two feeder cattle price variables in the model will become more apparent when the stochastic aspects of the model are discussed. Basically, the "average feeder cattle" price can be thought of as the average price paid for feeder cattle of a given weight in a given month. It is modeled by using OLS to estimate the relation of feeder cattle prices and placement weight and date. The "feeder price" variable is modeled to be reflective of the feeder price paid for individual pens of cattle. This price may be above or below the average price. The degree to which it may vary around the average price is related to the error term of the OLS estimate of the variable called "average feeder price." The variation of feeder prices around the average feeder price, as reflected by the difference between average feeder price and specific pen feeder price, serves as an effective proxy for the quality of feeder cattle in a given pen. For example, pens for which above average prices were paid are hypothesized to be of above average quality. This quality proxy, as shown in Figure 3, is used as a variable in determining slaughter weight, feed conversion rate, and slaughter price.

Slaughter weight is modeled to be a function of placement weight, slaughter month and quality. Slaughter weight in turn effects the feed conversion rate. Feed conversion is modeled as a function of slaughter weight, placement weight, slaughter month, and quality. The resulting feed conversion factor found then becomes a factor in determining days on feed. Days on feed are specified to be a function of conversion rate, slaughter weight, placement weight and slaughter month. Finally, slaughter price is diagrammed as being dependent upon the slaughter month, slaughter weight and the quality factor.

Feed price is specified to be independent of the other factors diagrammed in Figure 3. As was the case with feeder price, feed price for a given pen of cattle is hypothesized to be a function of the average industry feed price plus or minus an error term, or individual lot difference based upon the variance observed in the collected feed price data.

Model Estimation

The following section describes the logic and statistical properties of each of the six equations estimated for use in modelling the structure depicted in Figure 3.

Feeder Cattle Price

Average feeder cattle price is modelled to be dependent on the weight of the feeder cattle and the month of placement. Results of the equation indicate lighter feeder cattle typically command higher prices per pound than do heavier cattle. Similar results were found by Simon and Trapp (1981). As animals become heavier, their feed conversion efficiency declines, more energy is required for body maintenance, and more costly, higher energy feed is needed to maintain choice grade.

Feeder cattle prices are also characterized by seasonal price variations. These variations are primarily due to the biological nature of cattle production and peak demand periods. Spring calving seasons lead to a peak supply of feeder calves during the fall. Thus, feeder cattle prices tend to be lowest in the fall. Feeder cattle prices are expected to peak in March, start declining in April or May, and bottom in November (Ward, 1980).

Based on these contentions, feeder cattle price is estimated as a function of placement weight and seasonality. Both of these independent variables are exogenous to the model. It was expected that the placement weight variable would be negatively related to feeder price. Also, the use of a squared placement weight term, making the function quadratic, allows the rate of decline in feeder price to decrease as placement weight is increased. The seasonal dummy variables were expected to account for any variation in feeder price directly related to the month of the year in which the cattle were placed on feed. The estimated feeder cattle price equation is as follows:

$$
\begin{aligned}
FDRPR = .8227 &- \underset{(3.0775)^{**}}{(.0004*PLWT)} + \underset{(2.0477)^{*}}{(.0000002*PLWT^{2})} \\
&- \underset{(0.4510)}{(.0043*D1)} - \underset{(3.0294)^{**}}{(.0279*D2)} - \underset{(6.5351)^{**}}{(.0663*D3)} \\
&- \underset{(8.5117)^{**}}{(.0785*D4)} - \underset{(6.4762)^{**}}{(.0658*D5)} - \underset{(1.7173)^{*}}{(.0155*D6)} \\
&+ \underset{(1.6021)}{(.0146*D7)} + \underset{(1.6652)^{*}}{(.0154*D8)} + \underset{(0.0985)}{(.0009*D9)} \\
&+ \underset{(0.9878)}{(.0089*D10)} + \underset{(0.1496)}{(.0015*D11)}
\end{aligned}
$$

$R^2 = .54$
Standard Error of the Estimate = .03576
Coefficient of Variation = .0596
T-Values in Parentheses
Significance Levels: $(P<.05)=^{*}$ $(P<.01)=^{**}$

where FDRPR, PLWT, $PLWT^2$, and D1 through D11 are respectively equal to feeder price (cents/pound), placement weight (pounds), placement weight squared (pounds), and monthly dummy variables for the month of placement starting with February being D1 and proceeding through December being D11. The R^2 value indicates that the independent variables explain about 54% of the variation in the dependent variable over the time period May, 1986 through April, 1987 (479 observations).

Values below each parameter estimated are the t-values for the parameters. The parameters for the placement weight and placement weight squared variables were statistically significant at the .05 and .01 levels, respectively. Furthermore, the placement weight and placement weight squared variables had the theoretically expected signs. Figure 4 shows the general relationship estimated to exist between the independent placement weight variables and feeder cattle price.

Slaughter Weight

Cattle ready for slaughter generally range in weight from 1,000 to 1,300 pounds, depending on specific animal characteristics such as breed and frame size. Animal scientists contend that it takes about 500 pounds of grain- fed gain to bring a feeder animal to choice grade. Therefore, lighter placement weights tend to result in lighter slaughter weights. Likewise, heavier placement weights lead to heavier slaughter weights. A graphical depiction of this expected general relationship, as estimated from the collected data, is given in Figure 5. A second determinant of slaughter weight is thought to relate to the quality of the animal. Higher quality animals were assumed to achieve higher slaughter weights. As previously discussed, a quality factor variable was derived from the error term of the feeder cattle price equation. Finally, monthly dummy variables

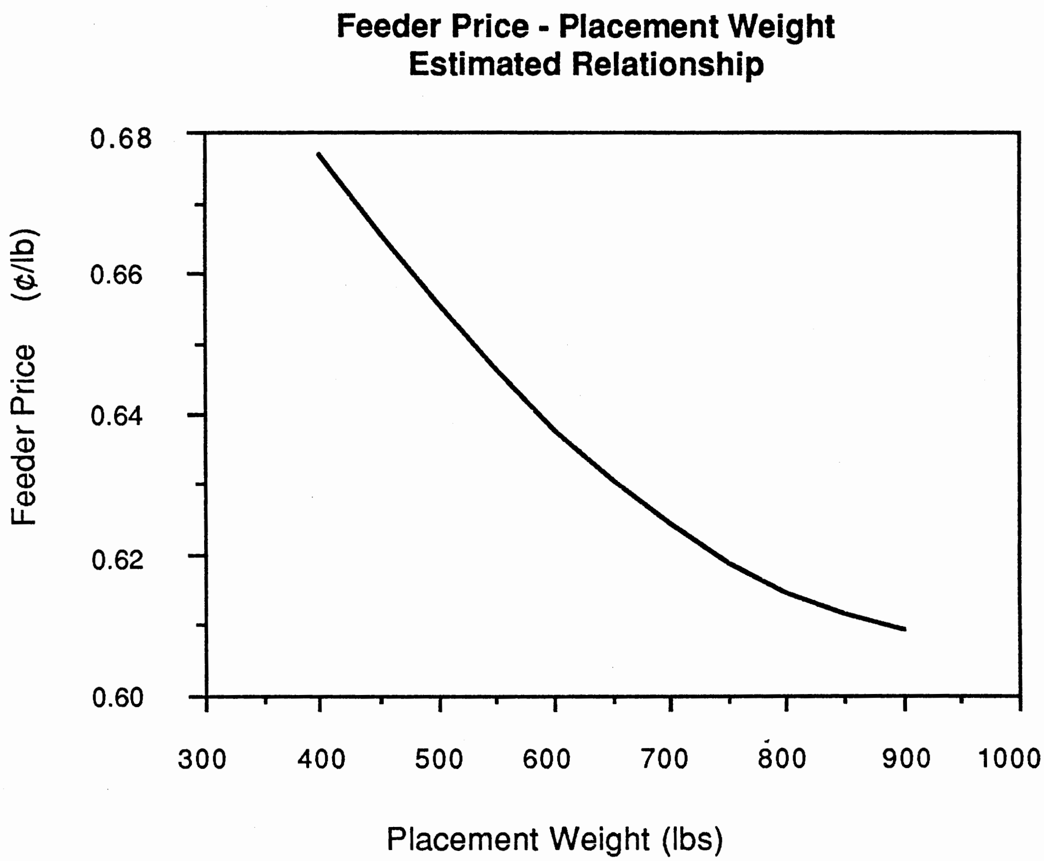

Figure 4. Graphical Representation of Estimated Feeder Price - Placement Weight Relationship

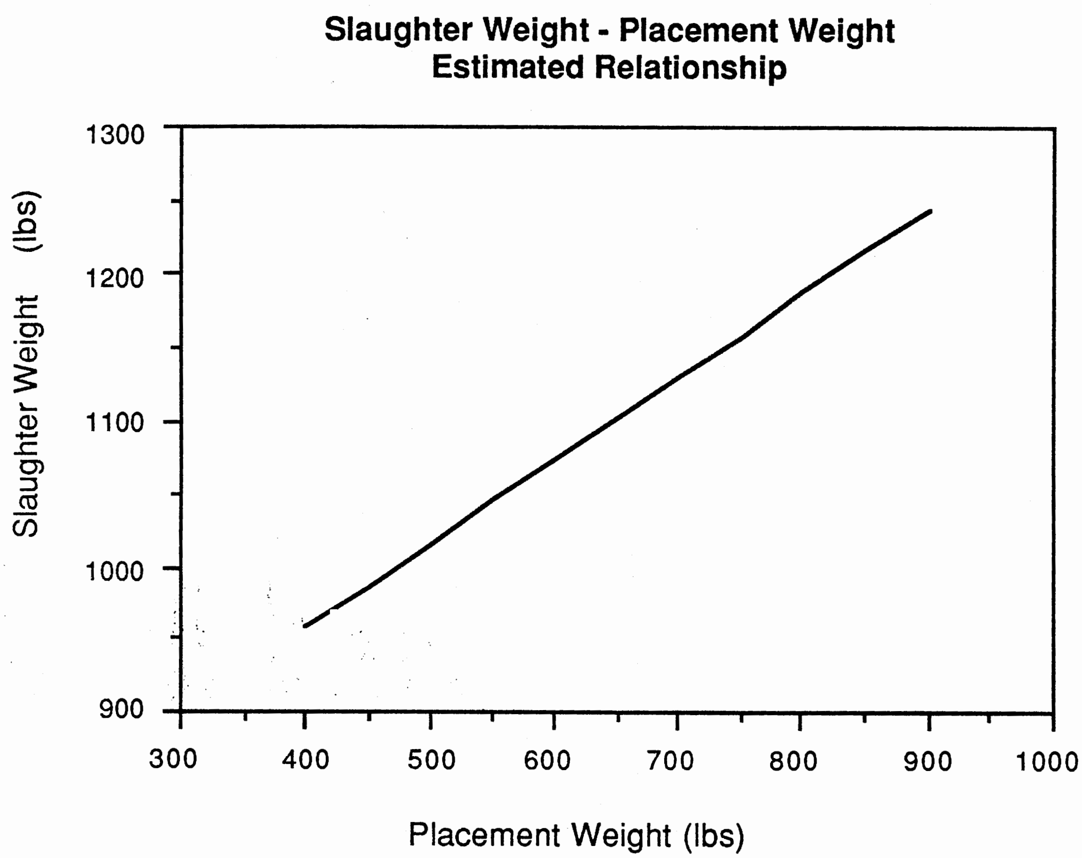

Figure 5. Graphical Representation of Estimated Slaughter Weight - Placement Weight Relationship

were used to account for any seasonal effects associated with slaughter cattle weights. The estimated slaughter weight equation is as follows:

$$
\begin{aligned}
SLWT = \; & 728.4253 + \underset{(24.8889)^{**}}{(.5718 * PLWT)} + \underset{(2.4275)^{**}}{(27.8182 * (P_o - P_e))} \\
& - \underset{(1.7323)^{*}}{(19.3330 * D1)} - \underset{(0.9939)}{(11.0851 * D2)} - \underset{(2.1412)^{*}}{(23.8748 * D3)} \\
& + \underset{(1.1954)}{(13.3590 * D4)} - \underset{(0.5301)}{(5.9145 * D5)} + \underset{(1.0476)}{(11.7216 * D6)} \\
& + \underset{(1.4292)}{(15.9259 * D7)} + \underset{(1.0069)}{(11.4564 * D8)} + \underset{(0.5719)}{(6.4981 * D9)} \\
& + \underset{(1.1520)}{(13.0674 * D10)} + \underset{(0.1825)}{(2.0682 * D11)}
\end{aligned}
$$

$R^2 = .63$
Standard Error of the Estimate = 49.8610
Coefficient of Variation = .043503
T-Values in Parentheses
Significance Levels: $(P<.05)=*$ $(P<.01)=**$

where SLWT, PLWT, P_o-P_e, and D1 through D11 are respectively equal to slaughter weight (pounds), placement weight (pounds), cattle quality (cents per pound), and dummy variables based on the month of slaughter starting with February being D1 and proceeding through December being D11. The cattle quality variable is the difference between the "average feeder price" (P_o) and the "expected" feeder price (P_e) as discussed earlier. As previously discussed, this quality proxy is the error term added to the OLS estimate for feeder price. The R^2 indicates that approximately 63 percent of the total variation in slaughter weight over the time period May, 1986 through April, 1987 (479 observations) was explained by the independent variables. Placement weight and the quality factor variable coefficients were significant at the .01 level, and two seasonal dummy variables (February and April) were statistically significant at the .05

level. The signs for the placement weight and quality factor coefficients were theoretically correct.

<u>Conversion Rate</u>

Conversion rate is a measure of the number of pounds of feed required per pound of gain. Conversion rate was hypothesized to be determined by placement weight, slaughter weight, animal quality, and seasonality. Conversion rate was expected to be positively related to placement weight and slaughter weight. This hypothesis was based on the earlier contention that heavier weights require more feed for body maintenance. Hence, the decreased efficiency results in higher conversion rates. Better conversion rates were expected to be associated with higher quality cattle. Higher quality results in more efficient feed conversion ability. Dummy variables based on the month the cattle were slaughtered were used to account for seasonal variability. The estimated conversion rate equation is as follows:

$$
\begin{array}{llllll}
CR = & 8.9248 & + & (.0065*PLWT) & + & (.0048*SLWT) \\
 & & & (16.9790)^{**} & & (9.4350)^{**} \\
 & - (3.0886*(P_o-P_e)) & + & (0.2116*D1) & + & (0.4749*D2) \\
 & \quad (4.3209)^{**} & & (1.7207)^{*} & & (3.8728)^{**} \\
 & + (0.9198*D3) & + & (0.1318*D4) & + & (0.1389*D5) \\
 & \quad (7.4740)^{**} & & (1.0722) & & (1.1335) \\
 & - (0.0242*D6) & - & (0.0607*D7) & - & (0.1372*D8) \\
 & \quad (0.1967) & & (0.4951) & & (1.0964) \\
 & - (0.1994*D9) & + & (0.0067*D10) & - & (0.1256*D11) \\
 & \quad (1.5971) & & (0.0537) & & (1.0092)
\end{array}
$$

$R^2 = .50$
Standard Error of the Estimate = .547627
Coefficient of Variation = .0660133
T-Values in Parentheses
Significance Levels: (P<.05)=* (P<.01)=**

where CR, PLWT, SLWT, P_o-P_e, and D1 through D11 are, respectively, conversion rate (pounds), placement weight (pounds), slaughter weight (pounds), animal quality (cents/pound), and monthly dummy variables for the month of slaughter starting with February being D1 and proceeding through December being D11. The R^2 indicates that approximately 50% of the total variation in the dependent variable is explained by the independent variables.

Those variables whose coefficients were statistically significant include placement weight, slaughter weight, animal quality, and the monthly dummy variables for February, March, and April. These dummy variables denote the month of slaughter and indicate cattle slaughtered in these months have higher than average conversion rates. The best (lowest) conversion rates are indicated to be for cattle slaughtered in September and October. Placement weight, slaughter weight, and the quality factor variable each exhibited the expected sign. Figures 6 and 7 are graphical representations of the general relationships estimated between conversion rate and placement weight, and conversion rate and slaughter weight, respectively.

Slaughter Price

Slaughter price refers to the price cattle feeders receive for their finished animal. Major determinants of slaughter cattle price were expected to include slaughter weight, animal quality, and seasonality. It is anticipated that cattle that were held on feed too long will sell at a discounted price because of the waste associated with the excess fat. Thus, slaughter price was expected to be negatively related to slaughter weight. Dummy variables were expected to account for the seasonal variability in slaughter price. Therefore, the month in which the cattle were slaughtered was used as an independent variable in

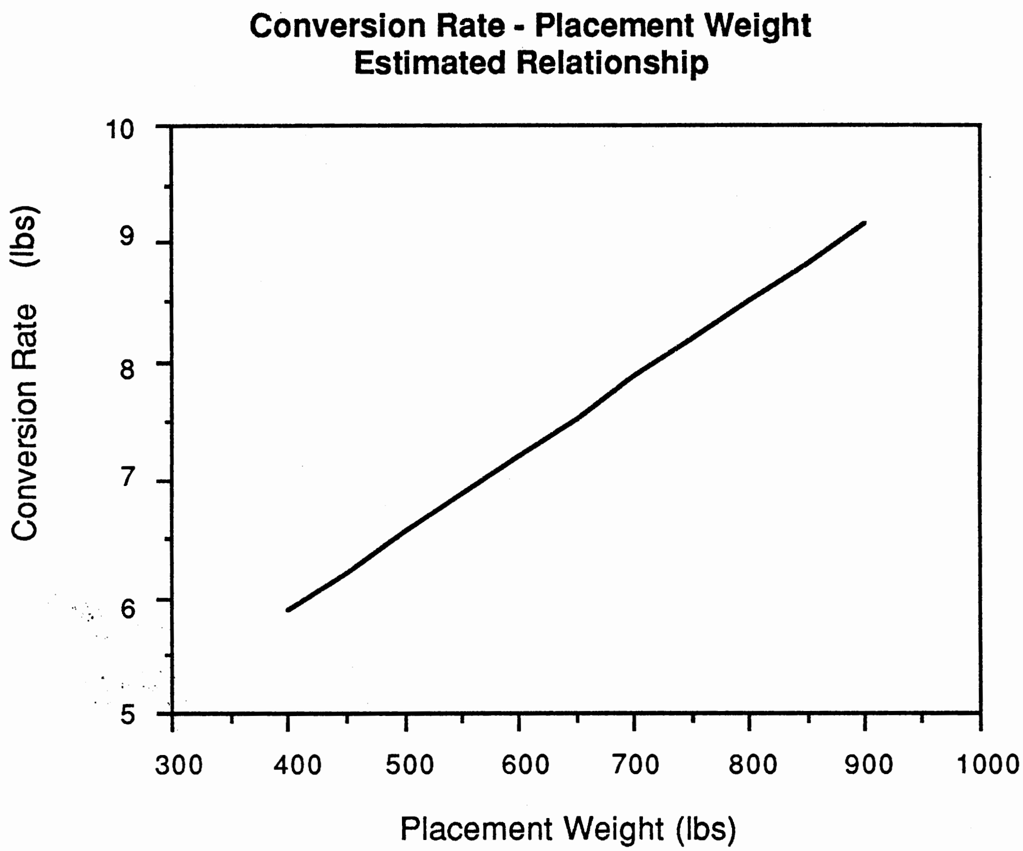

Figure 6. Graphical Representation of Estimated Conversion Rate - Placement Weight Relationship

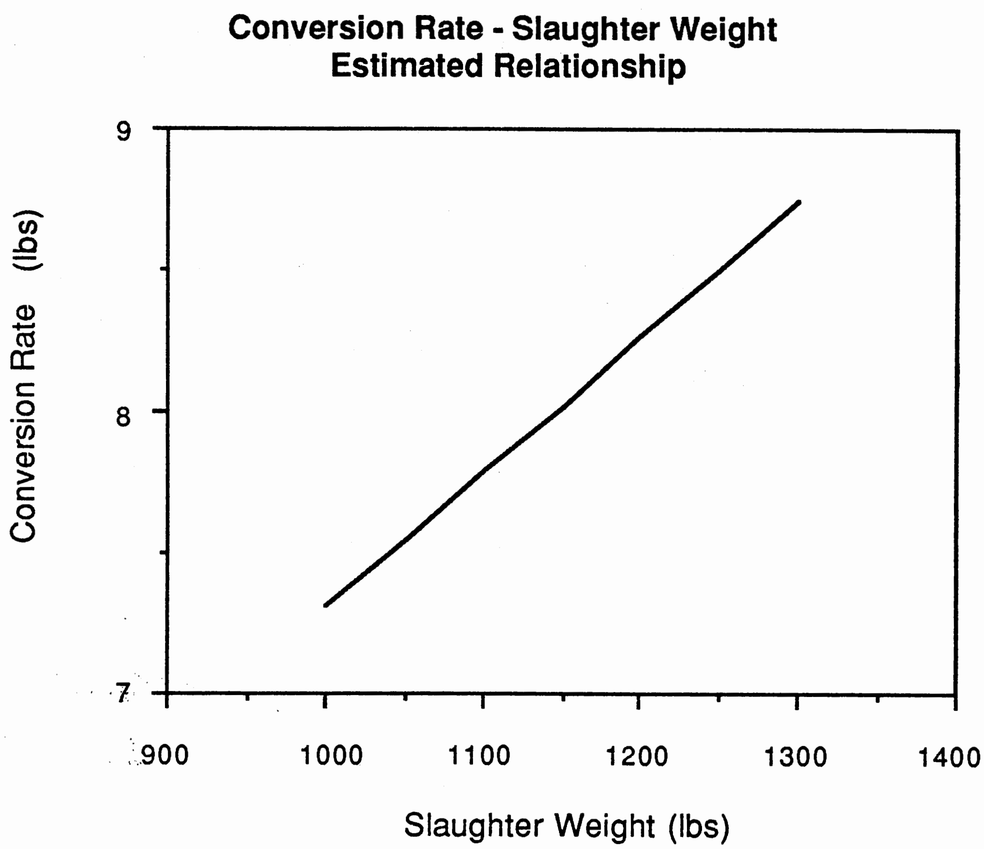

Figure 7. Graphical Representation of Estimated Conversion Rate - Slaughter Weight Relationship

estimating slaughter price. Figure 8 shows this estimated relationship. The estimated slaughter price equation is as follows:

$$SLPR = 0.6286 - \underset{(2.7791)^{**}}{(.00003*SLWT)} + \underset{(17.3402)^{**}}{(.4155*(P_o - P_e))}$$

$$+ \underset{(6.5030)^{**}}{(0.0267*D1)} + \underset{(10.3145)^{**}}{(0.0423*D2)} + \underset{(20.1272)^{**}}{(0.0828*D3)}$$

$$- \underset{(5.4716)^{**}}{(0.0223*D4)} - \underset{(11.9168)^{**}}{(0.0290*D5)} - \underset{(3.3889)^{**}}{(0.0140*D6)}$$

$$- \underset{(0.8039)}{(0.0033*D7)} + \underset{(2.1078)^{**}}{(0.0088*D8)} + \underset{(3.5099)^{**}}{(0.0146*D9)}$$

$$+ \underset{(6.1662)^{**}}{(0.0257*D10)} + \underset{(5.8756)^{**}}{(0.0244*D11)}$$

$R^2 = .79$
Standard Error of the Estimate = .018357
Coefficient of Variation = .0303757
T-Values in Parentheses
Significance Level: $(P<.05)=*$ $(P<.01)=**$

where SLPR, SLWT, P_o-P_e, and D1 through D11 are slaughter price (cents/pound), slaughter weight (pounds), animal quality (cents/pound), and seasonal dummy variables for slaughter months for starting with February being D1 and proceeding through December being D11. The R^2 indicates that about 79 percent of the total variation in slaughter price is explained by the independent variables. All of the coefficients for the independent variables were highly significant with the theoretically expected signs.

Days on Feed

Cattle are generally held on feed in a feedyard from 130 to 180 days. Key quantitative variables expected to best explain the variation in the number of days on feed are placement weight, slaughter weight, and conversion rate. A

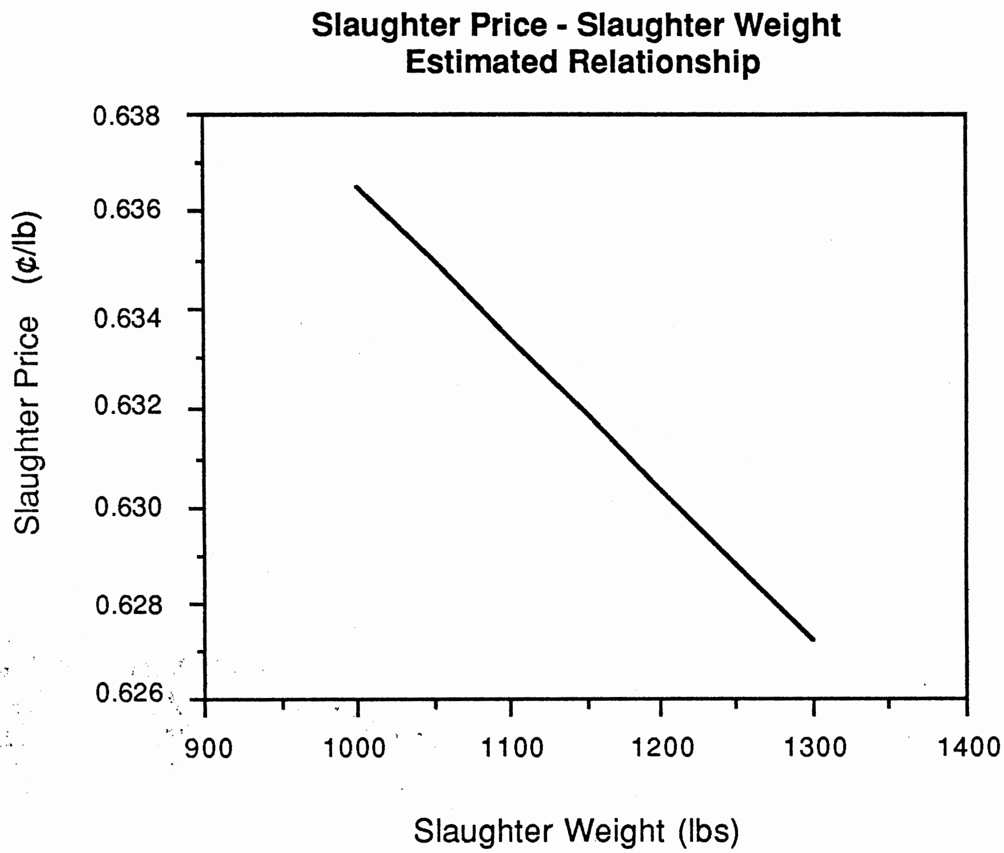

Figure 8. Graphical Representation of Estimated Slaughter Price - Slaughter Weight Relationship

seasonal effect was also expected. Placement weight was expected to be negatively related to the number of days the cattle were fed. Heavier placement weights were expected to decrease the pounds of gain required, thus decreasing the number of days of feeding required. Slaughter weight was expected to be positively related to the number of days on feed. Heavier slaughter weights were expected to be the results of longer periods of time on feed. Better conversion rates were theorized to decrease the amount of time on feed required. Therefore, a positive relationship was expected to exist. The seasonal volatility was expected to be accounted for by the use of dummy variables based on the month of slaughter. The estimated days on feed equation is as follows:

$$\begin{aligned}
Days = 164.6606 &- \underset{(14.0617)^{**}}{(0.3873*PLWT)} - \underset{(5.4529)^{**}}{(0.1710*SLWT)} \\
&+ \underset{(2.4971)^{**}}{(6.4227*CR)} + \underset{(0.3091)}{(2.1520*D1)} + \underset{(1.3159)}{(9.2513*D2)} \\
&+ \underset{(1.1081)}{(8.1412*D3)} + \underset{(1.0469)}{(7.2780*D4)} + \underset{(1.0719)}{(7.4282*D5)} \\
&+ \underset{(1.1648)}{(8.0926*D6)} + \underset{(1.2829)}{(8.8943*D7)} + \underset{(1.6999)^{*}}{(12.0318*D8)} \\
&+ \underset{(0.5845)}{(4.1344*D9)} + \underset{(0.1698)}{(0.1698*D10)} + \underset{(0.2683)}{(1.8898*D11)}
\end{aligned}$$

$R^2 = .48$
Standard Error of the Estimate = 30.9457
Coefficient of Variation = .2247629
T-Values in Parentheses
Significance Levels: $(P<.05)=*$ $(P<.01)=**$

where DAYS, PLWT, SLWT, CR, and D1 through D11 are respectively days on feed, placement weight (pounds), slaughter weight (pounds), conversion rate (pounds), and monthly dummy variables for the month of slaughter starting with

February being D1 and proceeding through December being D11. The R^2 value suggests that approximately 48% of the total variation in days on feed is explained by the independent variables.

Coefficients for the placement weight, slaughter weight, and conversion rate variables were statistically significant. Placement weight and conversion rate coefficient signs were theoretically correct. Figure 9 depicts the estimated relationship between placement weight and days on feed. As slaughter weight was increased (decreased), with other factors held constant, it was expected that the number of days on feed would be increased (decreased). However, the estimated equation suggested a negative relationship between the two variables. This is theorized to be the result of a correlated relationship between slaughter weight and placement weight. Even though heavy placement weight typically results in heavy slaughter weight, the difference between the two, total gain, may be smaller than for lighter placement weights. Thus, the number of days on feed would be negatively related to slaughter weight. The monthly dummy variables were only slightly significant in determining the number of days on feed.

Feed Price

The feed price variable provided by the data set was the average feed price paid for feed over the life of the individual pens of cattle. It was hypothesized that an average industry feed price at the time of placement would best predict actual feed price. The average industry feed price was obtained from the private feedlot consulting firm from which the data set was obtained. The consulting firm aggregates and summarizes individual feedyard closeout sheets to determine industry averages. The average feed price estimates for the placement months were therefore used to predict expected feed price. The

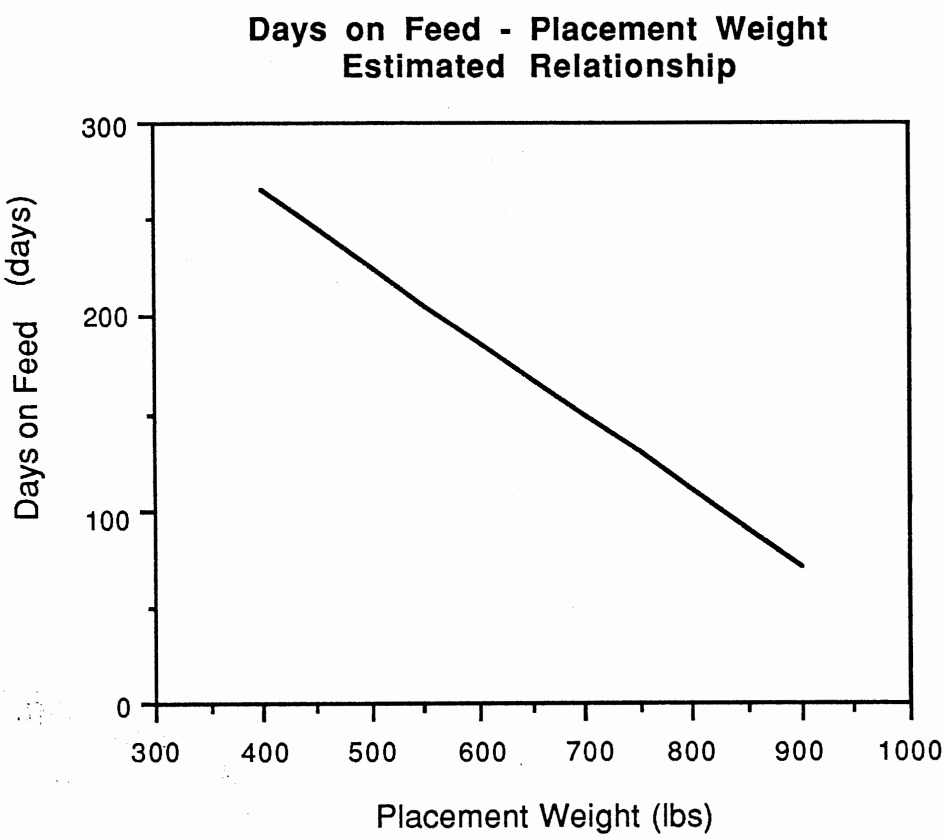

Figure 9. Graphical Representation of Estimated Days on Feed - Placement Weight Relationship

excess volatility not accounted for by the industry average was hypothesized to be due to such variables as purchase methods, timing, and ration compositions. The estimated feed price equation appears as follows:

$$\text{Feed Price} = .0001 + \underset{(11.0304)^{**}}{(0.7621 * \text{AIFP})}$$

$R^2 = .69$
Standard Error of the Estimate = .005229
Coefficient of Variation = .1022987
T-Values in Parentheses
Significance Levels: $(P<.05)=^{*}$ $(P<.01)=^{**}$

where AIFP is average industry feed price in cents per pound at the time the cattle were placed on feed. The R^2 indicates that about 69 percent of the total variation in feed price was explained by the average industry feed price. The coefficient for average industry feed price was statistically significant with the expected sign.

The Simulation Model

The system of equations developed through the use of regression analysis, coupled with the exogenous variables of the model, provide the necessary components to develop the model depicted in Figure 3. The model in turn provides a procedure for simulating net returns in a manner such that analysis of the volatility of net returns associated with each key variable can be undertaken.

Figure 10 is a flowchart representation of the framework used to calculate net returns. In essence, this figure is a graphical depiction of the closeout sheet presented in Table II. Beginning in the upper left hand corner, the logic flow of the figure is a follows. The difference between slaughter weight (SLWT) and

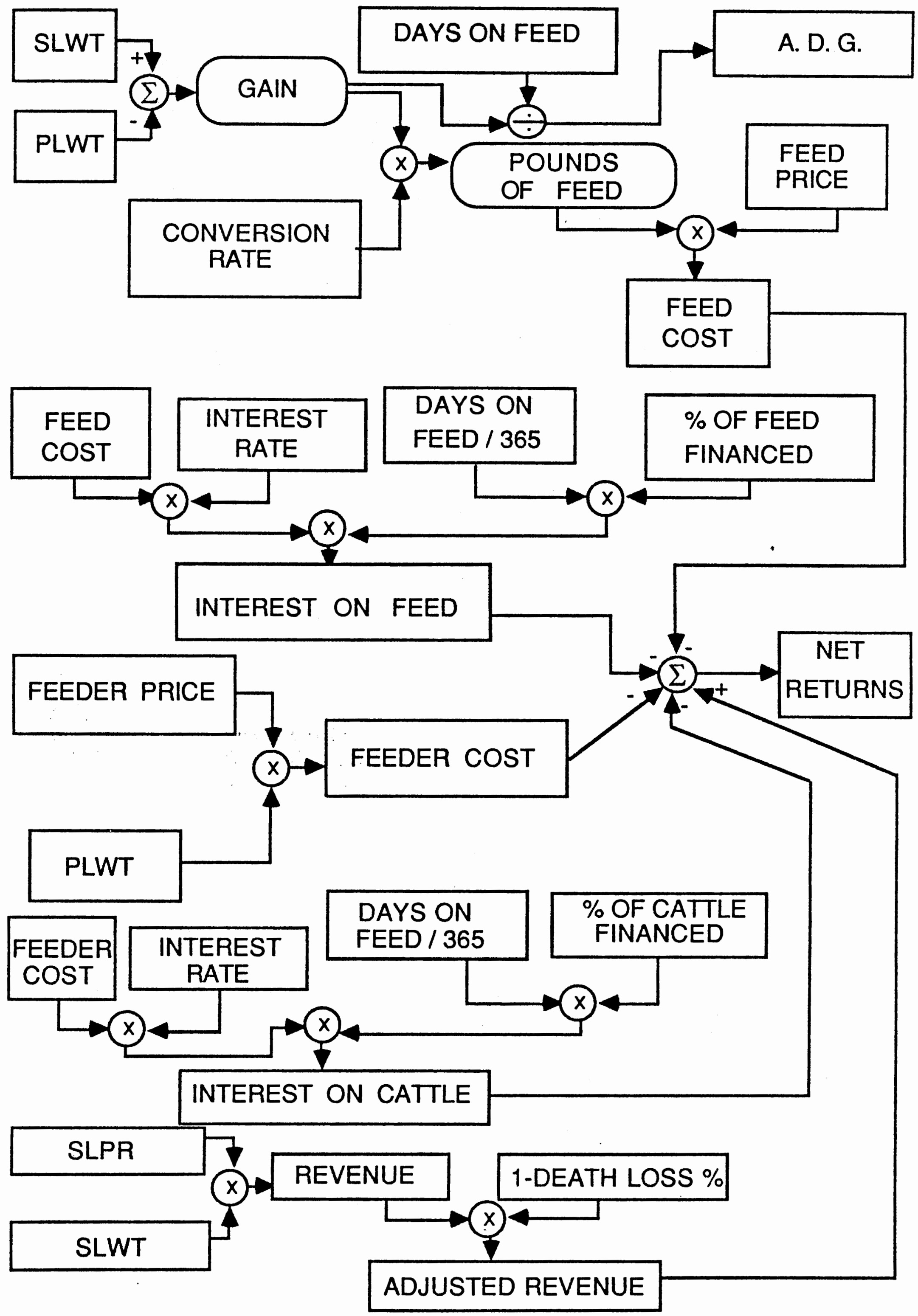

Figure 10. Flowchart Representation of Model Structure

placement weight (PLWT) is pounds of gain. Multiplication of pounds of gain and conversion rate is used to derive the total pounds of feed consumed. Pounds of gain divided by the number of days on feed determines a coefficient for average daily gain (ADG). Given total pounds of feed consumed, multiplied by feed price, the feed cost component is calculated. Interest charges for feed, as well as for cattle, are determined by multiplying total costs by the interest rate, the number of days on feed divided by 365, and the percent of the total cost being financed. Feeder cost is simply the estimated feeder price multiplied by placement weight (PLWT). Revenue is calculated by multiplying estimated slaughter price (SLPR) and slaughter weight (SLWT). This gross revenue was then adjusted for death loss by multiplying it by one minus a death loss percentage. Net return is derived by subtracting the cost components (feeder cost, feed cost, interest on cattle, and interest on feed) from the adjusted revenue. Net return is considered to be the return to the custom cattle feeder. All feedyard charges are assumed to be incorporated into the feed price.

Random Number Generator

A powerful and critical capability built into the simulation model for this study is the ability to simulate the effect of random events upon the system. The predictive relationships derived with regression analysis are not perfect, suggesting that some of the variation in the dependent variables of the system is not accounted for by the independent variables. This excess variation is described by the error terms of the regression equations. Regression function error terms are assumed to be normally distributed random variates with a mean value of zero. A second source of randomness in the system is random variation in the exogenous variables, hence all exogenous variables were considered to be random. Figure 11 is a graphical representation of the

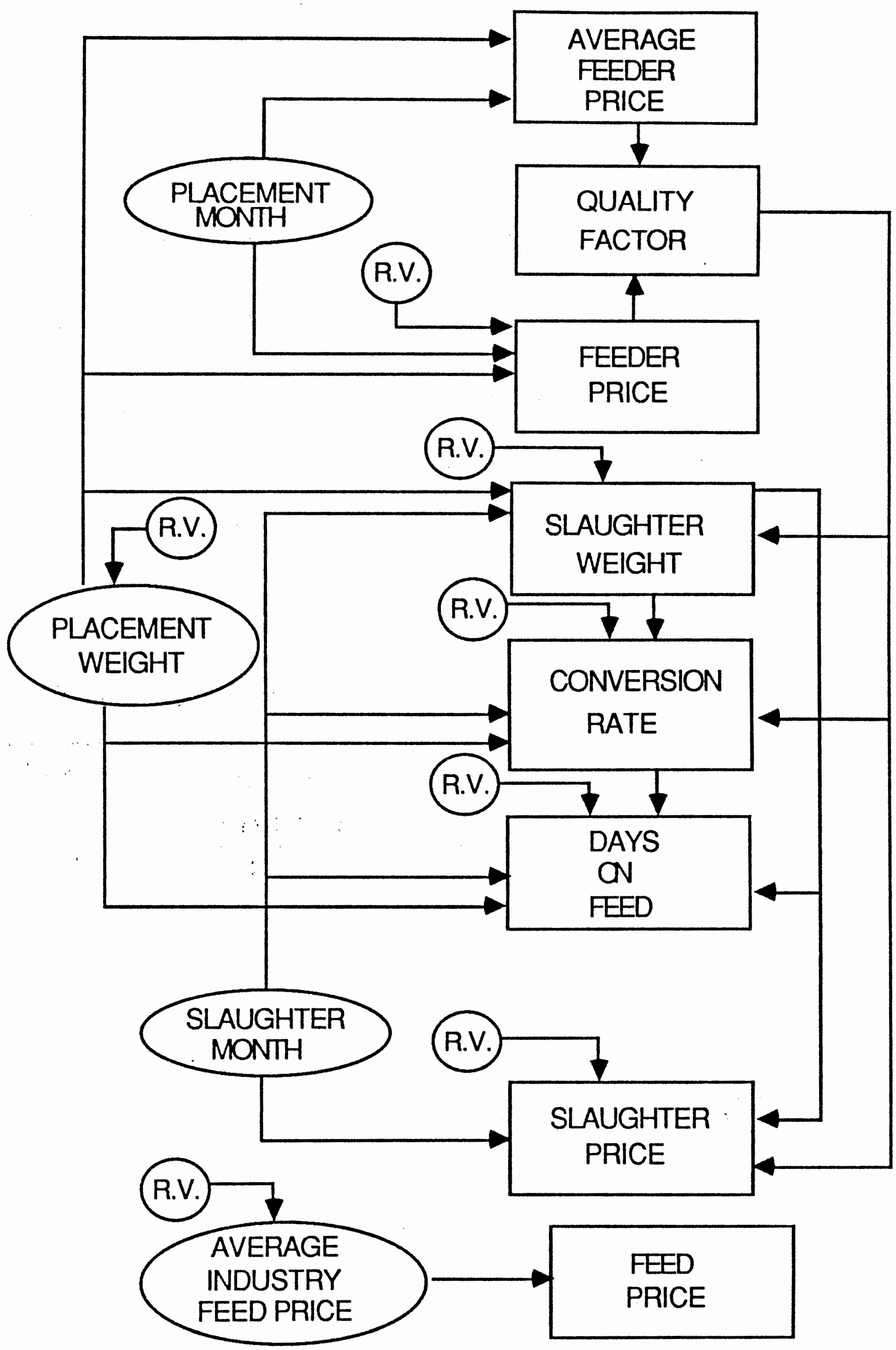

Figure 11. Flowchart Representation of Regression Equations With Random Error Terms

model's structure. It is identical to Figure 3, except the symbol R.V. has been added to denote points in the model's structure where random variation enters the system. As is apparent in the flowchart, randomness in specific variables tends to affect a number of other variables because of the interconnected nature of the system. The focus of this study is to determine the effect of all sources of randomness upon net returns. It is hypothesized that the impact of each of the sources of randomness denoted in Figure 11 can not be properly assessed without consideration of the structure through which the specific source of randomness eventually influences net return. An identical pattern/magnitude of randomness flowing through a different structure will have a different end effect upon net returns. Thus, achieving a valid model of the stochastic nature of feedlot profits requires correct specification of the feedlot profit model structure as well as correct generation of the stochastic distributions of the sources of random variation in question.

To model the specified sources of randomness a set of random numbers were generated. To assure that the same set of nonbiased random numbers would be generated for every run of the model, a pseudo-random number generation method referred to as the "linear congruential method" was used (Schildt, 1986).

$$R_{n+1} = (a R_n + c) \bmod m$$

The modulus (m) determines the range of the random numbers. The LOTUS 1-2-3 command @MOD generates this number. The multiplier, a, and the increment, c, were chosen to be 32719 and 3, respectively. Tests utilizing repeated samples confirmed these values as being adequate for generating a sequence of random numbers with the desired uniform distribution (Li, 1988). This method allows the user to provide the starting value for the random number sequence so that the sequence can be repeated as desired. It is critical that the same random numbers be used from run to run so that the changes that occur in the output variables can be identified as due to the experimental/sensitivity changes made rather that due to random change because of a different random number set.

The random numbers generated with the linear congruential method posses a 0,1 uniform distribution. Table V represents that portion of the spreadsheet which generates the recurring sequence of random numbers. The two top rows of numbers are the pseudo-random numbers generated with the linear congruential method. They are calculated based on the "seed value" in the top left corner of the printout which changes with each recalculation of the spreadsheet. These numbers must be transformed to the desired Normal distributions. This is done in two steps. The following LOTUS command is used to obtain a Standard Normal (0,1) random number.

$$RN = (-2*@LN(R_1))^{0.5}*(@COS(2*@PI*(R_2))$$

where R_1 and R_2 are two independent 0-1 Uniformly distributed variables and RN is a Standard Normal (0,1) random variate. LN is defined as the Log base e, and @PI is the LOTUS function for generating the value Pi (Trapp, forthcoming). Eleven Normal (0,1) random variates are calculated each time the spreadsheet is recalculated. The printout of the random number generator is shown in Table IV.

Transformation of a Normal (0,1) distribution to any desired Normal distribution with a mean U and variance V is straightforward if each random variant is independent. The procedure is a follows:

$$RV(U,V) = Mean + (Std * RN)$$

TABLE V

RANDOM NUMBER GENERATOR

101	29722	25315	26529	22858	1992	5741	24267	25220	29379	2856	27652
	12570	15891	14508	23249	23011	30151	12445	19641	255	25102	170
0-1 UNIFORM	0.907569	0.773000	0.810070	0.697975	0.060826	0.175303	0.740999	0.770099	0.897096	0.087208	0.844361
0-1 UNIFORM	0.383828	0.485236	0.443005	0.709914	0.702647	0.920669	0.380011	0.599743	0.007786	0.766496	0.581368
NORMAL (0,1)	-0.32821	-0.71451	-0.60787	-0.21133	-0.69369	1.639077	-0.56446	-0.58545	0.465473	0.228538	0.581368

where RV(U,V), a random normal variable with a mean U and variance V, is obtained by adding to the mean of the variable, its standard deviation (Std) multiplied by the Normal (0,1) random number (RN). In the case of the six regression equation variables, the standard error of the regression estimation is utilized as the Standard Deviation variable. In the case of the exogenous variables of the model, the standard deviation estimates made from the data set are utilized.

Simulating Correlated Random Events

The dependent variables generated from the estimated regression equations, as well as the exogenous variables of the model, can be made stochastic by adding a random number to each using the procedure described above. Agricultural simulation models typically incorporate randomness under the assumption that the correlation between any two events is either nonexistent (zero) or perfect (one). In many cases, this assumption does not realistically represent the covariance between related events and may even introduce artificial and unrealistic variability into the analysis (Clements, et al., 1971). It was hypothesized in this study that the error terms of the six regression equations, as well as those of two exogenous variables, interest rate and placement weight, were, in fact, correlated. The hypothesis was tested using t-tests at the .05 level of significance (Johnson, 1976). The hypothesis that the covariances between the error terms were equal to zero could not be accepted. It was therefore decided that the correlation between the random error terms should be incorporated into the simulation model.

A procedure for correlating events in simulation models was discussed in a bulletin by Clements, Mapp, and Eidman (Clements, et al., 1971). The methodology is also described in "Computer Simulation Techniques" by

Thomas Naylor, et al. (1966). That procedure, as adapted for LOTUS 1-2-3 by Trapp, was incorporated into this cattle feeding simulation model.

A brief explanation of the procedure used for correlating random variables is as follows. Eight correlated variables were generated using the formula:

$$V = R + (A^*W)$$

where V is an 8x1 matrix of the correlated variables, R is an 8x1 matrix of expected values for these variables (the solution value of the regression equations or data set means), A is an 8x8 matrix of coefficients, and W is an 8x1 matrix of random Normal (0,1) deviates. The Normal (0,1) deviates were generated as described in the preceding section. The eight random, but correlated variables to be modeled include feed price, placement weight, feeder price, slaughter weight, conversion rate, slaughter price, days on feed, and interest rate. The (A*W) product is the random value which is added to the regression equation solution values or exogenous averages (placement weight and interest rate) to simulate the stochastic elements of the cattle feeding industry.

Generation of the A matrix is explained by Clements, et al. (1971). The key input in defining A is the variance-covariance matrix of the variables being randomly generated. In this case, that matrix was formed from the error term series of the six equation estimations and the actual values for the exogenous variables placement weight and interest rates. Table VI reports the variance-covariance matrix derived as well as the A matrix. The A matrix, when multiplied by a vector of independent random Normal (0,1) deviates generates the eight desired correlated random variables.

TABLE VI

VARIANCE-COVARIANCE MATRIX AND TRANSFORMED A MATRIX

Variance-Covariance Matrix

	FEEDPRICE	PLWT	FEEDERPR	SLWT	CR	SLPRICE	DAYS	INTRATE
FEEDPRICED	.000027	-4.6E-12	-4.6E-12	-0.03416	-0.000160	-0.00000	0.014165	0.000002
PLWT		11091.35	0.000290	0.00000	-0.009400	-0.29990	-0.000000	-0.109380
FEEDERPR			0.001241	1.4E-13	-0.000000	-4.5E-14	-0.040430	0.000010
SLWT				2413.4590	-0.000000	-0.01714	1.124893	-0.014370
CR					0.290506	-0.00102	-0.124800	-0.000020
SLPRICE						0.000327	0.045920	-0.000000
DAYS							927.647900	-3.2E-15
INTRATE								0.000018

Transformed A Matrix

	FEEDPRICE	PLWT	FEEDERPR	SLWT	CR	SLPRICE	DAYS	INTRATE
FEEDPRICE	0.0051	0.0001	0.0000	-0.0007	-0.0003	-0.0002	0.0005	0.00050
PLWT		102.0746	1.7868	-1.8373	-0.6451	-3.3586	0.0000	-25.57100
FEEDERPR			0.0351	0.0002	0.0000	0.0003	-0.0013	0.00240
SLWT				48.9974	-0.1610	-1.1789	0.0369	-3.36160
CR					0.5359	-0.0573	-0.0041	-0.00560
SLPRICE						0.0180	0.0015	-0.00120
DAYS							30.4573	0.00000
INTRATE								0.00430

Generating Stochastic Placement Months and Death Losses

The procedure used to generate the random variables described above was not deemed appropriate for generating a random series for placement month and death loss. In the case of the placement month variable, the above approach could not be used because placement month is a discrete variable rather than a continuous variable. The placement month was randomly determined using the LOTUS command @INT(R1*12)+1. This command calculates the integer value for the product of a random Uniform (0,1) value (R1) and 12. It then adds one to that value. Thus, this command generates integer values between one and twelve, representing the months of January through December. Based on the integer value generated, the appropriate dummy variable is set equal to one, and all other dummy values are set to zero. For example, if the random number is 11, the November dummy variable is set equal to one while all other dummy variables are set equal to zero.

Given that the average number of days on feed for the data set was 137, the month in which the cattle were taken off feed was determined by adding 5 months to the randomly generated placement month. For example, if the placement month was 11, the random slaughter month would be 16. This corresponds to the month of April, i.e., 16-12=4, and April is the fourth month of the year. Again, the appropriate dummy variable is set equal to one for the generated month, and zero for all other months.

The random variation simulated for death loss also had to be given special consideration. Death losses were not observed to be normally distributed. The observed distribution was skewed toward low death rates. The method chosen to generate random death loss was the "Inverse Cumulative Distribution" method as defined by Naylor, et al. (1966) and modified for use with LOTUS by Trapp (forthcoming). The procedure involved two steps. The first was to estimate or approximate the Cumulative Distribution function for the variable in question. In this study, the distribution was approximated by ordering the death loss observations from low to high and establishing the death loss probability associated with each consecutive five percentile grouping. Linear interpolation between these points was then used to establish the approximated cumulative distribution function. The second step of the procedure was to "inversely" evaluate the cumulative distribution function. A random number between zero and one was generated which was used to determine the death loss percentage associated with that specific probability. This death loss percentage was then incorporated into the model. The cumulative distribution for death loss percentage as derived and used is presented in Figure 12.

Mean and Variance Estimation

When the previous generated random variables are injected into the simulation model, a set of random output values are generated. They include net return, feeder price, slaughter weight, conversion rate, days on feed, slaughter price, feed price, placement weight, interest rate, average feed price, pounds of gain, average daily gain, pounds of feed consumed, gross revenue, death loss percentage, revenue adjusted for death loss, feeder cost, feed cost, interest on feed, and interest on cattle.

Calculating estimated mean, variance, and standard deviation values of the variables generated in the model required that the spreadsheet be recalculated numerous times so that an adequate number of results could be obtained and recorded. The model was constructed so that one hundred iterations could be performed for the calculations of these values. The

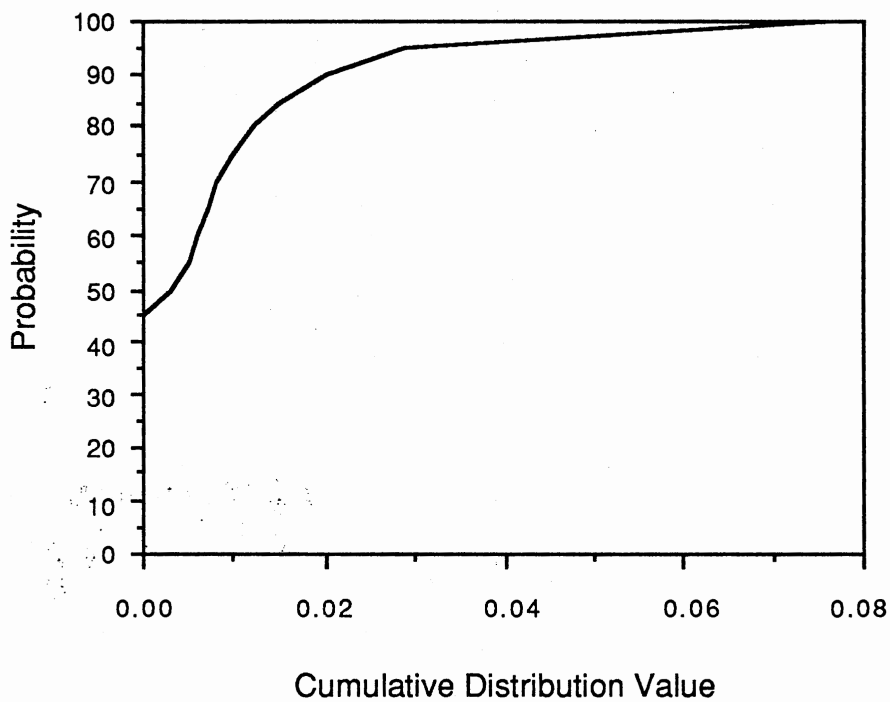

Figure 12. Cumulative Distribution of Death Loss Percentage

spreadsheet was programmed in such a way that each of the 100 values generated for the 20 output variables listed above could be recorded as they were generated. The mean and variance of each variable was then calculated from these recorded values. This was done internally within the program using the commands @AVG to calculate the average and @VAR to calculate the variance.

A portion of the summary printout from the model is displayed in Table VII. The estimated mean, variance, and standard deviation for each stochastic variable is reported in this portion of the spreadsheet. It was from this output that analysis of the volatility in cattle feeding net returns was made. The results of this analysis are discussed in Chapter IV.

TABLE VII

SIMULATION MODEL OUTPUT

NET RETURN ($)	
ESTIMATED MEAN	58.343400
ESTIMATED VARIANCE	4624.645000
ESTIMATED STANDARD DEVIATION	68.004000
FEEDER PRICE (¢/lb)	
ESTIMATED MEAN	0.595700
ESTIMATED VARIANCE	0.002400
ESTIMATED STANDARD DEVIATION	0.049900
SLAUGHTER WEIGHT (lbs)	
ESTIMATED MEAN	1147.035000
ESTIMATED VARIANCE	6398.987000
ESTIMATED STANDARD DEVIATION	79.993600
CONVERSION RATE (lbs)	
ESTIMATED MEAN	8.230100
ESTIMATED VARIANCE	0.619100
ESTIMATED STANDARD DEVIATION	0.786800
DAYS ON FEED (days)	
ESTIMATED MEAN	136.490500
ESTIMATED VARIANCE	1670.372000
ESTIMATED STANDARD DEVIATION	40.870100
SLAUGHTER PRICE (¢/lb)	
ESTIMATED MEAN	0.602400
ESTIMATED VARIANCE	0.001000
ESTIMATED STANDARD DEVIATION	0.033100
FEED PRICE (¢/lb)	
ESTIMATED MEAN	0.051382
ESTIMATED VARIANCE	0.000011
ESTIMATED STANDARD DEVIATION	0.003336
PLACEMENT WEIGHT (lbs)	
ESTIMATED MEAN	729.167500
ESTIMATED VARIANCE	11459.190000
ESTIMATED STANDARD DEVIATION	107.047600
INTEREST RATE ($)	
ESTIMATED MEAN	0.120330
ESTIMATED VARIANCE	0.000018
ESTIMATED STANDARD DEVIATION	0.004268

CHAPTER IV

MODEL ANALYSIS

The primary purpose of the LOTUS Spreadsheet simulation model developed was to analyze the variability in cattle feeding net returns. The structure of the model is such that simulated mean and variance estimates for key variables can be calculated and compared with those of the collected data set or other estimates from previous studies. It is also possible to use the model to determine the contribution of each of the modeled variables to the overall volatility of net returns. This can be done by controlling the magnitude of variability simulated for specific variables and recording the effect upon the overall variance in net returns.

Model Validation

The effectiveness of the simulation model in representing the cattle feeding industry was tested by comparing the mean and variance estimates from the model to those of the data set. As was explained in Chapter III, each recalculation of the spreadsheet resulted in the use of a new set of random values and hence a new set of estimates for the key variables. To validate the model, the spreadsheet was recalculated one hundred times so that one hundred random observations were drawn for each variable. The simulated mean and variance estimates for selected key variables were then compared to the respective means and variances of the data set. Statistical tests were conducted to determine if the simulated values were equal to the data set values. Table VIII shows the estimated variances derived from the simulation model, as well as the variances calculated from the individual pen data. An F-test was conducted with the risk of making a Type I error controlled at .05 and .01. The acceptance range for these two confidence levels were .764 to 1.42 and .707 to 1.66, respectively (Neter, et al., 1986). Each variance estimation for the key variables forming net returns was accepted as being equal at the .05 level of significance, except for average daily gain. The estimate of net return variance was accepted as being equal to that of the data set at the .01 level of significance. The variance in average daily gain was significantly greater in the simulation model than in the data set. One possible reason for this inequality was that the actual correlation between variables forming average daily gain were not accurately correlated in the model. However, average daily gain had no effect in determining the variance in net returns.

The model was further validated by comparing estimated mean values with those of the data set. A Z-value was calculated for each variable (Salvatore, 1982). Table IX contains the simulated mean estimates and the estimated pen data means. Each calculated Z value fell into the acceptance range at the 5% significance level. Therefore, the hypothesis that the simulated means were statistically equal to the means of the pen data could not be rejected.

Following the above statistical tests, the simulation model was accepted as being valid. Therefore, it was decided that the model was sufficiently adequate for analyzing the nature and sources of volatility in cattle feeding net returns.

TABLE VIII

VARIANCE COMPARISONS USED FOR MODEL VALIDATION

VARIABLE	PEN DATA	MODEL ESTIMATES
Feeder Price (¢/lb)	0.002681	0.002497
Slaughter Weight (lbs.)	6531.501	6398.987
Conversion Rate (lbs.)	0.581513	0.619132
Days on Feed (days)	1794.521	1670.372
Slaughter Price (¢/lb)	0.001585	0.001099
Feed Price (¢/lb)	0.000011	0.000011
Placement WeightT (lbs)	11091.35	11459.19
Interest Rate ($)	0.000018	0.000018
Average Industry Feed Price (¢/lb)	0.000015	0.000014
Pounds of Gain (lbs)	4163.683	4881.788
Average Daily Gain (lbs)	0.265018	1.051788
Pounds of FeedD (lbs)	200473.2	189637.6
Death Loss Percentage (%)	0.000116	0.000159
Revenue ($)	4112.47	2998.177
Feeder Cost ($)	3649.275	4031.962
Feed Cost ($)	645.5927	612.6995
Interest on Cattle ($)	17.93413	18.45022
Interest on Feed ($)	1.789087	1.577522
Net Return ($)	2798.647	4624.645

TABLE IX

MEAN COMPARISONS USED FOR MODEL VALIDATION

VARIABLE	PEN DATA	MODEL ESTIMATES
Feeder Price (¢/lb)	$0.5991	$0.595709
Slaughter Weight (lbs)	1146.15	1147.035
Conversion Rate (lbs)	8.2957	8.230116
Days on Feed (lbs)	137.6815	136.4905
Slaughter Price (¢/lb)	$0.6043	$0.6024
Feed Price (¢/lb)	$0.051123	$0.051382
Placement Weight (lbs)	728.578	729.1675
Interest Rate ($)	0.1202	0.12033
Average Industry Feed Price (¢/lb)	$0.0669	$0.670
Pounds of Gain (lbs)	419.4474	417.8684
Average Daily Gain (lbs)	3.2073	3.3003
Pounds of Gain (lbs)	3397.304	3402.557
Death Loss Percentage (%)	0.0069204	0.007464
Revenue ($)	$685.4531	$685.2446
Feeder Cost ($)	$434.2895	$432.7271
Feed Cost ($)	$175.3796	$174.7828
Interest on Cattle ($)	$16.45595	$16.1742
Interest on Feed ($)	$3.350453	$3.21691
Net Return ($)	$56.3189	$58.3434

Comparison to Previous Estimations

A typical approach to estimating the volatility in net returns has been to assume each random variable forming net returns is independent of the other variables. Correlation between variables has commonly been ignored in risk analysis studies and stochastic modeling. As mentioned earlier, typical agricultural simulation models incorporate randomness under the assumption that the correlation between any two events is either non-existent (zero) or perfect (one). Consideration is usually not given for correlations falling between zero and one. Failure to consider the correlated relationships has been hypothesized to result in questionable estimates of the variation in net returns as well as the average level of net returns. To investigate this hypothesis, the cattle feeding simulation model was modified to calculate the mean and variance values of each key variable, assuming independence among the variables. This was done by eliminating the variance-covariance matrix used to obtain the transformed matrix of values and the six structural equations estimated with ordinary least squares. In essence, the model was collapsed to just those relations shown in Figure 10. These relations basically depict the calculations present in the closeout sheet that generate a net return figure. In this modified version of the model, the random variation is now added directly to the mean of each variable in Figure 10. All of the structural relationships between variables as depicted in Figure 3 are now ignored and each random variable is generated independently. The resulting means and variances estimated with this simplified version of the model are compared with those of the model when structure and correlation of random events are considered. The results are reported in Table X where the Correlated Model represents the original model with all the correlation present. The Independent Model represents the simpler, uncorrelated model. A third model modification referred

TABLE X

NET RETURN COMPARISONS UNDER VARYING DEGREES OF STRUCTURAL INDEPENDENCE OF VARIABLES

	MEAN	VARIANCE
Correlated Model	$58.34	4624.645
Independent Model	-$1.97	3942.719
Non-Correlated Model	$61.40	4320.793

to in Table X as the Non-correlated model will be discussed presently. Eliminating all the covariance present in the model reduced the amount of variation in net returns. However, the variance estimates for net returns for each of the methods were not found to be statistically different by an F-test. Therefore, the hypothesis that studies ignoring structure and correlation distort variance estimates could not be accepted. However, it was determined that the average net return was substantially and statistically significantly greater in the case where the correlation among key variables was included in the model. Thus, the assumption of independence between these key variables tends to significantly underestimate average net returns in this case.

The above results are deemed to be quite revealing. Many previous studies have casually assumed independence between the random components of a production/marketing system. Some concern may have been voiced in these studies about the effect of this assumption upon the variance of composite variables, such as net profit, estimated by the system. However, very little concern was ever raised over the effect of the assumption upon the mean values of the composite variables. The results of this study raise major questions about the accuracy of such assumptions with regard to the mean values generated by such simplified models.

The above results deserve some further reflection with regard to why they occurred. The differences between the two sets of results are due to the covariances present in the model. Covariance is being generated through the six regression equations and the transformed variance-covariance matrix for eight of the random variables in the model. The majority of the covariance is being generated by the structural relationships between the endogenous variables contained in the six regression equations. This is evidenced by calculating the variance of net returns by a third method where the model depicted in Figure 11 is used, except the random variables injected into the system are now no longer correlated. To achieve this simulation, the off diagonal elements of the variance-covariance matrix are set to zero, resulting in independent random variables. The correlation generated by the regression equation interlinkage is, however, still present. This version of the model yields a variance of 4320.793 and a mean value of $61.40. Both of these values are very similar to the values found with the variance-covariance matrix present.

From a strictly statistical viewpoint, it may seem intuitively illogical that the presence of non-zero covariances, as modelled in the Correlated Model, could change the mean value of net return while not significantly changing it's variance. The presence of covariance does not change the expected value of sums and differences of two random variables. However, it does change the expected values of the product of two random variables, i.e., $E(YX) = (\overline{Y} * \overline{X}) + Cov(X,Y)$. There are numerous products of correlated random variables in the model. Indeed, there are even products of products of random variables because of the sequential interrelatedness of the random variables. Thus, one's strictly quantitative intuition of the impact of covariance upon the expected value of the model becomes quickly lost when the structure generating the expected value is very complex at all. The same is true with regard to hypothesizing the net effect of the presence of covariance upon the variance generated for net returns. The presence of covariance between two random variables has a different effect upon the variance of their mathematical relation depending upon whether the two variables are added, subtracted or multiplied, i.e., $Var(X+Y) = Var(X) + Var(Y) + (2 * Cov(XY))$; $Var(X-Y) = Var(X) + Var(Y) - (2 * Cov(XY))$; $Var(X*Y) \approx (Var(X)*\overline{Y}^2) + (Var(Y)*\overline{X}^2) + (2 * Cov(XY)*\overline{X}^2*\overline{Y}^2)$. Thus, the effect of covariance upon the output variables of a complex model would appear to be even more difficult to intuitively understand and hypothesize.

An intuitive explanation appears to exist for why profits may be underestimated when independence is assumed among the random components of a system. The basic explanation appears to lie in the fact that systematic relationships that are overtly controlled by management exist between many of the so-called random components of net revenues. For example, when feed prices are high, management adjusts by buying heavier feeder cattle and selling at lighter slaughter weights. Likewise, poor performing cattle are probably sold at lighter weights while good performing cattle are sold at heavier weights. All of these efforts are coordinated efforts directed at making a profit. In the process, one might think that these efforts would reduce profit variance, as well as raise profit, but that is not the focus of management's efforts in most cases.

Considering each of the components of profit to be independent ignores the coordination ability of management. The modeling effort undertaken here does not ignore this coordination effort. That effort is captured in the model's structural relations and the variance-covariance matrix used. Ignoring management's coordinating ability would appear to result in consistently underestimating profits in risk analysis. This, in turn, would appear to indicate that the risk associated with a given activity would tend to be overestimated if Bullock's definition of risk is used, i.e., risk is the probability of suffering an undesirable level of loss, such as a negative net return.

The results found here using independent versus correlated random components provide an explanation of the results Trapp and Webb (1986) found with regard to differences between industry data and USDA data. Trapp and Webb found USDA and industry data to have similar variances but very different means. They attributed the difference in means to have perhaps been due to their sampling an above average set of producers. The analysis here indicates the difference is probably due to the USDA data not reflecting the coordination ability of typical management, let alone superior management.

Sources of Variance

Analyzing the sources of risk in cattle feeding is not a straightforward task. Technically speaking, this study will consider that a variable's contribution to risk is the increase in net return variance caused by the presence of volatility for the variable in question. Given the model's structure, isolating this contribution might appear to be a straightforward task in sensitivity testing. Referring to Figure 11, one would conceive that all that needs to be done is to remove each of the randomly generated R.V. variables one at a time and observe the change in the variance of net returns. This simple concept is complicated somewhat by the fact that eight of the R.V. variables are correlated through a variance-covariance matrix generation process. Recall that in generating correlated random variables, the process is to generate an 8X8 upper triangular A matrix from a variance-covariance matrix and multiply it times a vector of eight Normal (0,1) random variables. The resulting values are a vector of eight correlated random variables that can be added to the expected value of the variables in question to generate eight desired Normal distributions. One way to reflect the absence of volatility for a given variable would be to "zero out" the random Normal(0,1) deviate for that variable. To do this ignores the fact that assuming one of eight correlated variables to have a variance of zero, also assumes its covariances are zero. To consider that a variable's covariances, as well as it's variance, are zero necessitates deriving a new variance-covariance matrix, with the appropriate variance and covariances set to zero, and a new transformed A matrix. Alternatively, the variance-covariance matrix could be redefined to be a 7X7 matrix, leaving out the variable in question since it is no longer considered to be random.

Dealing with the variation generated for a given variable by the variance-covariance portion of the model does not deal with all of the sources of volatility for a given variable. The variance-covariance operation generates the random error term to be added to each of the structural equations of the model and creates randomness in the exogenous variables. In the case of an endogenous variable, such as slaughter price, eliminating the randomness coming from the variance-covariance matrix portion of the model does not lead to a zero variance for slaughter price. Slaughter price variation will still be generated from changes in variables present in the structural equation for slaughter price, i.e. slaughter price is specified to be a function of slaughter weight, feeder quality as denoted by the difference between expected feeder price and actual feeder price, and time as reflected by the dummy variables in the equation. Indeed, a large percentage of the simulated volatility generated for slaughter price is due to changes in the variables in the slaughter price equation and not due to the random error term of the equation. A similar logic exists for each of the six endogenous variables of the model.

To eliminate all of the volatility associated with a given endogenous variable would require replacing the endogenous variable's structural equation with the variable's mean value. This would appear to be in violation of the basic logic of the model's structure. For example, to hold slaughter price constant while allowing feeder quality, time, and slaughter weight to vary is inconsistent with the estimated structure of the model. What is consistent is the fact that slaughter price volatility, as modeled and perceived in reality, is caused by a number of factors. To totally stabilize slaughter price would necessitate stabilizing all the contributing factors. However, these contributing factors are all interrelated. Volatility in slaughter price due to slaughter weight variance could be eliminated by stabilizing slaughter weight. But in turn, stabilizing slaughter weight would logically necessitate stabilizing placement weight due to the structural interrelatedness of placement weight and slaughter weight. Thus, the interrelatedness of the sources of volatility leads to the fact that one can not legitimately totally stabilize a variable such as slaughter price without stabilizing nearly every other variable considered in this model.

Slaughter price was picked as an example variable in the above discussion to raise an additional point. Many past studies of cattle feeding risk have simplistically assumed that hedging fat cattle prices will eliminate all volatility present in slaughter cattle prices. Given the preceding discussion, this would appear to be a rather formidable assumption. In reality, what has been achieved with a hedge is that the price for a given weight of animal, of a given quality, at a given location, at a given point in time has been established. However, the volatility of the actual price received for the animal versus the hedged price, often called basis risk, has not been eliminated. As modeled here, a hedge basically will serve to eliminate the random error term of the slaughter price equation, but not the randomness due to the variables in the equation, i.e., weight, animal quality, and time.

The complexity of the sources of volatility of each of the variables in the model, and finally of profit itself, is as complex as that just discussed for slaughter price. It is beyond the scope and application of this study to investigate the detail of the volatility due to each variable in the model to the degree suggested in the preceding discussion. A more general approach will be taken. The first application of the model will be to totally eliminate the variation due to each variable in the model and observe it's effect upon the variance of net revenue. In the case of five of the six endogenous variables, i.e., feeder cattle price, slaughter weight, conversion rate, slaughter price, and days on feed, this action will be in violation of the model's fundamental logic. However, it will serve as a basis of reference for subsequent, more logical actions and will point out the magnitude of fallacy involved in simplistic assumptions such as assuming hedging fat cattle removes all slaughter price volatility.

The second application of the model will be to remove only the randomness associated with the error terms of the endogenous equations and the randomness added to the exogenous variables, i.e., the randomness generated through the variance-covariance matrix and exogenous random error modeling process. This process can be thought of in general as eliminating error in a ceteris paribus context. In the case of slaughter price, it is the volatility in slaughter price given slaughter weight, animal quality, and time held constant. Likewise, in the case of feeder cattle price, it is the volatility in feeder cattle price, given feeder cattle weight and time. For conversion rate, it is the feed conversion rate volatility given placement weight, slaughter weight, animal quality, and time. And so on for the other endogenous variables.

Total Elimination of Individual Variable Volatility

Totally eliminating the variation due to each variable in the model was accomplished by replacing the structural equations of the model for each specific variable with the mean value found from the data set for that variable. In the case of exogenous variables for which no equation exists, the variable was held at its mean value. Table XI reports the results. The table reports the standard deviation in net returns calculated when the volatility due to each variable is removed from the model. The column labeled % OF TOTAL

DEVIATION compares each new standard deviation estimate with the standard deviation calculated when all sources of variance are present in the model.

As is evidenced in Table XI, elimination of slaughter cattle price volatility contributed the greatest amount of reduction in the variability of net returns. It was followed closely by feeder cattle price, monthly variation, feeder cattle quality, and feed price. Eliminating the variance present in the remainder of the variables listed had virtually no effect upon the variance of net returns. In fact, stabilizing interest rates resulted in a slight increase in net return variance. This may either be due to rounding error in the model or the covariance structure present for interest rates. It is feasible that the variance present for interest rates is such that it offset other sources of variance and acted as a stabilizing influence.

Table XI also reports the contribution to net return volatility due to combined price and combined physical volatility. It was found that when all three price variables; feeder cattle price, slaughter cattle price, and feed price, were held constant at their mean values, net return volatility was substantially decreased. The resulting standard deviation in net returns was only 34.44% of the total variation estimated when all sources of volatility were present.

Likewise, total volatility in net returns was decreased when all the physical variables were held constant. That is, when feeder cattle quality, death loss percentage, conversion rate, placement weight, days on feed, and slaughter weight were set to their mean values. However, total volatility in net returns was only reduced to 77.95% of the total variation. It is therefore apparent that price volatility contributes far more to total net return variability than does physical volatility.

It should be noted here that neither the time variable nor the interest rate variable were included in the above two categories of risk. Interest rate is

TABLE XI

SIMULATED CHANGES IN NET RETURN VARIANCE WITH SELECTED VARIABLES HELD CONSTANT

STABILIZED VARIABLE	NET RETURNS STANDARD DEVIATION	PERCENT OF TOTAL DEVIATION[1]
Slaughter Price	$45.98	67.67
Feeder Price	$48.83	71.80
Month (Time)	$52.47	77.15
Feeder Quality	$58.27	85.68
Feed Price	$63.76	93.75
Death Loss Percentage	$66.86	98.31
Conversion Rate	$66.88	98.34
Placement Weight	$67.08	98.64
Days on Feed	$67.87	99.80
Slaughter Weight	$67.74	99.61
Interest Rate	$68.42	100.60
Price (Feeder Price, Slaughter Price, and Feed Price)	$23.42	34.44
Physical (Feeder Quality, Death Loss Percentage, Conversion Rate Placement Weight, Days on Feed, and Slaughter Weight)	$53.01	77.95

[1]Calculated by taking the deviation in net returns in Column 1 and dividing by the deviation in net returns reported in Table VII (68.004), which was calculated with all sources of randomness active.

considered a source of financial risk and apparently has little impact on total net return volatility. Financial risk is examined later in the form of equity levels.

The time variable was not included in either of the above categories because of the difficulty in distinguishing whether it should be associated with price or physical risk. Time in the context of price risk could refer to the tendency of prices to follow a seasonal pattern. However, time in the physical sense could refer to the impact of weather when feeding cattle. Time was therefore considered separately in this study.

Elimination of Variation Due to Random Error Terms

Replacing the structural equations of the model with average values violates the model's logical interrelatedness. However, it makes it possible to analyze the contribution to net return volatility from each variable by totally deleting the variance of that variable. Perhaps a more intuitive approach would be to allow the structure to remain unchanged while deleting only the random error term of the six regression equations or the randomness added to each exogenous variable. As was explained earlier, this process does not totally eliminate the volatility in each variable. Elimination of the random error for each of the eight variables included in the variance-covariance matrix was achieved by placing zeros in the appropriated cells of the matrix to reflect zero variance and covariance for the variable in question. A new transformed A matrix was then calculated and used in the model based on the specified variance-covariance matrix. In the case of the variables Month, Feeder Quality, Death Loss, Placement Weight, and Interest Rate, this procedure results in the elimination of all variance for the variable in question and the results are the same as those reported in Table XI. This is the case since all these variables are exogenous to the model and are not predicted by equations. The results of an analysis conducted where only the random error was removed is reported in Table XII. The results indicate the net return volatility, as measured by the standard deviation, estimated when the error terms associated with the six regression equations were deleted one at a time.

When Table XI is compared to Table XII, it can be seen that removing the error term only does not decrease net return volatility as much as does removing all the volatility associated with any given variable. In fact, removing only the error term actually increases volatility in the case of conversion rate. However, the magnitude of the increase is so small as to be basically insignificant. It is hypothesized that the removed error term in question was somehow correlated to the volatility of the other independent variables of the conversion rate equation so that the removal of the error term actually increases volatility in net returns.

Eliminating the variance due to the error term in the equations for the price variables of the model is hypothesized to reflect the stability achieved by hedging the price in question. For example, in the case of slaughter price, removing only the error term reduces net return volatility by 4.43% to 95.57% of the original estimate. However, removing all slaughter price volatility reduces net return volatility by 32.39% to only 67.61% of the original. Based on this model, it is therefore concluded that hedging eliminates only about one-eighth (4.43/32.39) of the price volatility associated with slaughter price. By the same token, it was determined that hedging feeder cattle price and feed price eliminates about 63% and 24% of their total price volatility, respectively.

TABLE XII

SIMULATED CHANGES IN NET RETURN VARIANCE WITH SELECTED ERROR TERMS HELD CONSTANT

VARIABLE	NET RETURN STANDARD DEVIATION	PERCENT OF TOTAL DEVIATION[1]
Slaughter Weight	$67.52	99.28
Conversion Rate	$69.14	101.67
Days on Feed	$67.94	99.90
Feed Price	$66.86	98.31
Feeder Price	$55.98	82.31
Slaughter Price	$64.93	95.47

[1]Calculated by taking the deviation in net returns in Column 1 and dividing by the deviation in net return in Table VII (68.004), which was calculated with all sources of randomness active.

Controlling Profit Volatility

The above-mentioned analysis gave an indication as to the major sources of feedlot profit volatility. Given this knowledge, cattle feeders can prioritize their efforts to effectively control the volatility of their net returns.

Feeder Cattle Price Volatility Control

Stabilization of feeder cattle price volatility would appear to have first priority. One possible way of controlling feeder price volatility is through the use of the futures market. Hedging protects against adverse price fluctuations, thus decreasing the associated price risk. The cattle feeding simulation model was utilized to determine the effects of hedging feeder cattle price upon the probability of achieving various levels of net returns. The analysis included determining the probability of a negative net return with different levels of hedging, as well as the expected variability in net returns. Six hedging strategies were incorporated. They included a fully hedged strategy, a totally unhedged strategy, and four partially hedged strategies. These strategies were simulated by modifying the amount of random variation permitted in the Normal (0,1) random variables generated for feeder price, i.e., in the case of a total hedge zero variation was allowed, for a 20% hedge the random value generated was multiplied by .80. The structure of the variance-covariance matrix and associated transformed A matrix was not altered. The mean value of feeder cattle prices paid was assumed to not be changed by the hedging activity. Also, no charges were made for the hedging activity. The resulting average net returns, standard deviations, and probability of a negative net return can be seen in Table XIII.

TABLE XIII

EFFECTS OF HEDGING STRATEGIES OF FEEDER CATTLE PRICES ON NET RETURN MEAN AND VARIANCE ESTIMATES

% HEDGED	PROBABILITY OF LOSS	----NET RETURN---- MEAN	STD DEV
0	20%	$58.34	$68.00
20	19%	$58.06	$64.82
40	19%	$57.76	$62.01
60	19%	$57.45	$59.56
80	17%	$57.15	$57.54
100	15%	$56.85	$55.98

With no hedging, there was a 20% probability of a loss. This compares to a 15% probability if there was a 100% hedge, allowing no variability in feeder price to exist. However, the average net return tended to decrease with decreased volatility. Table XIII shows that without a hedging strategy, the expected net return was $58.34 with a standard deviation of $68.00. A total deletion of feeder price variability decreased the average net return estimation to $56.85 and the standard deviation to $55.98. Thus, while net return decreased 2.55%, volatility decreased 1.77%.

Equity Level Control

One way financial risk associated with cattle feeding can be controlled is through the use of alternative equity levels. Typically, cattle feeders are required to provide 30% of the equity necessary for financing a cattle feeding operation. The simulation model was utilized to analyze the effects of various equity levels on net returns. This was done by varying the interest charges for feeder cattle and for feed to reflect varying levels of equity.

The LOTUS 1-2-3 Spreadsheet was recalculated one hundred times for each of seven equity levels to determine the average net return, variability in net returns, and probability of a negative net return. Table XIV is a summary of the analysis. Generally, as the equity percentage was increased, the average net returns increased, while the volatility associated with them decreased. Also, increased equity levels tended to decrease the probability of a negative net return. Specifically, with 100% of the operating capital being financed, i.e., 0% equity, the average expected net return was $50.78 with a standard deviation of $68.05. The probability of a loss was 22%. At the other extreme, where 100% of the operating capital was provided by the cattle feeder, the average net return was $77.73. The associated standard deviation was $67.19 and there was a

TABLE XIV

EFFECTS OF ALTERNATIVE EQUITY LEVELS ON NET RETURN MEAN AND VARIANCE ESTIMATES

EQUITY LEVEL	PROBABILITY OF LOSS	----NET RETURN---- MEAN	STD DEV
0%	22%	$50.78	$68.05
20%	21%	$56.08	$68.00
30%	19%	$59.91	$66.22
40%	17%	$61.49	$67.75
60%	16%	$66.91	$67.52
80%	14%	$72.32	$67.34
100%	14%	$77.73	$67.19

14% probability of a negative net return. The results indicated that average net returns can be increased by 34.67%, volatility can be decreased by 1.26%, and the probability of a loss can be decreased by 36.36% when cattle feeders are able to provide 100% of the necessary operating capital as opposed to none.

It should be noted here that equity capital is assumed to be available at a zero opportunity cost. Thus, as the equity level is increased and net returns increase, what is actually being increased is the return to a greater capital investment.

Placement Weight Control

A final analysis was made concerning the volatility in cattle feeding net returns associated with various placement weights. Six placement weight scenarios were examined. The information obtained was used to analyze the effects of these alternative placement weights on average net returns. The volatility in these net returns was measured, as well as the probability of receiving a negative net return. A table summarizing the results can be seen in Table XV.

It was generally concluded that as placement weight was increased, the probability of a loss and the volatility in net returns also increased. Average net returns tended to decrease as placement weight was increased.

A feeder animal weighing 400 pounds resulted in an average net return estimation of $93.20. The standard deviation measure was $51.34. An animal weighing 900 pounds when placed on feed resulted in an average net return estimation of $52.11. The related standard deviation was $73.49. Therefore, the lighter placement weight tended to increase net returns by 44.09% while decreasing volatility by 30.14%, as compared to the heavier placement weight.

TABLE XV

EFFECTS OF ALTERMATIVE PLACEMENT WEIGHTS ON NET RETURN MEAN AND VARIANCE ESTIMATES

PLACEMENT WEIGHT	PROBABILITY OF LOSS	----NET RETURN---- MEAN	STD DEV
400 Pounds	2%	$93.20	$51.34
500 Pounds	10%	$77.61	$55.34
600 Pounds	15%	$67.03	$59.63
700 Pounds	21%	$60.12	$64.13
800 Pounds	24%	$55.57	$68.76
900 Pounds	24%	$52.11	$73.49

The probability of a loss decreased by 91.67%, from 24% to only 2%, when placement weight decreased from 900 pounds to 400 pounds.

It is likely invalid to generalize that lighter placement weights will always increase profits and reduce risk. This finding likely reflects the nature of the market condition during the data period. Under other market conditions, heavier cattle may be more profitable than lighter cattle.

Summary

Controlling the volatility in cattle feeding net returns decreases the risk faced by cattle feeders. The ability to control this risk stems from making management decisions that decrease the chance of erratic behavior in net returns. Cattle feeders must first determine the sources of volatility. Once these sources are identified, methods of controlling variance can be implemented. The three control methods discussed in this study are management tools which may prove to reduce some of the volatility in cattle feeding net returns. More work is needed in this area to identify other management strategies useful in controlling volatility. Reduced volatility in net returns is hypothesized to lead to a less risky and more economically viable industry.

CHAPTER V

SUMMARY AND CONCLUSIONS

Net returns to cattle feeding enterprises tend to be volatile. This volatility is a concern of the industry in that it makes cattle feeding risky. With risk comes increased cost in the form of cash reserve requirements, more restrictive financial contracts, smaller scale operations, etc. Such costs are harmful to the industry and reduce the supply of cattle, thus leading to higher consumer prices for beef without added profit to the industry.

Previous studies of cattle feeding risk have focused on the use of the futures market and based their analysis on aggregate data. This study uses pen level data and focuses upon identifying the structure of the price and production risk associated with cattle feeding. The study concludes that the factors causing volatility in net cattle feeding revenue have a complex and highly interlinked structure. Data from four hundred seventy nine pens of cattle fed over a one year period were used to define this structure. A simulation model of the structure was developed. The model was able to simulate the mean and variance of net profit and eleven variables from which net profit is calculated with a .05 level of statistical accuracy.

Many studies of risk have casually assumed that the factors (prices, quantities, and technical coefficients) causing profit volatility are random and independent. As stated above, this study found factors causing cattle feeding profit volatility to be highly interrelated. Factors considered included feeder cattle price, feed price, slaughter cattle price, interest rate, placement weight, slaughter weight, feeder animal quality, feed conversion rate, days on feed, death loss percentage, and date of placement on feed.

It was shown in this study that assuming independence among these factors leads to biased results. Assuming independence among the factors listed resulted in significant underestimation of the average profit level, i.e., profits were estimated to be -$1.97 assuming independence and $58.34 with interdependence among the factors contributing to profit. The true value, as defined by the data set was $56.32. However, assuming independence among the factors modeled as causing profit volatility did not significantly alter the value estimated for the variance of profit.

It is hypothesized that the assumption of independence among the factors forming net returns leads to biased estimates of profit levels because it ignores the overt control that management has over these assumed random components of profit. Management attempts to manage each pen of cattle to obtain a profit. For example, if a pen of cattle are poor feed converters, they will likely be slaughtered at lighter weights. Cattle placed on feed at heavy weights are generally bought at lower prices per pound, etc. These and other similar actions by management result in significant correlations and covariances among the components from which profit is derived. Because the objective of management in controlling these factors is to raise profit, it is hypothesized that proper consideration of the interrelationship of the factors will lead to a model structure that generates a higher simulated expected profit than a structure that assumes independence among these variables. This hypothesis appears to be validated by the results of this study. Based on this study's results, it is further generalized that many complex production activities in agriculture contain the same type of interrelationships. Thus, analyzing the risk involved in these activities using the simple assumption of independence between the random components may be highly misleading.

A major objective of this study was to prioritize the sources of volatility in cattle feeding. This did not prove to be an easy task due to the close interrelationships found to be present among the sources of profit volatility. This interrelatedness made it difficult to separate one source of risk from another. Procedures were however developed to effectively separate the sources of volatility in cattle feeding profits. The largest contributor to profit volatility was estimated to be slaughter price. Removal of slaughter price volatility reduced profit variance by 32.33%. The second largest factor was feeder cattle price. Stabilizing feeder cattle prices reduced profit variance by 28.2%. Other important contributors to profit variance and the reduction in profit variance associated with stabilizing them were: timing of placement - 22.85%; feeder cattle quality - 14.32%; feed price - 6.25%; death loss percentage - 1.69%; conversion rate - 1.66%; and placement weight - 1.35%. Days on feed, slaughter weight, and interest rates had less that a 1% effect upon profit volatility.

In reviewing the above ranking of factors contributing to profit volatility, it is obvious that price volatility is an important source of risk in cattle feeding. An analysis was conducted to determine the collective amount of risk from market risk, i.e., price volatility, and production risk, i.e., physical volatility. The combined effect of stabilizing slaughter price, feeder cattle price, and feed price was to reduce profit volatility by 65.56%. The combined effect of stabilizing feeder quality, death loss percentage, conversion rate, placement weight, days on feed, and slaughter weight was to reduce profit volatility by 22.05%. Thus, marketing risk is concluded to be about three times larger than production risk.

The ultimate purpose of this study was to determine methods for controlling risk in cattle feeding. The primary method of risk control that has traditionally been used in cattle feeding is hedging. This fact, coupled with the result that marketing risk was found to be the largest cause of profit volatility prompted an analysis to estimate the potential reduction in profit volatility possible through hedging. Not all of the volatility in profit attributed to slaughter price, feeder price, and feed price volatility can be eliminated by hedging each of these respective prices. Once a price has been hedged, basis risk still remains. The hedged price, for example in the case of slaughter price, is for a specified weight and grade of cattle at a given point in time. The actual price received for the cattle can vary from the hedged price because of volatility in the weight, quality, and time of sale for the cattle. Using the model developed, an estimate was able to be made of the percent of total slaughter price, feeder price and feed price volatility which could be eliminated by hedging, versus the price volatility that would still remain due to other factors such as weight, grade, and time. In the case of slaughter price, it was found that only approximately 14% of the total price variation in slaughter price could be controlled by hedging. For feeder cattle price, almost 73% of the volatility was estimated to be controllable through hedging. For feed, approximately 27% of the price volatility could be eliminated by hedging.

These results may explain why many cattle feeders do not choose to hedge. The most effective hedges would appear to be for feeder cattle and feed. However, if an individual is not a continuous feeder or in a position where he is committed to feeding cattle at some future date, they can establish the price of feeder cattle at the date of placement and then pre-purchase their feed and eliminate all further feeder cattle and feed price risk. Thus, only slaughter price risk remains. This study indicates that hedging does not eliminate a large part of slaughter price variation.

An alternative method of considering the effectiveness of hedging is to analyze its effect upon changing the probability of taking a loss on feeding cattle. The effect of hedging feeder cattle prices was analyzed in this manner. It was found that with unhedged feeder cattle prices, the average profit was $58.34 with a variance of $68, leaving the producer with a 20% probability of having a negative profit. With feeder cattle prices fully hedged, profit variance fell to $55.98, with an expected profit of $56.85, thus reducing the probability of a negative profit to 15%.

An analysis similar to that done for the effect of feeder price hedging was done to determine the effect of various levels of equity upon the probability of receiving negative profits. With a zero level of equity, the probability of a negative net return was estimated to be 22%. With 100% equity, the probability of a negative profit was reduced to 14%.

Limitations

Although the simulated model of the cattle feeding industry utilized in this study was determined to accurately reflect the workings of the industry, there were limitations. The feedlot consulting firm from which the individual pen data was obtained had only a limited number of pen close-out sheets. Monthly data was therefore only available for the year May, 1986 through April, 1987. Also, only four feedyards had reported close-out sheets for the entire time period.

The information reported by the four representative feedyards was somewhat incomplete. Specifically, interest charges and feed costs were inconsistent between feedyards. The available data was nevertheless utilized, with mean and variance estimations calculated accordingly.

A third limitation was the fact that only 12 months of data were available. Furthermore, the specific time period studied reflected an unusually profitable time for the cattle feeding industry.

Finally, it was beyond the scope and application of this simulation model to investigate the detail of the volatility in net returns associated with each individual variable. To totally eliminate the variance of any given variable necessitated also eliminating the variance of other interrelated variables. In some cases, all variables would be required to remain constant, making it impossible to identify the actual volatility sources in detail. The analysis of net return volatility sources was therefore accomplished by simply removing the structural equation for each endogenous variable and replacing it with the mean value of that variable. Although this analysis made it possible to identify variance sources, it violated the structural interrelatedness of the model. Likewise, the assumption was made that hedging would eliminate the random error left in the structural equations estimated for price. This assumption may be an oversimplification but is believed to be justifiable.

Recommendations for Further Studies

The study of feedlot profit volatility conducted in this research was useful in determining the sources of net return variability. The relationships between these volatility sources were also examined, as were methods for controlling them. However, there are ways in which the study could be improved.

First, a larger data set covering a greater time span would be beneficial. More data would likely provide a better representation of the cattle feeding industry. The seasonal effects on profit volatility could be determined with a data set comprising a longer time period. It is hypothesized that in the southern and high plains area, physical performance may be more volatile through the winter months.

Secondly, the simulation model could possibly be improved in its ability to represent the cattle feeding industry. Improved estimation techniques for the regression equations could result in more accurate explanations of the variation in the dependent variables. The differences between the four feedyards could have been accounted for through the use of dummy variables. Another recommendation deals with the elimination of the volatility of specific variables. It appears possible to "dissect" the regression equations in more detail in order to determine the source of the variance in each variable. For example, slaughter price is a function of slaughter weight, feeder cattle quality, and time. As an alternative to simply replacing the equation with its mean value, it may be possible to leave the equation, incorporating a constant value for each of the independent variables into the intercept. This method also violates the structural interrelatedness of the model, but would provide a more detailed description of volatility sources.

The cattle feeding simulation model has the potential to be used in analyzing risk as it relates to firm size. Increased volume presumably increases risk. The ability to reduce risk makes it possible to expand the size of the operation while encountering the same total risk exposure. If size is considered in the model, it would be possible to determine trade offs between size and total risk. In order to accomplish this analysis, the model would have to be modified. It is currently representative of a single animal. To analyze the affect of risk on firm size, the model would need to be capable of representing a continuum of firm sizes, i.e., animal numbers.

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