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A breakeven analysis of a preconditioned beef calf management program

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by

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INTRODUCTION

How should one manage his beef calves? This is a question that cow-calf producers are frequently faced with. Should they wean their calves prior to sale? If so, when should they perform this management practice? They are also faced with decisions on creep feeding, when to dehorn and castrate, and a host of other management decisions. The use or nonuse of certain management practices and the timing of these practices have an effect on the calf's sales weight and how it performs after the sale. Also, the producer must decide whether these practices are profitable for him. This paper attempts to help the producer to economically evaluate a preconditioning calf program to answer these questions.

Background Information

The data that are used by this paper came from a study conducted from 1978 through 1980 by the Iowa State University Animal Science Department. One of its objectives was to study how various management and health practices at or around weaning time would affect the calf's weight gain. The site of this study was the Rhodes Beef Ranch at Rhodes, Iowa.

Uncastrated male calves were assigned to the study in September with 148 calves in 1978, 116 calves in 1979, and 160 calves in 1980. These calves were born in a 60 day period which started around March 10 and ended May 10. In September, they were randomly assigned to a treatment group, but care was taken so that there was at least one calf of each breed cross in each treatment group.

There were four main treatment effects analyzed in the study. They were:

1. Weaning calves 42 days prior to sale time or wean the day of sale
2. Creep feeding calves versus noncreep feeding
3. Vaccinate and grub treat 28 days prior to weaning or one day following weaning
4. Castrate and dehorn(if needed) 28 days prior to weaning or one day following weaning

This experimental design led to 16 treatment groups for all possible combinations or a 2^4 factorial design. The creep feeding was replicated so there were creep fed calves in two pastures and noncreep fed calves in two pastures. Also, all treatment combinations were placed in each pasture to avoid any complications due to pasture differences.

To give the reader a clearer understanding of the experiment, all of the possible treatment combinations are listed in Table 1. These treatments are based on a December 13 sale date. All of an animal's vaccinations and grub treatments were given together, and its dehorning and castration were also performed together.

The conclusion reached by this study was that the calves who had all of the surgical operations, and received their vaccination and grub treatment 28 days before weaning gained more weight than the calves receiving these treatments later. They also found out that creep feeding the calves leads to heavier calves at sale time. Also, if a

TABLE 1. Treatment Combinations

Group	Vacc. & Grub	Cast & Dehorn	Creep feed
Weaned November 1, 42 Days Before Sale			
	Date of Activity		
Group	Vacc. & Grub	Cast & Dehorn	Creep feed
1	October 4	October 4	Sept. 23 - Nov. 1
2	October 4	November 2	Sept. 23 - Nov. 1
3	November 2	October 4	Sept. 23 - Nov. 1
4	November 2	November 2	Sept. 23 - Nov. 1
5	October 4	October 4	None
6	October 4	November 2	None
7	November 2	October 4	None
8	November 2	November 2	None
Weaned Day of Sale, December, 13			
	Date of Activity		
Group	Vacc. & Grub	Cast & Dehorn	Creep feed
1	November 15	November 15	Sept. 23 - Dec. 13
2	November 15	December 14	Sept. 23 - Dec. 13
3	December 14	November 15	Sept. 23 - Dec. 13
4	December 14	December 14	Sept. 23 - Dec. 13
5	November 15	November 15	None
6	November 15	December 14	None
7	December 14	November 15	None
8	December 14	December 14	None

producer is not creep feeding, the earlier weaning, vaccination and grub treatment, and castration and dehorning also led to a larger sale weight[1].

Scope

This paper economically evaluates a preconditioning calf management program that incorporates the main treatments in the Animal Science study. First, a model is developed to estimate the weight gain effects of different management practices. This is necessary because the Animal Science study used an Analysis of Variance (ANOVA) statistical procedure which deals with differences in treatment means. This paper is concerned with how all of the treatments affect the overall weight gain of an animal so a least squares regression procedure is used. Secondly, a breakeven analysis is performed to determine whether the use of the management practices are economically justified. This paper is going to analyze these effects from the standpoint of a producer and seller of calves.

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[1] For more complete information on this study, refer to: A.S. Leaflet R329, Iowa State University Cooperative Extension Service, Ames, Iowa, December, 1981.

ECONOMIC MODELS

Weight Gain Model

To estimate the effects that certain calf management practices have on weight gain, one must first develop an economic model. In the economic model, one tries to determine which variables should be included in the model. The inclusion of a variable is usually based on economic and biological principles, experimental reasons, and any other knowledge that one may possess about the situation being modelled. It is through the use of this framework that the economic model is developed.

In developing an economic model, one must first determine what is the dependent variable. Since this paper is interested in evaluating how different preconditioning management practices affect a calf's weight gain, a weight gain variable is used as the dependent variable. This weight gain variable is measured as the weight gain from September 23 to the sale date, December 13. The starting date of September 23 is used because that is the date when the different treatments began.

With the dependent variable determined, one needs to develop a set of independent variables which affects the dependent variable. Since this paper is interested in the affect of weaning, creep feeding, vaccination and grub treatment, castration and dehorning, and their timing on weight gain; there should be a variable for each of these treatments. These variables should capture whether the practice is performed or not and the timing of the practice. With the experiment taking place over a time period of three years, variables need to be included to account for any year effects. These variables should capture any environmental differences such as weather, pasture conditions, etc. that occurred among the years. There also needs to be a replication variable included because calves were creep fed or noncreep fed in two different pastures each year. This variable accounts for any differences between the pastures within each year. Variables need to be included to account for the different frame sizes of the calves. This is because the Animal Science study explicitly included calves of different frame sizes to see how they responded to the main treatments. There were three frame size groups, large, medium, and small, defined in the Animal Science study and this paper uses these same groups and definitions. A calf is classified in the large frame size group if its sire was a large Angus or a large Simmental bull, and its dam was a large female of mixed breed. A medium frame size calf was sired by a large Jersey, average Angus, or small Simmental bull, and its dam was a medium sized female of mixed breed. A small frame size calf was sired by a small Angus or small Jersey bull, and its dam was a smalled sized female of mixed breed. The last two variables that need to be included are: age of dam at birth, and the age of the calf at sale date. The age of dam variable is used because calves from heifers or young cows, and from older cows may not perform as well as calves from cows that are at the peak of their reproductive capabilities. Also, an older calf at sale date should have gained more weight than a younger calf. Now the economic model can be specified in a general form: Weight Gain = f(weaning, creep feed, vaccination and grub treatment, dehorning and castration, year effects, replication effects, frame size of calf, age of dam, and age of calf at sale date). It should be noted here that a calf's genetic makeup also effects its weight gain but it is impossible to measure such a variable.

Now that the relevant variables are determined, one needs to think about whether there are any interaction effects between variables. For example, would performing all surgical operations (castration and dehorning) and vaccinations at the same time affect the calf's weight gain? If so, then there is an interaction between dehorning and castration, and vaccination; and an interaction variable is included. Since it does seem plausible that there may be some interaction effects, the weight gain model includes interactions between the following variables:

1. replication and creep feed
2. creep feed and weaning
3. creep feed and dehorning-castration
4. creep feed and vaccination
5. creep feed and age of dam
6. weaning and dehorning-castration
7. weaning and vaccination
8. weaning and age of dam
9. dehorning-castration and vaccination

The inclusion of these variables allows for nonlinear affects to be included in the model. The exact meaning of these interaction variables becomes apparent when the independent variables are defined. Also, it should be noted that only one-way interactions are included in the model. This is based on consultations between Dr. Daryl Strohbehn, Dr. George Ladd and the author where Dr. Strohbehn suggested which interactions he thought should be included based on his work with the project.

It is appropriate at this point to define the variables of the weight gain model before going on to other topics. This is to enhance the reader's understanding of the previous discussion. The variables are defined as follows:

WG(i) = weight gain of the ith animal

= WS(i) - WB(i)

WS(i) = weight of ith animal at sale date

WB(i) = weight of ith animal at 160 days (Sept. 23)

RP(i) = 0 if ith animal is in replication 1

= 1 if ith animal is in replication 2

Y2(i) = 1 if ith animal is observed in year 2 of experiment(1979)

= 0 otherwise

Y3(i) = 1 if ith animal is observed in year 3 of experiment(1980)

= 0 otherwise

CR(i) = 1 if ith animal is creep fed

= 0 if ith animal is not creep fed

W(i) = 1 if ith animal is weaned 42 days before sale date

= 0 if ith animal is weaned at the sale date

DC(i) = 1 if ith animal is dehorned and castrated 28 days before weaning

= 0 if ith animal is dehorned and castrated 1 day following weaning

V(i) = 1 if ith animal is vaccinated 28 days before weaning

= 0 if ith animal is vaccinated 1 day following weaning

M(i) = 1 if ith animal is in the medium frame size group

= 0 otherwise

L(i) = 1 if ith animal is in the large frame size group

= 0 otherwise

D(i) = age of dam at birth of ith animal

C(i) = age of ith animal at sale date

CRRP(i) = interaction between replication and creep feed

= RP(i) * CR(i)

= 1 if RP(i) = 1 and CR(i) = 1

= 0 otherwise

CRW(i) = interaction between creep feed and weaning

= CR(i) * W(i)

CRDC(i) = interaction between creep feed and dehorn-castrate

= CR(i) * DC(i)

CRV(i) = interaction between creep feed and vaccination

= CR(i) * V(i)

CRD(i) = interaction between creep feed and age of dam

= CR(i) * D(i)

= D(i) if CR(i) = 1

= 0 otherwise

WDC(i) = interaction between weaning and dehorn-castrate

= W(i) * DC(i)

WV(i) = interaction between weaning and vaccination

= W(i) * V(i)

WD(i) = interaction between weaning and age of dam

= W(i) * D(i)

DCV(i) = interaction between dehorn-castrate and vaccination

= DC(i) * V(i)

Thus the model is written as follows:

(1) $WG(i) = \beta_0 + \beta_1 RP(i) + \beta_2 Y2(i) + \beta_3 Y3(i) + \beta_4 CR(i) + \beta_5 W(i) + \beta_6 DC(i) + \beta_7 V(i) + \beta_8 M(i) + \beta_9 L(i) + \beta_{10} D(i) + \beta_{11} C(i) + \beta_{12} CRRP(i) + \beta_{13} CRW(i) + \beta_{14} CRDC(i) + \beta_{15} CRV(i) + \beta_{16} CRD(i) + \beta_{17} WDC(i) + \beta_{18} WV(i) + \beta_{19} WD(i) + \beta_{20} DCV(i) + U(i)$ where the β are unknown parameters and U(i) is a random error term.

So by using dummy variables, one can easily define variables which capture the performance and timing of the management practices. The dummies representing the management practices capture the linear effect of the practices on weight gain. This is shown by using creep feeding as an example. If an animal is creep fed and no other practices are performed by the producer (also all other dummies are assumed to equal zero) then $E(WG(i)|CR(i)=1$, all other dummies $= 0) = \beta_0 + \beta_4 + \beta_{10} D(i) + \beta_{11} C(i)$. This can be rewritten as $\beta_4 = E(WG(i)|CR(i)=1$, all other dummies $= 0) - E(WG(i)|$all dummies $= 0)$ which says that β_4 is the experimental effect of creep feeding when none of the other management practices are performed; all other dummies being zero. Also, it should be noted that β_0 is the intercept term when all of the dummy variables in equation (1) are equal to zero. The definitions of the dummy variables also allow one to look at the effect that certain combinations of practices (interactions) have on weight gain. These interactions allow for any nonlinear effects to be incorporated in the model. For example, the interaction term CRW(i) looks at the effect of creep feeding, and weaning the calf 42 days before sale date (because if CRW(i)=1 then CR(i)=1 and W(i)=1). Thus $E(WG(i)|CR(i)=W(i)=CRW(i)=1;$ all other dummies $=0) = \beta_0 + \beta_4 + \beta_5 + \beta_{13} + \beta_{10}D(i) + \beta_{11}C(i)$, and $\beta_4 + \beta_5 + \beta_{13}$ is the effect of creep feeding and weaning 42 days before sale when no other practices are performed. So the existence of the interaction added β_{13} more to weight gain than the linear effects of the practices added.

Breakeven Model

The breakeven model looks at economic returns from performing certain combinations of the management practices. A management practice is profitable if the total revenue received from the treated calf exceeds the total revenue obtained from the untreated calf plus the cost per calf of the specified practice. This can be stated more formally and concisely by the following expression:

(2) $P_2(j)\ W_2(j) \geq P_1(j)\ W_1(j) + CM(j)$

where: M(j) =management practice or combination of practices under consideration

$W_2(j)$ =weight of calf at sale date if M(j) is employed

$W_1(j)$ =weight of calf at sale date if $M(j)$ is not employed

$P_2(j)$ =selling price per cwt. if $M(j)$ is employed

$P_1(j)$ =selling price per cwt. if $M(j)$ is not employed

$CM(j)$ =per calf cost of $M(j)$

To determine the breakeven price of a specifed combination of management practices, expression (2) is rewritten as:

(3) $P_2(j) \geq [P_1(j)\ W_1(j) + CM(j)]/W_2(j)$

Thus in order to compute a breakeven price for a specified combination of management practices, one needs to know $P_1(j)$, $W_1(j)$, $W_2(j)$, and $CM(j)$. Values for $W_1(j)$ and $W_2(j)$ are estimated from equation (1) but values for $P_1(j)$ and $CM(j)$ need to be determined from other sources.

Since the price of calves varies over time and regional area, it seems logical to specify a range or distribution of prices for animals not receiving any of the specified management practices ($P_1(j)$). This eliminates the need to statistically estimate a value for $P_1(j)$, which would probably be difficult to accomplish with any accuracy. Also, by using a distribution of prices a sensitivity analysis is incorporated into the model. Thus, a producer can look at how much the breakeven price changes due to a change in $P_1(j)$.

The costs of the different management practices, $CM(j)$, are estimated from the data in the Animal Science study, estimated weight gain coefficients, and veterinarian fees. Creep feeding costs are determined by multiplying the pounds of gain attributable to creep feeding by the pounds of creep feed per extra pound of gain by the estimated cost per pound of the creep feed. The pounds of gain attributable to creep feeding are obtained from the estimated coefficients of the weight gain model. For example, if the calves are creep fed only, then β_4 from equation (1) is the weight gain attributable to creep feeding. If the calves are weaned 42 days before sale and creep fed, then the weight gain attributable to creep feeding is $\beta_4 + \beta_{13}$ and so on. The creep feed conversion rates used in this paper are listed in Table 2. Castrating, dehorning, vaccination and grub treatment costs are estimated from veterinarian fees for these treatments. Here again, the cost of creep feed and veterinarian fees varies over time and area so a range of costs are specified for each practice or combination of practices. This distribution allows for a sensitivity analysis to be incorporated for the costs. The distribution of veterinarian fees used in this paper are listed in Table 3.

It should be noted here that the producer can perform the practices himself instead of having a veterinarian perform them and save on veterinarian costs. But in order to get a certificate in the Iowa Preconditioned Calf Program, a veterinarian must administer the vaccinations. Also, the age at which the calf is dehorned and castrated in the Animal Science study probably dictates that a veterinarian perform those operations. Another reason why veterinarian fees are used is that it is difficult to reasonably estimate the cost of a practice performed by an individual producer. A producer performing castration and dehorning himself can determine his costs and use them to determine his breakeven price using the same procedure presented in this paper.

TABLE 2. Feed Conversion Rates

Time Period	Weaned Nov. 1 42 Days Before Sale: Creep Fed		Weaned Nov. 1 42 Days Before Sale: Noncreep Fed		Weaned Dec. 13 On Sale Date: Creep Fed	Weaned Dec. 13 On Sale Date: Noncreep Fed
Sept.18 to Nov.1	12.7 lbs. creep/extra lb. of gain		----		12.7 lbs. creep/extra lb. of gain	----
	G/S[a]	Hay[b]	G/S	Hay		
Nov.1 to Dec.13	4.3	5.6	4.5	7.2	7.8 lbs. creep/extra lb. of gain	----

[a] G/S stands for the pounds of grain and protein supplement for each pound of gain.

[b] Hay stands for the pounds of hay for each pound of gain.

TABLE 3. Cost of Veterinarian Services for One calf

Service	Average Cost[a]	Range[a] High	Low
Vaccination	$3.50	$6.00	$2.50
Grub Treatment	1.00	1.25	0.75
Dehorning	1.50	3.00	1.00
Castrating	1.50	3.00	1.00

[a] These cost averages and ranges were estimated by Dr. Daryl Strohbehn, Extension Livestock Specialist; and Dr. John B. Herrick, Extension Veterinarian.

Some management practices include additional costs beyond the cost of just performing the practice. If a producer weans his calves before the sale date, he needs a separate area or facility to put the calves in after weaning. Thus, there is a facility charge made against the calves weaned early. Also, the calves weaned early have a higher morbidity rate and a slightly higher death loss in the Animal Science study. So there are additional health costs and death losses in the calves weaned before the sale date. (It should be noted that the difference in death loss between calves weaned early and the calves weaned at sale date is not statistically different than zero but it is an added cost that the producer should consider.) Finally, the cost of not weaning the calves until sale date needs to be considered. Leaving a large calf on the cow for a longer period of time may cause a detrimental effect on the cow's longevity and body maintenance. This leads to a lower cull value and reproductive rate.

This study explicitly includes estimates for the additional facility charge and health costs for the early weaned calves. Estimates for these costs are obtained from Dr. Strohbehn who participated in the Animal Science study. Additional death loss and cow costs are not explicitly included because there is no statistical difference in death loss in the Animal Science study and it is difficult to obtain reasonable estimates on the costs of leaving a calf on the cow for a longer period. But, as mentioned previously, these two factors should be taken into account by the producer in making his decision.

Once a distribution of prices, $P_1(j)$, and costs, $CM(j)$, are established, a schedule of breakeven prices, $P_2(j)$, from equation (3) can be computed. For example, if there are three different values of $P_1(j)$ and three values of $CM(j)$, a schedule with nine breakeven values of $P_2(j)$ can be computed as in Table 4 where the values of $W_1(j)$ and $W_2(j)$ are estimated from equation (1). To use this schedule, a producer selects the values of $P_1(j)$ and $CM(j)$ that are appropriate for his operation and reads across the row to find the value of $P_2(j)$ necessary to break even. If the producer thinks he can obtain a higher price than the breakeven price, he should use the management practices considered.

TABLE 4. Breakeven Schedule

	$P_1(j)$	$CM(j)$	Breakeven $P_2(j)$
1)	$P_1(j),1$	$CM(j),1$	$(P_1(j),1W_1(j) + CM(j),1)/W_2(j)$
2)	$P_1(j),2$	$CM(j),1$	$(P_1(j),2W_1(j) + CM(j),1)/W_2(j)$
3)	$P_1(j),3$	$CM(j),1$	$(P_1(j),3W_1(j) + CM(j),1)/W_2(j)$
4)	$P_1(j),1$	$CM(j),2$	$(P_1(j),1W_1(j) + CM(j),2)/W_2(j)$
5)	$P_1(j),2$	$CM(j),2$	$(P_1(j),2W_1(j) + CM(j),2)/W_2(j)$
6)	$P_1(j),3$	$CM(j),2$	$(P_1(j),3W_1(j) + CM(j),2)/W_2(j)$
7)	$P_1(j),1$	$CM(j),3$	$(P_1(j),1W_1(j) + CM(j),3)/W_2(j)$
8)	$P_1(j),2$	$CM(j),3$	$(P_1(j),2W_1(j) + CM(j),3)/W_2(j)$
9)	$P_1(j),3$	$CM(j),3$	$(P_1(j),3W_1(j) + CM(j),3)/W_2(j)$

STATISTICAL MODELS

Weight Gain Model

The weight gain model that is to be statistically estimated is given in equation (1). This equation can also be rewritten as:

(4) $Y = X\beta + U$

where;

$$Y = \begin{bmatrix} WG_1 \\ WG_2 \\ \cdot \\ \cdot \\ WGn \end{bmatrix}_{(nx1)} \qquad X = \begin{bmatrix} 1 & RP_1 & Y2_1 \ldots\ldots\ldots & DCV_1 \\ 1 & RP_2 & Y2_2 \ldots\ldots\ldots & DCV_2 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ 1 & RPn & Y2n \ldots\ldots\ldots & DCVn \end{bmatrix}_{(nxk)}$$

$$\beta = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \cdot \\ \cdot \\ \beta(k-1) \end{bmatrix}_{(kx1)} \qquad U = \begin{bmatrix} U_1 \\ U_2 \\ \cdot \\ \cdot \\ Un \end{bmatrix}_{(nx1)}$$

n = sample size
k = the number of independent variables plus an intercept

Thus, Y is a (nxl) vector of values of the dependent varible WG(i), X is a (nxk) matrix which contains all of the independent variables as column vectors, β is a (kxl) vector of unknown, fixed parameters, and U is a (nxl) vector of unobservable random error terms. This also shows that the model is linear in the parameters so it is a standard linear model. Now an appropriate estimation procedure must be developed to statistically estimate the parameter β of equation (4).

One possible estimation procedure to use with a model linear in the parameters and an unobservable random error is ordinary least squares (OLS). In this procedure, the unknown parameters are estimated by:

(5) $b = (X'X)^{-1}X'Y$

(Note: in this paper all estimates are lower case letters and all parameters are upper case letters.) This estimator is unbiased and has the lowest variance of all the possible linear unbiased estimators if the following assumptions hold:

1. $E(U) = 0$
2. $E(UU') = \sigma^2 I$
3. Rank of X is k or $|X'X| \neq 0$
4. X is fixed and measured without error

To determine if OLS is an appropriate estimation procedure one must determine if these assumptions seem reasonable. If not, then another estimation procedure must be developed.

When the independent variables are looked at carefully, it becomes evident that the X matrix is not fixed. The age of calf, C(i), appears to be somewhat stochastic in nature. This is due to the fact that the experimenter could control the length of the calving season but not the exact day of birth. Thus, the fourth assumption of OLS is violated because the X matrix is not fixed.

There is a way to get around the stochastic X matrix problem and still be able to use OLS. This solution is to use Asymptotic Distribution Theory and to make some modifications in the first two assumptions.

Asymptotic Distribution Theory looks at the properties of the estimator when the sample size, n, goes to infinity or its large sample properties. The reason for using large sample properties is that the X matrix is stochastic and in small samples, |X'X| may be equal to zero since the X matrix is random. So by using a very large sample, |X'X| converges in probability to a nonzero constant or:

$$\text{plim } 1/n\ (X'X) = \Sigma xx$$

where Σxx is a (kxk) matrix with $|\Sigma xx| \neq 0$

Thus one needs a large sample when a stochastic X matrix is present. This presents no problem here because there are 344 observations in the sample.

Next, because the X matrix is stochastic, the first two assumptions need to be modified to conditional expectations.

(6) 1. $E(U|X) = 0$

2. $E(UU'|X) = \sigma^2 I$

The most important of these two is the exogeneity restriction: $E(U|X) = 0$. This says that with a stochastic X matrix, the OLS estimator is unbiased only if the error terms and the independent variables are independent of each other. This is a difficult assumption to justify since the error terms are not observable. So one needs to think about what sort of things are in the U's and are they independent of the variables in the X matrix. The error term, U(i), contains all factors that influence weight gain that are not included in the X matrix. These factors include genetics, biological differences, etc. It seems likely that the age of the calf is independent of these factors and thus the exogeneity restriction holds.

Another problem with the modified OLS assumptions is that the assumption $E(UU'|X) = \sigma^2 I$ is too restrictive. This says that the error terms are homoscedastic and uncorrelated with each other. But some of the early results indicate that the error terms are not homoscedastic but heteroscedastic. Therefore, a Generalized Least Squares (GLS) estimator is more appropriate than an OLS estimator.

In GLS, the assumption $E(UU'|X) = \sigma^2 I$ is modified to $E(UU'|X) = \sigma^2\Omega$ where Ω is a (nxn) positive definite matrix. The GLS estimator for β is then:

(7) $b = (X'\Omega^{-1}X)^{-1}X'\Omega^{-1}Y$

This estimator is unbiased and has minimum variance in its class of estimators[2].

Now a consistent estimator can be developed that is appropriate for the weight gain model. This estimator has the following assumptions:

1. $E(U|X) = 0$
2. $E(UU'|X) = \sigma^2\Omega$
3. $\lim_{n\to\infty} 1/n(X'\Omega^{-1}X) = \Sigma xx$

where Σxx is a (kxk) matrix and $|\Sigma xx| \neq 0$

Thus, the Generalized Least Squares (GLS) estimator in equation (7) is a consistent estimator of β or

(8) $\lim_{n\to\infty} P(|b(GLS) - \beta|<\varepsilon) = 1$

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[2] C. Radhakrishna Rao, Linear Statistical Inference and Its Applications, 2nd Ed. (New York: Joh Wiley & Sons, 1973), pp. 220-230.

where ε is a very small, positive, arbitrary constant.

OR

plim $b(GLS) = \beta$

Also in this paper, Ω is assumed to be a known, diagonal matrix, whose value equals ω, which is estimated from the sample data.

Another assumption that needs to be made is that the error terms are normally distributed or

(9) $U \sim NID\ (0,\ \sigma^2\Omega)$

This assumption is needed in order for the test statistics, t and F, to have the appropriate distributions. In this paper, it is appropriate to make this assumption because the sample size is large and the Central Limit Theorem concludes that as the sample size becomes large the variables' distribution becomes approximately normal.

The sample obtained from the Iowa State University Animal Science Department study originally contained 424 observations, but only 344 of these observation are used to estimate the weight gain model. The basis for using a truncated sample is in the experimental design of the Animal Science study. This design set the length of the calving season to 60 days and any cow that had not given birth near the end of the calving season was injected with a drug to induce labor. Thus, the calves born because of the induced labor were slightly premature. These premature calves caused problems in the variable C(i), age of calf at sale date, because calves born a week or two early are a week or two older at the sale date than they should be. To correct this problem, the observations from the premature calves are dropped from the sample. In order to minimize or avoid possible bias in the weight gain estimates due to nonrandom deletion of observations, observations from the oldest calves are also deleted. The observations dropped from the original sample are the calves whose ages are not in a range of plus or minus twenty days from the mean age at sale date of 247 days. Thus, all calves in the sample are between 227 and 267 days old at sale date.

Breakeven Model

In order to estimate a breakeven price in equation (3), estimates for $W_1(j)$ and $W_2(j)$ must first be obtained from equation (1).

(3a) $p_2(j) = [P_1(j)\ w_1(j) + CM(j)]/w_2(j)$

These estimates, $w_1(j)$ and $w_2(j)$, are random variables and thus the estimated breakeven price, $p_2(j)$, is also a random variable.

Since the estimated breakeven price is a random variable, one needs to determine its sample properties. The distribution of equation (3a), the breakeven price, is of the form of a ratio of normal random variables since $w_1(j)$ and $w_2(j)$ are normal random variables. Therefore, the distribution of $p_2(j)$ does not have finite sample moments. This is shown by considering a normal random variable X^{-1} with mean μ and variance σ^2 The first moment of X^{-1} is:

$$(10)\quad E(X^{-1}) = \int_{-\infty}^{\infty} \frac{X^{-1}}{\sigma\sqrt{2\pi}}\, e^{-\frac{1}{2}\sigma^2(x - \mu)^2}$$

which is not defined. So because no finite sample moments exist, the estimated breakeven price, $p_2(j)$, is a biased estimator; $E[p_2(j)] \neq P_2(j)$. But when the asymptotic properties are considered, it can be shown that

$p_2(j)$ is a consistent estimator of $P_2(j)$ or

(11) $\lim_{n \to \infty} P(|p_2(j) - P_2(j)| < \varepsilon) = 1$

where ε is a very small, positive, arbitrary constant. This is because $p_2(j)$ is a continuous function of $w_1(j)$ and $w_2(j)$ which are normal random variables with mean of $W_1(j)$ and $W_2(j)$. So as the sample size goes to infinity, the values of $w_1(j)$ and $w_2(j)$ tend toward $W_1(j)$ and $W_2(j)$, and $p_2(j)$ tends toward $P_2(j)$.

Also, since the estimated breakeven price is random, appropriate confidence intervals are estimated to give information on its dispersion. This is a little more difficult because $p_2(j)$ is derived from $w_1(j)$ and $w_2(j)$, which are derived from the estimated coefficients of equation (1). So a method must be developed to compute the appropriate confidence intervals.

An approach proposed by E. C. Fieller[3] is used to compute the confidence intervals of the estimated breakeven price. This method uses equation (3a) by letting $R = p_2(j)$, $V_2 = w_2(j)$, and $V_1 = P_1(j)\ w_1(j) + CM(j)$ or

(12) $R = V_1/V_2$

Thus, this method computes the confidence interval for the ratio V_1/V_2. Equation (12) can be rewritten as

(13) $V_1 - RV_2 = 0$

with equation (13) being normally distributed (because $w_1(j)$ and $w_2(j)$

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[3] E. C. Fieller, "The Distribution of the Index in a Normal Bivariate Population," Biometrika 24 (1932):428-40.

are normal) with mean of zero and variance of

(14) $Var(V_1) + R^2 Var(V_2) - 2R\ Cov(V_1,V_2)$

The values of the variances and covariance of V_1 and V_2 are computed by:

(15) $Var(V_1) = P_1(j)^2\ Var[w_1(j)]$

(16) $Var(V_2) = Var[w_2(j)]$

(17) $Cov(V_1,V_2) = P_1(j)\ Cov[w_1(j),w_2(j)]$

Since the variances and covariance of V_1 and V_2 are functions of $P_1(j)$, and $w_1(j)$, and $w_2(j)$; then the value of equation (14) is computed from sample data.

Next a t-statistic is developed to use in the estimation of the confidence interval. In order for this statistic to be a t distribution, the numerator must have a standard normal distribution and the denominator a chi-squared distribution. Therefore,

$$(18)\quad \frac{(V_1-RV_2)}{\sqrt{\{Var(V_1)+R^2Var(V_2)-2RCov(V_1,V_2)\}}} \sim t_{n-k}$$

is distributed as a student's t distribution with (n-k) degrees of freedom, where (n-k) is the number of degrees of freedom of the t distribution of V(i)/[Var(i)]. So the α confidence interval of R = $p_2(j)$ is defined by the values of R such that

$$(19)\quad P\{\frac{(V_1-RV_2)^2}{[Var(V_1)+R^2Var(V_2)-2RCov(V_1,V_2)]}\}<(t_{1-\alpha/2})^2=1-\alpha$$

Simplifying equation (19) gives a quadratic expression for R which is solved to give the endpoints of the α confidence interval for $p_2(j)$. Rewriting (19) gives

$$(20)P\{R^2[V_2{}^2-t^2Var(V_2)]-2R[V_1V_2-t^2\ Cov(V_1,V_2)]+V_1{}^2-t^2Var(V_1)\le 0\}=1-\alpha.$$

An example of this procedure is presented in an article by Wayne A. Fuller[4].

The last step that needs to be done is the actual computation of V_1, V_2, and their variances and covariance. These estimates are obtained from the estimation of equation (1). As discussed previously, the GLS estimator of β is $b = (X'\Omega^{-1}X)^{-1}X'\Omega^{-1}Y$. The variance-covariance matrix of the elements of β is computed as

(21) $Var(b) = s^2(X'\Omega^{-1}X)^{-1}$

where: s^2 is the sample variance of the estimated weight gain model

$s^2 = (Y - Xb)\Omega^{-1}(Y - Xb)'/n-k$

which helps determine the variances and covariance of V_1 and V_2.

This paper is using the estimated weight gain model to be able to predict the weight gain of animals that are subjected to certain management practices. So GLS is used as a prediction tool. But there are two types of prediction: individual and mean predictions. A farmer who has a group of calves is more interested in the mean weight gain predicted for all of his animals so the mean prediction method is used in this paper. These mean predictions give the values of $w_1(j)$, and $w_2(j)$ and their variances and covariance; and thus the values of V_1, V_2, and their variances and covariance.

The mean predictions are obtained from

(22) $wg_1(j) = X1'b$

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[4] Wayne A. Fuller, "Estimating the Reliability of Quantites Derived from Empirical Production Functions," Journal of Farm Economics 44, No. 1 (February 1962), 82-99.

(23) $wg_2(j) = X2'b$

where X1' is a row vector of values of the independent variables if M(j), the management practice or combination of practices, is not employed; and X2' is the row vector if M(j) is employed. The variances and covariance of the predicted means are

(24) $Var[wg_1(j)]=X1'Var(b)X1=s^2X1'(X'\Omega^{-1}X)^{-1}X1$

(25) $Var[wg_2(j)]=X2'Var(b)X2=s^2X2'(X'\Omega^{-1}X)^{-1}X2$

(26) $Cov[wg_1(j),wg_2(j)]=X1'Var(b)X2=s^2X1'(X'\Omega^{-1}X)^{-1}X2$

The values of $w_1(j)$ and $w_2(j)$ are obtained from

(27) $w_1(j) = WB(i) + wg_1(j)$

(28) $w_2(j) = WB(i) + wg_2(j)$

where WB(i) equals the weight of the animal at 160 days. Now the values of V_1, V_2 and their variances and covariance are obtained by using equations (22) through (28) and known values of $P_1(j)$ and CM(j) by

(29) $V_1 = P_1(j)w_1(j) + CM(j)$

(30) $V_2 = w_2(j)$

(31) $Var(V_1) = P_1(j)^2\ Var[wg_1(j)]$

(32) $Var(V_2) = Var[wg_2(j)]$

(33) $Cov(V_1,V_2) = P_1(j)\ Cov[wg_1(j),wg_2(j)]$

Then the values of equations (29) through (33) are substituted into equation (20) to obtain the confidence interval for $p_2(j)$.

RESULTS

Weight Gain Model

To obtain estimates of the effects of different management practices upon weight gain, a modified version of equation (1) is statistically estimated. Equation (1) is modified because some of the early results indicated that several additional variables should be included in the model. These additional variables are:

H(i) = 1 if the ith animal is horned

= 0 if the ith animal is polled

WB(i) = weight of ith animal at 160 days (Sept. 23)

WBM(i)= interaction between weight of ith animal at 160 days and medium size group

= WB(i) * M(i)

= WB(i) if M(i) = 1

= 0 otherwise

The horn variable, H(i), is included because the dehorning-castration variable, DC(i), may not be picking up the entire effect that dehorning has on weight gain. This is because only 30% of the calves in the Animal Science study were horned, so not all of the calves castrated 28 days before weaning were also dehorned. Thus, not all of the calves that are assigned a DC(i)=1 value are subjected to the same stress level. The variables WB(i) and WBM(i) are included because some of the early results found these variables to be statistically significant. Thus, the final specification of the weight gain model is:

(1a) $WG = \beta_0 + \beta_1 RP(i) + \beta_2 Y2(i) + \beta_3 Y3(i) + \beta_4 CR(i) + \beta_5 W(i) + \beta_6 H(i) + \beta_7 DC(i) + \beta_8 V(i) + \beta_9 M(i) + \beta_{10} L(i) + \beta_{11} D(i) + \beta_{12} C(i) + \beta_{13} CRRP(i) + \beta_{14} CRW(i) + \beta_{15} CRDC(i) + \beta_{16} CRV(i) + \beta_{17} CRD(i) + \beta_{18} WDC(i) + \beta_{19} WV(i) + \beta_{20} WD(i) + \beta_{21} DCV(i) + \beta_{22} WB(i) + \beta_{23} WBM(i) + U(i)$

At this point, it is appropriate to digress a little from reporting the results to help the reader understand how the results are obtained. As mentioned earlier, this paper concludes that a GLS estimation procedure is appropriate for the weight gain model. But this is not the original hypothesis about the model. The early results, which are the basis of the model modification, are obtained from an OLS estimation procedure. It is the use of these OLS results that lead to the assumption of heteroscedasticity and the use of GLS as the appropriate estimation procedure. To allow the reader to compare the results obtained from OLS, with the assumption of homoscedasticity, to GLS, with the assumption of heteroscedasticity, the results of estimating equation (1a) by OLS are listed in Table 5 (the standard errors are in parentheses below the estimated coefficients).

As mentioned in the previous paragraph, the early OLS results lead to the assumption of heteroscedasticity. This conclusion is obtained from performing a residual analysis on the full model estimated by OLS. A residual analysis plots the residuals from the estimated model against the independent and dependent variables to see if the assumptions of the statistical model hold. In this case, the question is does the OLS assumptions hold? In the residual analysis, the plot of the residuals against CR(i), creep feeding, suggested that the OLS assumption of

TABLE 5. OLS Results

$$
\begin{aligned}
WG = {} & \underset{(48.822)}{172.076^{***}} - \underset{(4.770)}{11.881RP^{***}} - \underset{(4.466)}{6.058Y2} + \underset{(4.264)}{2.274Y3} + \underset{(10.257)}{50.684CR^{***}} \\
& + \underset{(9.578)}{4.024W} - \underset{(3.928)}{10.331H^{***}} - \underset{(6.788)}{18.498DC^{***}} - \underset{(6.909)}{13.061V^{*}} - \underset{(24.400)}{37.544M} \\
& + \underset{(4.864)}{18.773L^{***}} + \underset{(1.044)}{0.971D} - \underset{(0.190)}{0.202C} - \underset{(6.738)}{2.449CRRP} - \underset{(6.751)}{28.237CRW^{***}} \\
& + \underset{(6.833)}{2.943CRDC} + \underset{(6.762)}{5.192CRV} - \underset{(1.194)}{0.992CRD} + \underset{(6.787)}{21.320WDC^{***}} \\
& + \underset{(6.771)}{11.396WV^{*}} - \underset{(1.188)}{1.219WD} + \underset{(6.731)}{0.769DCV} + \underset{(0.043)}{0.059WB} + \underset{(0.063)}{0.112WBM^{*}} + e(i)
\end{aligned}
$$

$s^2 = 963.943$
e(i) = residual
* significant at .10 level
*** significant at .01 level

homoscedasticity did not hold. In the economic models section, CR(i) is defined as a binary variable and if the assumption of homoscedasticity is to hold, the residual variances from animals that are creep fed (CR=1) and those not creep fed (CR=0) should be the same. But the residual analysis found the creep fed calves have a larger residual variance, 1306.290, than noncreep fed calves, 497.578. This clearly shows that the OLS assumption of homoscedasticity is not appropriate for the weight gain model.

One point that needs to be made about the residual analysis is that there are inherent difficulties in using the residuals to test the assumptions of U(i), the random error term. It can be shown mathematically that the residuals are unbiased estimators of U(i) but they may be heteroscedastic and correlated with each other while the U(i)'s are actually homoscedastic and uncorrelated with each other. Thus, the residuals may suggest that the assumptions about the U(i)'s in the statistical model are not appropriate when they really are appropriate. In this case though, the large differences in the residual variances indicate that the random error terms are heteroscedastic.

Now that GLS is supported by the residual analysis of the OLS results, an estimate of the Ω matrix is developed so equation (1a) can be estimated by GLS. As previously mentioned, Ω is assumed to be a known, diagonal matrix whose value, ω, is estimated from the sample data. The estimates of the diagonal elements of ω are the residual variance ratio of creep feeding to noncreep feeding obtained from the OLS results and ones. If the calf is not creep fed, the corresponding diagonal element of ω takes on the value of one. If the calf is creep fed, the corresponding diagonal element is the residual variance ratio: 1306.290/497.578 = 2.625. This can be stated in matrix form as:

$$34)\ \omega = \begin{bmatrix} \begin{matrix} 1 & \cdots & 0 \\ 0 & 1 \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & 0 \cdots & 1 \end{matrix} & \underset{\sim}{0} \\ \underset{\sim}{0} & \begin{matrix} 2.625 & \cdots & 0 \\ 0 & 2.625 \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & 0 \cdots & 2.625 \end{matrix} \end{bmatrix}$$

Due to the difficulties mentioned earlier in using the residual variances as estimators for the variances of the error term's (U(i)'s), the residual variance ratio from the sample may not be the actual variance ratio of the error terms. Thus, the residual variance ratio from the OLS results(equation (34)) is used as an initial value of ω in an iterative search procedure. The goal of this iterative search is to find a ω matrix that has a residual variance ratio of creep feeding to noncreep feeding, from GLS, of approximately one. The ω matrix that is used in estimating equation (1a) replaces the diagonal values of 2.625 in equation (34) with the value of 3.00. This gives a residual variance ratio of 1.06.

The results of estimating equation (1a) by GLS are listed in Table 6. The numbers in parentheses below the estimated coefficents are the standard errors of the estimates. These results are similar to those obtained by using OLS (Table 5) to estimate equation (1a). All the variables that are significant in the OLS results are also significant in the GLS results and the values of those significant coefficients are fairly close to one another. In the GLS results, Y2(i) and WB(i) are significant but they are not significant in the OLS results.

TABLE 6. GLS Full Model

$$WG = \underset{(42.082)}{140.854^{***}} - \underset{(3.392)}{11.749^{***}RP} - \underset{(3.910)}{11.775^{***}Y2} - \underset{(3.752)}{1.791Y3} + \underset{(10.133)}{48.585^{***}CR}$$

$$+ \underset{(8.061)}{5.281W} - \underset{(3.452)}{6.164^{*}H} - \underset{(5.329)}{16.125^{***}DC} - \underset{(5.519)}{11.985^{**}V} - \underset{(21.069)}{31.459M}$$

$$+ \underset{(4.133)}{14.556^{***}L} + \underset{(0.801)}{0.710D} - \underset{(0.166)}{0.156C} - \underset{(6.753)}{2.523CRRP} - \underset{(7.758)}{28.157^{***}CRW}$$

$$+ \underset{(6.827)}{3.777CRDC} + \underset{(6.765)}{4.016CRV} - \underset{(1.190)}{0.712CRD} + \underset{(5.907)}{19.120^{***}WDC} + \underset{(5.914)}{13.020^{**}WV}$$

$$- \underset{(1.039)}{1.245WD} - \underset{(5.857)}{2.092DCV} + \underset{(0.036)}{0.120^{***}WB} + \underset{(0.055)}{0.094^{*}WBM} + e(i)$$

$s^2 = 484.970$
* significant at .10 level
** significant at .05 level
*** significant at .01 level

To help in forecasting weight gain, a reduced model is developed. This model contains all of the significant variables in Table 6 except for WBM(i). The results from estimating this reduced model are listed in Table 7. The reason why WBM(i) is not included in the reduced model is that when all of the nonsignificant coefficients in Table 6 are dropped, WBM(i) becomes nonsignificant (its significance level becomes greater than 10%).

TABLE 7. GLS Reduced Model

$$
\begin{aligned}
WG = {} & \underset{(10.777)}{95.012} - \underset{(2.904)}{12.448RP} - \underset{(3.383)}{10.847Y2} + \underset{(4.644)}{48.241CR} - \underset{(3.287)}{7.211H} \\
& - \underset{(3.864)}{16.043DC} - \underset{(3.892)}{11.288V} + \underset{(3.414)}{11.323L} - \underset{(6.379)}{28.163CRW} + \underset{(4.794)}{19.799WDC} \\
& + \underset{(4.970)}{11.613WV} + \underset{(0.026)}{0.149WB} + e(i)
\end{aligned}
$$

$s^2 = 479.575$
All coefficients are significant at .01 level except the coefficents on H(i) and WV(i) which are significant at the .05 level

To see if this reduced model is appropriate, an F-test is performed with the following hypothesis:

Ho: $\beta_3=\beta_5=\beta_9=\beta_{11}=\beta_{12}=\beta_{13}=\beta_{15}=\beta_{16}=\beta_{17}=\beta_{20}=\beta_{21}=\beta_{23}=0$
Ha: not Ho

F is calculated from the estimation results as follows:

$$35)\ F = \frac{\{SSR(r) - SSR(f)\}/ Kr}{SSR(f)/ n - Kf} \quad \text{:with Kr, n-Kf degrees of freedom}$$

Where: SSR(r)= sum of squares residual - reduced model
SSR(f)= sum of squares residual - full model
Kr = number of variables dropped from the full model
Kf = number of variables plus an intercept in full model
n = sample size

If F is less than a tabular value of $F(\alpha)$ with the same degrees of freedom, one can not reject the null hypothesis. From the results, F = 0.692 with 12 and 320 degrees of freedom and $F(\alpha)$ .05,12,320 $\approx$ 1.75.

Thus, $F < F(\alpha)$, so one can not reject the null hypothesis at the $\alpha = .05$ significance level. So the reduced model given in Table 7 is appropriate to use in forecasting weight gain.

With the reduced model determined, one needs to check the signs on the estimated coefficients to see if they make sense. The negative signs on RP(i) and Y2(i) are plausible since the weather conditions in 1979 were poor and one of the replicated pastures may have been of better quality. The positive sign on creep feeding makes sense because one would think that creep feeding would increase weight gain. The negative signs on DC(i) and V(i) make sense because dehorning, castration, and vaccination are very stressful events for the calves and should reduce weight gain. A positive sign on L(i) is plausible since a larger sized calf should gain more than a smaller calf. CRW(i)'s negative sign makes sense because it says that earlier weaned (42 days before sale), creep fed calves do not gain as much weight from creep feeding as the later weaned, creep fed calves. This is logical since the early weaned, creep fed calves are not on creep feed as long as the creep fed calves that are weaned at sale date. The positive signs on WDC(i) and WV(i) says that calves dehorned, castrated, and vaccinated 28 days before weaning, and weaned 42 days before sale date gain more weight than the other calves. This is consistent with the findings of the Animal Science study. WB(i)'s positive sign makes sense because one would expect that the larger a calf is on September 23, the more weight it would gain. The negative sign of H(i) is reasonable because a horned calf should gain less than a polled calf since the horned calf is dehorned and the polled calf is not. Thus, all of the signs of the coefficients are what one would expect them to be.

The reader may have noticed that the weight gain results did not report any values for R^2. The reason for this is that the R^2 statistic is not appropriate with the GLS estimation procedure used. This estimation procedure uses a (nXn) matrix P, such that $PP'=\Omega^{-1}$, to transform equation (4) to:

$$\text{(4a)}\quad PY = PX\beta + PU$$
$$\text{OR}$$
$$Y^* = X^*\beta + U^*$$

The transformed equation is then estimated by OLS because it now meets the assumptions necessary to use OLS. The estimator is:

$$\text{(5a)}\quad b = (X^{*\prime}X^*)^{-1}X^{*\prime}Y^*$$
$$= (X'P'PX)^{-1}X'P'PY$$
$$= (X'\Omega^{-1}X)^{-1}X'\Omega^{-1}Y$$

which is the same as the GLS estimator. But the transformed model no longer has a constant intercept term because the column of ones in the X matrix are multiplied by the elements in the P matrix. It is this lack of an intercept term that causes the R^2 value to be inappropriate because the R^2 statistic requires that an intercept be included in the model.

Breakeven Model

Before proceeding on to the actual breakeven prices and confidence intervals, its seems appropriate to discuss the possible size of the breakeven analysis in this paper. As mentioned earlier, the four main treatments in this paper gives rise to 16 different treatment combinations. Since all of the main treatments are included in the reduced model in Table 7 through linear terms or interactions, there are 15 possible breakeven price schedules for just the main treatments (one of the treatments is the control). But also the variables for frame size and horned calves are significant in the reduced model. When considering these variables, the number of possible breakeven price schedules becomes 60. Thus, the size of the breakeven analysis becomes unwieldy when considering all possible breakeven price schedules.

To solve the size problem in the breakeven analysis, only seven of the sixteen possible main treatments, plus a control group, are explicitly analyzed. These seven treatment combinations are listed in Table 8. These seven treatments were chosen because it was felt that a producer would dehorn, castrate, vaccinate and grub treat at the same time so he would not have to run the calves through a holding facility more than once. Also, these seven treatments will be analyzed across all frame sizes and then analyzed looking at the frame size differences. To obtain results for all frame sizes of calves, assign a value of 1/3 to the ij-th element of X1' and X2' from equations (22) and (23) that corresponds to the large frame size variable coefficent in the b vector from Table 7. The value of 1/3 gives the average frame size effect in the estimated weight gain because there are three different frame sizes. These values are then substituted into equations (27) through (33) to obtain the breakeven price and confidence interval.

To develop a breakeven schedule, estimates must first be obtained

TABLE 8. Treatment Combinations Analyzed

M(j)	Creep Feed	Weaning Date	Preconditioning Date[a]
1	Sept. 23 - Dec. 13	Dec. 13	Dec. 14
2	Sept. 23 - Nov. 1	Nov. 1	Nov. 2
3	Sept. 23 - Dec. 13	Dec. 13	Nov. 15
4	Sept. 23 - Nov. 1	Nov. 1	Oct. 4
5	None	Dec. 13	Nov. 15
6	None	Nov. 1	Oct. 4
7	None	Nov. 1	Nov. 2
Control	None	Dec. 13	Dec. 14

[a] Date of dehorning, castration, vaccination, and grub treatment.

for $w_1(j)$ and $w_2(j)$; the weight of the calf at sale date if M(j) is not employed and if M(j) is employed. These estimates are obtained by using equations (22), (23), (27), (28) and the results from the reduced weight gain model in Table 7. First, values for X1' and X2' in equations (22) and (23) must be determined to forecast the weight gains of the control group and the calves subjected to the various management practices. These vectors are then post multiplied by the b column vector which contains the estimated coefficients in Table 7. But there is a problem in determining the X1' and X2' vectors that forecast weight gain for all calves because of the significant replication and year effect variables.

To get a forecast of the weight gain of a calf across all replications and years, X1' and X2' are developed to include average replication and year effects. A value of 1/2 is used to get the average replication effect because there were two replications, and a value of 1/3 is used for the average year effect because there were three years. The values of 1/2 and 1/3 are assigned to the RP(i) and Y2(i) positions in the vectors X1' and X2'. Thus, 1/2 is multiplied by the estimated replication coefficient to get the average replication effect and 1/3 is multiplied by the estimated second year coefficient to get the average year effect.

Now values for X1' and X2' can be determined to forecast the weight gain of the calves across all replications, years, and frame sizes. The vectors that are used to forecast weight gain of polled calves across all frames sizes are:

(36) X1' = [1 1/2 1/3 0 0 0 0 1/3 0 0 0 394.092]

X21' = [1 1/2 1/3 1 0 0 0 1/3 0 0 0 394.092]

X22' = [1 1/2 1/3 1 0 0 0 1/3 1 0 0 394.092]

X23' = [1 1/2 1/3 1 0 1 1 1/3 0 0 0 394.092]

X24' = [1 1/2 1/3 1 0 1 1 1/3 1 1 1 394.092]

X25' = [1 1/2 1/3 0 0 1 1 1/3 0 0 0 394.092]

X26' = [1 1/2 1/3 0 0 1 1 1/3 0 1 1 394.092]

X27' = [1 1/2 1/3 0 0 0 0 1/3 0 0 0 394.092]

The other vectors used to forecast the weight gain of horned calves across all frame sizes, polled calves of different frame sizes, and horned calves of different frame sizes are listed in Appendix 2. The vectors differ only in the values assigned to the horned and large frame size variables in each vector. These vectors are then multiplied by the b vector to obtain $wg_1(j)$ and $wg_2(j)$ in equations (22) and (23). To get $w_1(j)$ and $w_2(j)$, the weight of the animals at 160 days, WB(i) is added to $wg_1(j)$ and $wg_2(j)$. The values of WB(i) that are used are: 394.092, the average beginning weight of all of the calves in the study; 379.681, the average beginning weight of all small and medium frame size calves; and 426.009, the average beginning weight of all large frame size calves. The estimates of $w_1(j)$ and $w_2(j)$ obtained in this study are listed in Appendix 2.

Now that one has estimates of $w_1(j)$ and $w_2(j)$, the next step in developing a breakeven schedule is to determine the costs of each management practice. To do this, the costs of the creep feed ration, the dry feed ration fed after weaning, and the preconditioning practices must be determined. The costs of the various preconditioning practices (dehorning, castration, vaccination, and grub treatment) are listed in Table 3. The creep feed ration that was fed to the calves in the Animal Science study is listed in Table 9. The cost of the cracked shelled corn in Table 9 is based on a corn price of \$2.90 per bushel plus a \$0.001/lb. cost to crack the corn. The costs of the soybean oilmeal and molasses came from the April, 1983 edition of Agricultural Prices[5]. The prices used in Table 9 were prices for Iowa in April, 1983. The price of the soybean oilmeal was the price for 44% soybean meal and the price

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[5] U.S., Department of Agriculture, Agricultural Prices, April 1983 (Washington, D.C.: Government Printing Office, 1983).

of dried molasses was derived from the quoted liquid molasses price of \$8.80/cwt. (the author assumed the liquid molasses was 75% dry matter and 90% molasses thus, (8.80)(.90)/.75 =10.50). The dry feed ration after weaning consisted of grain and supplement, and hay. The grain and supplement portion of this ration consisted of 80% corn and 20%, 36% supplement. The April, 1983 price of 36% beef supplement was \$12.90/ton. So the cost per pound of the grain and supplement portion is \$0.067/pound. Also, in April, 1983 the average price of all hay in Iowa was \$55/ton or \$0.0275/pound. The overall cost of the dry feed is \$0.045/pound for creep fed calves and \$0.043/pound for noncreep fed calves. This difference in the cost per pound is due to different consumption levels of grain and supplement, and hay per pound of gain in creep fed and noncreep fed calves. These costs are based on 4.3 pounds of grain and supplement, and 5.6 pounds of hay per pound of gain for creep fed calves; and 4.5 pounds of grain and supplement, and 7.2 pounds of hay per pound of gain for noncreep fed calves. Now the costs of the individual management practices and a range of costs for each practice can be determined.

The cost of each management practice and the cost ranges used in the breakeven analysis are listed in Appendix 1. These costs are based on the feed and preconditioning costs listed in Table 10. The cost of creep feeding is based on the feed efficiency rates given in Table 2 and the weight gain attributable to creep feeding from the results in Table 7. A calf that is creep fed for the entire 84 days (Sept. 23 - Dec. 13) will gain 48.241 pounds from the creep feeding with 20.078 pounds (β_4 +

TABLE 9. Creep Feed Ration

Ingredients	Pounds	Cost/pound	Cost
Cracked shelled corn	1700	$0.0528	$89.76
Soybean oilmeal	200	0.13	26.00
Molasses (dried)	100	0.105	10.50
Vitamin premix	10	0.20	2.00
Total	2010	$0.064	$128.26

β_{14}) being gained the first 42 days (Sept. 23 - Nov. 1) and 28.163 pounds gained the second 42 days (Nov. 2 - Dec. 13). So the calf will consume 254.99 pounds of creep feed the first 42 days (20.078 * 12.7) and 219.67 pounds the second 42 days (28.163 * 7.8). The consumption rates are then multiplied by the cost per pound of the creep feed to get the total cost. The total dry feed costs after weaning are based on the daily feed consumption rates after weaning in the Animal Science study. These rates were 18.3 pounds consumed daily for calves creep fed before weaning and 17.1 pounds comsumed daily for noncreep fed calves. Thus, the total feed consumption was 768.6 pounds for creep fed calves (18.3lbs./day * 42 days) and 718.2 pounds for noncreep fed calves (17.1lbs./day * 42 days). These total consumption rates are then multiplied by the cost per pound of the dry feed. The facility charge is based on a rate of $0.15 per day per calf for 42 days. Both the facility charge and the health cost are based on estimates obtained from

Dr. Daryl R. Strohbehn. It also should be noted that the average preconditioning costs are based on the average charges listed in Table 3.

TABLE 10. Feed and Preconditioning Costs

	Average	Low	High
Creep feed	\$0.064/lb.	\$0.054/lb.	\$0.074/lb.
Dry feed: creep	0.045/lb.	0.035/lb.	0.055/lb.
noncreep	0.043/lb.	0.033/lb.	0.053/lb.
Preconditioning: horned	7.50/hd.	5.25/hd.	13.25/hd.
polled	6.00/hd.	4.25/hd.	10.25/hd.
Health[a]	3.00/hd.		
Facility	6.30/hd.		

[a] It was assumed that facility and health costs remained constant.

Finally, to be able to compute a breakeven schedule, a range of prices for calves that have not received any of the management practices ($P_1(j)$) must be determined. This price range is for calves that are uncastrated, horned (possibly), noncreep fed, and have not been weaned. The values for $P_1(j)$ that are used in this study are: \$60/cwt., \$65/cwt., and \$70/cwt. These prices were chosen because the average price of calves in Iowa during April, 1983 was \$63.40/cwt. and a range of \$10/cwt. was desired.

Now, the breakeven schedules can be computed using the procedure developed earlier in this paper. In this procedure, each breakeven price in the schedule is computed by using equation (3a). The results of this procedure are listed in Appendix 3.

Since every estimated breakeven price listed in Appendix 3 is a random variable, confidence intervals are estimated to provide information on the dispersion of each estimated breakeven price. To calculate these confidence intervals, the variance-covariance matrix of b must first be obtained. This matrix is then used in equations (24) through (26) to obtain the variances and covariance of the estimated weight gains. Then these results, along with the estimates of $w_1(j)$ and $w_2(j)$ in Appendix 2, are used in equations (29) through (33) and substituted in equation (20). Finally, equation (20) is set up in a quadratic form and solved by using the quadratic formula.

(37) $R^2[V_2{}^2-t^2Var(V_2)]-2R[V_1V_2-t^2Cov\ (V_1,V_2)]+V_1{}^2-t^2Var(V_1)=0$

OR $AR^2 - BR + C = 0$

where:

$A = V_2{}^2-t^2Var(V_2)$

$B = [V_1V_2-t^2Cov(V_1,V_2)] * 2$

$C = V_1{}^2-t^2Var(V_1)$

Then: $R=\dfrac{-B \pm \sqrt{B^2-4AC}}{2A}$

The solution of equation (37) gives the two endpoints of each confidence interval. The estimated confidence intervals for all of the estimated breakeven prices are listed in Appendix 3.

There was a potential problem in estimating the confidence intervals because WB(i) helps to determine both wg(j) and w(j). From equations (22) and (23), wg(j)= X'(j)b, and there is a coefficient in the b matrix which corresponds to the WB(i) variable. Thus, WB(i) helps to determine $wg_1(j)$ and $wg_2(j)$. But also from equations (27) and (28) it is clear that WB(i) helps to determine $w_1(j)$ and $w_2(j)$. This interrelationship changes the variance of V_1 and V_2, and may change the formula for the confidence interval. The variance of V(j) now becomes:

(42) $wg(j) = X'(j)b$

$$V(j) = WB(i) + X'(j)b$$

$$Var[V(j)] = Var[WB(i) + X'(j)b]$$

$$= Var[WB(i)] + Var[X'(j)b] + Cov[WB(i),X'(j)b]$$

If WB(i) is fixed, then Var[WB(i)] and Cov[WB(i),X'(j)b] equals zero and the confidence interval formula remains the same. In this particular case, it seems logical to assume that WB(i) is fixed because a producer can obtain the beginning weights of his calves by weighing them. So WB(i) becomes a fixed variable for the producer, and Var[WB(i)] and Cov[WB(i),X'(j)b] becomes zero so the confidence interval formula remains unchanged.

Interpretation of Results

Now that all of the breakeven prices and confidence intervals can be estimated, it seems appropriate to determine the conclusions that can be drawn from these results. To obtain these conclusions, one must analyze the results that are presented in Appendix 3. This study will analyze the following:

1. Creep feeding the calves for 84 days alone, (M_1), across all classes of animals
2. Differences between management combinations within each class
3. Differences between management combinations between classes
4. How changes in $P_1(j)$ and $CM(j)$ effect the confidence intervals

These four topics are discussed in that order. A class is defined to be one of the six categories of horned or polled calves, and large framed, small-medium framed, or all frame sizes of calves. The six classes are:

1. Polled calves, all frame sizes
2. Horned calves, all frame sizes
3. Polled, large frame size calves
4. Polled, small-medium frame size calves
5. Horned, small-medium frame size calves
6. Horned, large frame size calves

The effect of a specific management practice, such as M_1, on breakeven prices is compared across all classes by comparing the schedules of breakeven prices for each one of the six classes. Using management practice M_1 as an example, to compare M_1 across all classes one would compare the following breakeven schedules in Appendix 3: 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1. Comparing the effects of specific management practices within each class looks at the differences in the breakeven prices of the different management practices in one class, such as polled, large frame size calves.

When comparing creep feeding (management practice M_1, see Table 8) across all classes one finds that the breakeven prices and confidence intervals are virtually the same for all classes. This seems to suggest that creep feeding the calves for 84 days alone, has the same effect on all sizes of calves, and on polled and horned calves. But the calves in this treatment are not subjected to any preconditioning practices and thus the horned calves are not subjected to any more stress than the polled calves. Looking at the estimated breakeven prices, one notices that about one half of them are less than $P_1(j)$ (here one can almost compare $P_1(j)$ and $p_2(j)$ directly because $P_1(j)$ is the price of uncastrated, horned, noncreep fed, and nonweaned calves and $p_2(j)$ is the price of uncastrated, horned, nonweaned calves). The breakeven prices above $P_1(j)$ are the ones with the highest creep feed cost of \$0.074/lb. Therefore, creep feeding the calves the entire 84 days has a high probability of positive profits if the cost of the creep feed is less than \$0.074/lb. This is because as $p_2(j)-P_1(j)$ declines, the probability of positive profits increases and when the cost of creep feed is less than \$0.074/lb., $p_2(j)-P_1(j)$ is negative so there is a high probability of positive profits. It should be noted that the probability of positive profits may vary. This is because the upper endpoints of the confidence intervals are above $P_1(j)$, which says the breakeven price can fluctuate above $P_1(j)$ due to variances in the weight gain of the creep fed calves.

Next, the effects of creep feeding and the timing of the preconditioning practices are examined within each class. To look at the effects of creep feeding within each class, one can compare management practices (see Table 8) M_2 with M_7 (breakeven schedules 1.2 with 1.7, 2.2 with 2.7, 3.2 with 3.7, 4.2 with 4.7. 5.2 with 5.7, and 6.2 with 6.7), practice M_4 with M_6 (breakeven schedules 1.4 with 1.6. 2.4 with 2.6, 3.4 with 3.6, 4.4 with 4.6, 5.4 with 5.6, and 6.4 with 6.6), and practice M_3 with M_5 (breakeven schedules 1.3 with 1.5, 2.3 with 2.5, 3.3 with 3.5, 4.3 with 4.5, 5.3 with 5.5, and 6.3 with 6.5). In these groups, all of the preconditioning practices and weaning are performed on the same date in each comparison group, the only difference is one group is creep fed and the other is not creep fed. In every class, the management practices that creep fed the calves for the first 42 days only, had higher breakeven prices than the management practices that did not creep feed at all (all else being equal). But the management practice (M_3) that creep fed the calves for the entire 84 days had lower breakeven prices in seven out of nine prices (except rows 7 & 8) in every class than the management practice that did not creep feed at all (all else equal). Therefore, one can conclude that creep feeding the first 42 days only, increases the breakeven price but creep feeding for the entire 84 days reduces the breakeven price, all else being equal.

A comparison of the timing of the preconditioning practices can be accomplished in the same manner as in the previous paragraph. This compares management practices M_1 with M_3 (breakeven schedules 1.1 with 1.3, 2.1 with 2.3, 3.1 with 3.3, 4.1 with 4.3, 5.1 with 5.3, 6.1 with 6.3), practice M_2 with M_4 (breakeven schedules 1.2 with 1.4, 2.2 with 2.4, 3.2 with 3.4, 4.2 with 4.4, 5.2 with 5.4, 6.2 with 6.4), and practice M_6 with M_7 (breakeven schedules 1.6 with 1.7, 2.6 with 2.7, 3.6 with 3.7, 4.6 with 4.7, 5.6 with 5.7, 6.6 with 6.7). In every class, M_1 had lower breakeven prices than M_3 but the breakeven prices of these two practices are difficult to compare. This is because the calves in M_1 are uncastrated, horned, and unweaned so they are discounted when they are sold but the calves in M_3 are preconditioned so they are not discounted when they are sold. Thus, comparing the breakeven price of M_1 and M_3 is like comparing bulls and heifers. When M_2 with M_4, and M_6 with M_7 are compared, the earlier preconditioned calves (practices M_4 and M_6) have lower breakeven prices than the later preconditioned calves in all classes. This suggests that the earlier the calves are preconditioned, the lower the breakeven prices.

Next, the differences in the management practices between classes are examined. The object of this analysis is to see if there are any differences between frame sizes, and polled and horned calves. The comparisons that are made are:

1. Polled vs. horned across all frame sizes
2. Polled, large frame size vs. polled, small-medium frame size
3. Horned, large frame size vs. horned, small-medium frame size
4. Polled, large frame size vs. horned, large frame size
5. Polled, small-medium frame size vs. horned, small-medium frame size

These comparisons are made by comparing a management practice in one class to the same management practice in another class; for example, comparing M_2 in the polled calves, all frame sizes class with M_2 in the horned calves, all frame sizes class. After completing these comparisons, one finds that large framed calves have lower breakeven prices than the small-medium framed calves and polled calves have lower breakeven prices than horned calves. This is a reasonable conclusion because polled calves are not subjected to the stress of dehorning and thus gain more weight than horned calves; and large frame calves also gain more weight than small or medium frame calves. This increased weight gain reduces the breakeven prices for these calves.

Finally, when $P_1(j)$ and/or CM(j) changes in value the confidence interval also changes in value. This fluctuation occurs because as $P_1(j)$ and CM(j) change, V_1 also changes. Since V_1 is in the confidence interval formulation in equation (20), as V_1 changes so does the confidence interval. In the breakeven schedules in Appendix 3, as $P_1(j)$ and CM(j) increase the confidence interval widens. The changes in the confidence intervals are not large, about $0.10/cwt. to $0.20/cwt., but these fluctuations need to be kept in mind.

Now that the results have been analyzed, it is time to explain how a producer can use these results. A cow-calf producer who wants to know what the breakeven price would be for implementing one of the management practices in this study should locate the appropriate breakeven schedule in Appendix 3. The schedule he would use depends on whether he has polled or horned calves; and large framed, or small-medium framed calves. If the producer is interested in the breakeven price of a management practice regardless of the frame size of the calves, he should use schedules that estimate the breakeven price for all frame sizes of calves. Once the producer has found the appropriate schedule for his operation and management combination he is considering, he then needs to determine the price he could receive for his calves if he performed none of the management practices ($P_1(j)$). This price would be for uncastrated, horned (if the calves were horned), noncreep fed, and nonweaned calves. It must be remembered that uncastrated, horned, noncreep fed, and nonweaned calves are discounted in price when they are sold. A producer needs to keep this discount in mind when he is estimating $P_1(j)$ and when he is evaluating the estimated breakeven price. Once $P_1(j)$ has been determined, then the producer must determine his costs ($CM(j)$) for that management combination. He can use the method outlined in this paper or just use the costs listed in Appendix 1 if he feels those costs are close to what would be his actual costs. Now, the producer can determine the breakeven price by finding the $P_1(j)$ and $CM(j)$ that he has determined to be appropriate for his operation and reading across the row of the appropriate breakeven schedule.

An example of this is a producer considering whether to creep feed, precondition before weaning, and wean before the sale date (M_4, see Table 8). If he has polled calves that are small-medium in frame size, then he would use the breakeven schedule 4.4 in Appendix 3. If the producer determined he could receive \$65/cwt. for uncastrated, noncreep fed, and nonweaned calves and his cost of implementing the management practice is \$66.21, then his breakeven price is \$74.25/cwt. As mentioned earlier, this breakeven price must be evaluated with the discount for uncastrated, noncreep fed, and nonweaned calves in mind.

In this example, the management practice under considering needs a $9.25/cwt. premium over the price of uncastrated, noncreep fed, and nonweaned calves. To determine if this practice is profitable, the producer must determine if he could receive that premium for his calves.

After the producer has determined his breakeven price, he can use the estimated confidence interval to gain some information on the dispersion of that estimated breakeven price. A confidence interval gives the probability that the stated interval contains an unknown parameter. In this case, the confidence interval gives the probability of that interval containing the actual breakeven price. In Appendix 3, all of the estimated confidence intervals are 95% confidence intervals. This says the probability that the stated interval contains the actual breakeven price is 95%, or the breakeven price will be in that interval 95 out of 100 times. In the example from the previous paragraph, the confidence interval for that breakeven price is (72.69, 75.87) so the breakeven price will be in that interval 95% of the time. These confidence intervals can be used to evaluate the variance of the estimated breakeven prices. The narrower the confidence interval, at a given probability, the smaller the variance is of the breakeven price and the estimated breakeven price is more reliable. Therefore, the smaller the confidence interval is in Appendix 3, the smaller the variance is in the estimated breakeven price.

CONCLUSIONS

Summary

Weight Gain Results

The weight gain results used in the economic analysis were obtained by estimating equation (1a) by Generalized Least Squares. GLS was used because it was found that the residuals were heteroscedastic. The reduced model obtained by this estimation procedure is listed in Table 7. This reduced model gives the variables that have a significant effect on the weight gain of the calves from September 23 to the sale date December 13. These variables are: an intercept, a replication effect and a year effect, creep feeding, a horn variable for horned calves, dehorning and castration, vaccination and grub treatment, large frame size, beginning weight of the calf, and one-way interactions between creep feed and weaning date, weaning date and date of dehorning and castration, and weaning date and date of vaccination and grub treatment. Also, all of the signs of the estimated coefficients made sense. Finally, the estimated sale weights of the seven management practices analyzed in this study (see Table 8) are listed in Appendix 2.

Breakeven Results

There are five general conclusions obtained from the breakeven analysis of this study. First, creep feeding the calves for the first 42 days only, has a lower probability of positive profits than not creep feeding at all. This conclusion was reached by comparing the breakeven prices of different management practices that were the same in all respects except one practice creep fed the first 42 days and the other did not (compared M_2 with M_7, M_4 with M_6). This comparison showed that the management practices that did not creep feed the first 42 days had lower breakeven prices.

Second, creep feeding the calves the entire 84 days and performing no other management practices has a high probability of positive profits in most instances. Only the highest creep feed costs (see Appendix 3) decreased the probability of positive profits.

Third, if the preconditioning management practices are performed (dehorning, castrating, etc.) then creep feeding for the entire 84 days reduces the breakeven prices compared to not creep feeding. This conclusion was reached by comparing management practice M_3 with M_5 across all breakeven schedules in Appendix 3.

Fourth, the earlier the calves are preconditioned, the lower the breakeven prices, all else being equal. This conclusion was obtained by comparing management practices M_2 with M_4, and M_6 with M_7. These comparisons showed that the management practices that preconditioned the calves earlier had lower breakeven prices.

Finally, polled and large frame calves have lower breakeven prices than horned calves and small-medium frame calves. This conclusion was found by comparing the managment practices in one class to the management practices in another class. In all cases, calves that were polled had lower breakeven prices than horned calves, and large framed calves had lower breakeven prices than small-medium framed calves.

Recommendations for Farmers

When giving recommendations about the results of this study, one needs to determine which management practices are likely to have a high probability of positive profits. It has all ready been mentioned that M_1, creep feeding the calves the entire 84 days only, has a high probability of positive profits in most instances. M_3 and M_5 have lower breakeven prices than M_2, M_4, M_6, and M_7 so M_3 and M_5 have higher probabilities of positive profits than M_2, M_4, M_6, and M_7. But M_3 has lower breakeven prices in most instances than M_5. Also, M_3 and M_5 were chosen because they are the only management practices, besides M_1, that required less than a $5.00/cwt. premium over the price of uncastrated, horned, noncreep fed, and nonweaned calves in most cases. All of the other practices require a premium greater than $5.00/cwt. which probably can not be obtained.

It should be noted that a lower breakeven price does not necessarily mean that a management practice has higher profits than the other management practices but that the management practice has a higher probability of positive profits than the others.

One limitation of this study a producer should keep in mind is that the estimated breakeven prices are random. As mentioned earlier, the actual breakeven will occur in the stated confidence interval 95% of the time. In most cases, the confidence intervals are at least $1.00/cwt. on each side of the estimated breakeven price so there is a chance that the actual breakeven price will be higher than the estimated breakeven. This variation could mean the difference between a profit or a loss from performing a certain management practice. But it should be noted that even though the breakeven price can not be estimated with certainty, the confidence interval gives an idea of the range of possible breakeven prices. Also, even though the information from this study is not certain, it is better than no information at all.

APPENDIX 1

Cost of Management Practices

CM1

Creep feed costs:

(20.078 lbs. gained)(12.7 lbs. creep/lb. gain)($0.064/lb. creep)= $16.32

(28.163 lbs. gained)(7.8 lbs. creep/lb. gain)($0.064/lb. creep) = 14.06

total costs $30.38

Cost range:

Low: (474.66 lbs. creep)($0.054/lb. creep) = $25.63

High: (474.66 lbs. creep)($0.074/lb. creep) = $35.13

CM2

		Polled	Horned
Creep feed costs: (254.99 lbs.)($0.064/lb.)	=	$16.32	$16.32
Dry feed costs: (768.6 lbs. comsumed)($0.045/lb.)	=	34.59	34.59
Preconditioning: dehorning, vacc., castrate & grub	=	6.00	7.50
Facility and Health	=	9.30	9.30
total costs		$66.21	$67.71

Cost ranges	Low	High
Polled	$54.22	$80.69
Horned	55.22	83.69

CM3

		Polled	Horned
Creep feed costs: (254.99 lbs. creep)($0.064/lb.)	=	$30.38	$30.38
Preconditioning costs	=	6.00	7.50
Total Costs		$36.38	$37.88

Cost ranges	Low	High
Polled	$29.88	$45.38
Horned	30.88	48.38

CM4

		Polled	Horned
Creep feed costs: (254.99 lbs. creep)($0.064/lb.)	=	$16.32	$16.32
Dry feed costs: (768.6 lbs. consumed)($0.045/lb.)	=	34.59	34.59
Preconditioning costs	=	6.00	7.50
Facility and Health costs	=	9.30	9.30
Total Costs		$66.21	$67.71

Cost ranges	Low	High
Polled	$54.22	$80.69
Horned	55.22	83.69

CM5

		Polled	Horned
Preconditioning costs	=	$ 6.00	$ 7.50

Cost ranges	Low	High
Polled	$4.25	$10.25
Horned	5.25	13.25

CM6			Polled	Horned
Dry feed costs: (718.2 lbs. consumed)($0.043/lb.)			= $30.88	$30.88
Preconditioning costs			= 6.00	7.50
Facility and Health			= 9.30	9.30
Total costs			$46.18	$47.68

Cost ranges	Low	High
Polled	$37.25	$57.61
Horned	38.25	60.61

CM7			Polled	Horned
Dry feed costs: (718.2 lbs. consumed)($0.043/lb.)			= $30.88	$30.88
Preconditioning costs			= 6.00	7.50
Facility and Health			= 9.30	9.30
Total costs			$46.18	$47.68

Cost ranges	Low	High
Polled	$37.25	$57.61
Horned	38.25	60.61

APPENDIX 2

Vectors Used to Forecast Weight Gain

Horned calves across all frame sizes

X1' = [1 1/2 1/3 0 1 0 0 1/3 0 0 0 394.092]

X21' = [1 1/2 1/3 1 1 0 0 1/3 0 0 0 394.092]

X22' = [1 1/2 1/3 1 1 0 0 1/3 1 0 0 394.092]

X23' = [1 1/2 1/3 1 1 1 1 1/3 0 0 0 394.092]

X24' = [1 1/2 1/3 1 1 1 1 1/3 1 1 1 394.092]

X25' = [1 1/2 1/3 0 1 1 1 1/3 0 0 0 394.092]

X26' = [1 1/2 1/3 0 1 1 1 1/3 0 1 1 394.092]

X27' = [1 1/2 1/3 0 1 0 0 1/3 0 0 0 394.092]

Polled, large frame size

X1' = [1 1/2 1/3 0 0 0 0 1 0 0 0 426.009]

X21' = [1 1/2 1/3 1 0 0 0 1 0 0 0 426.009]

X22' = [1 1/2 1/3 1 0 0 0 1 1 0 0 426.009]

X23' = [1 1/2 1/3 1 0 1 1 1 0 0 0 426.009]

X24' = [1 1/2 1/3 1 0 1 1 1 1 1 1 426.009]

X25' = [1 1/2 1/3 0 0 1 1 1 0 0 0 426.009]

X26' = [1 1/2 1/3 0 0 1 1 1 0 1 1 426.009]

X27' = [1 1/2 1/3 0 0 0 0 1 0 0 0 426.009]

Polled, small-medium frame size

X1' = [1 1/2 1/3 0 0 0 0 0 0 0 0 379.681]

X21' = [1 1/2 1/3 1 0 0 0 0 0 0 0 379.681]

X22' = [1 1/2 1/3 1 0 0 0 0 1 0 0 379.681]

X23' = [1 1/2 1/3 1 0 1 1 0 0 0 0 379.681]

X24' = [1 1/2 1/3 1 0 1 1 0 1 1 1 379.681]

X25' = [1 1/2 1/3 0 0 1 1 0 0 0 0 379.681]

X26' = [1 1/2 1/3 0 0 1 1 0 0 1 1 379.681]

X27' = [1 1/2 1/3 0 0 0 0 0 0 0 0 379.681]

Horned, large frame size

X1' = [1 1/2 1/3 0 1 0 0 1 0 0 0 426.009]

X21' = [1 1/2 1/3 1 1 0 0 1 0 0 0 426.009]

X22' = [1 1/2 1/3 1 1 0 0 1 1 0 0 426.009]

X23' = [1 1/2 1/3 1 1 1 1 1 0 0 0 426.009]

X24' = [1 1/2 1/3 1 1 1 1 1 1 1 1 426.009]

X25' = [1 1/2 1/3 0 1 1 1 1 0 0 0 426.009]

X26' = [1 1/2 1/3 0 1 1 1 1 0 1 1 426.009]

X27' = [1 1/2 1/3 0 1 0 0 1 0 0 0 426.009]

Horned, small-medium frame size

X1' = [1 1/2 1/3 0 1 0 0 0 0 0 0 379.681]

X21' = [1 1/2 1/3 1 1 0 0 0 0 0 0 379.681]

X22' = [1 1/2 1/3 1 1 0 0 0 1 0 0 379.681]

X23' = [1 1/2 1/3 1 1 1 1 0 0 0 0 379.681]

X24' = [1 1/2 1/3 1 1 1 1 0 1 1 1 379.681]

X25' = [1 1/2 1/3 0 1 1 1 0 0 0 0 379.681]

X26' = [1 1/2 1/3 0 1 1 1 0 0 1 1 379.681]

X27' = [1 1/2 1/3 0 1 0 0 0 0 0 0 379.681]

Weight of Calves at Sale Date

All Frame Sizes

M(j)[a]	Polled	Horned
Control($W_1(j)$)	541.914	534.703
($W_2(j)$) 1	590.155	582.944
2	561.992	554.781
3	562.825	555.614
4	566.072	558.863
5	514.583	507.373
6	545.996	538.785
7	541.914	534.703

[a] Treatments are listed in Table 8

Large Frame Size

M(j)	Polled	Horned
Control	586.185	578.975
1	634.427	627.216
2	606.263	599.053
3	607.096	599.886
4	610.346	603.135
5	558.855	551.644
6	590.304	583.057
7	586.185	578.975

Small-medium Frame Size

M(j)	Polled	Horned
Control	521.613	514.403
1	569.855	562.644
2	541.691	534.480
3	542.524	535.313
4	545.774	538.563
5	494.283	487.072
6	525.696	518.485
7	521.613	514.403

APPENDIX 3

Breakeven Schedules

Polled Calves, All Frames Sizes

M_1 Schedule 1.1

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$25.63	$59.44	(58.53, 60.37)
2)	65	25.63	64.03	(63.05, 65.04)
3)	70	25.63	68.62	(67.57, 69.70)
4)	60	30.38	60.24	(59.32, 61.19)
5)	65	30.38	64.83	(63.84, 65.85)
6)	70	30.38	69.42	(68.36, 70.52)
7)	60	35.13	61.05	(60.11, 62.01)
8)	65	35.13	65.63	(64.64, 66.67)
9)	70	35.13	70.22	(69.16, 71.33)

M_2 Schedule 1.2

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	\$60	\$54.22	\$67.51	(66.45, 68.59)
2)	65	54.22	72.33	(71.20, 73.49)
3)	70	54.22	77.15	(75.94, 78.39)
4)	60	66.21	69.64	(68.55, 70.75)
5)	65	66.21	74.46	(73.30, 75.65)
6)	70	66.21	79.29	(78.04, 80.55)
7)	60	80.69	72.21	(71.09, 73.37)
8)	65	80.69	77.04	(75.84, 78.27)
9)	70	80.69	81.86	(80.58, 83.17)

M_3 Schedule 1.3

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	\$60	\$29.88	\$63.09	(61.78, 64.42)
2)	65	29.88	67.90	(66.49, 69.34)
3)	70	29.88	72.71	(71.20, 74.26)
4)	60	36.38	64.24	(62.92, 65.59)
5)	65	36.38	69.05	(67.63, 70.51)
6)	70	36.38	73.86	(72.34, 75.43)
7)	60	45.38	65.84	(64.49, 67.22)
8)	65	45.38	70.65	(69.20, 72.14)
9)	70	45.38	75.46	(73.92, 77.06)

M_4 Schedule 1.4

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$54.22	$67.01	(65.65, 68.43)
2)	65	54.22	71.80	(70.33, 73.32)
3)	70	54.22	76.59	(75.02, 78.21)
4)	60	66.21	69.13	(67.73, 70.58)
5)	65	66.21	73.92	(72.42, 75.47)
6)	70	66.21	78.71	(77.10, 80.36)
7)	60	80.69	71.69	(70.25, 73.18)
8)	65	80.69	76.48	(74.94, 78.07)
9)	70	80.69	81.27	(79.62, 82.96)

M_5 Schedule 1.5

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$ 4.25	$64.01	(62.84, 65.21)
2)	65	4.25	69.28	(68.01, 70.58)
3)	70	4.25	74.55	(73.18, 75.94)
4)	60	6.00	64.35	(63.18, 65.56)
5)	65	6.00	69.62	(68.35, 70.92)
6)	70	6.00	74.89	(73.52, 76.29)
7)	60	10.25	65.18	(64.00, 66.39)
8)	65	10.25	70.45	(69.16, 71.76)
9)	70	10.25	75.72	(74.33, 77.12)

M_6 Schedule 1.6

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	\$60	\$37.25	\$66.37	(65.27, 67.51)
2)	65	37.25	71.33	(70.14, 72.56)
3)	70	37.25	76.29	(75.02, 77.61)
4)	60	46.18	68.01	(66.89, 69.16)
5)	65	46.18	72.97	(71.76, 74.21)
6)	70	46.18	77.93	(76.64, 79.26)
7)	60	57.61	70.10	(68.95, 71.28)
8)	65	57.61	75.06	(73.83, 76.33)
9)	70	57.61	80.02	(78.71, 81.38)

M_7 Schedule 1.7

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	\$60	\$37.25	\$66.87	(66.81, 66.94)
2)	65	37.25	71.87	(71.81, 71.94)
3)	70	37.25	76.87	(76.81, 76.94)
4)	60	46.18	68.52	(68.44, 68.61)
5)	65	46.18	73.52	(73.44, 73.61)
6)	70	46.18	78.52	(78.44, 78.61)
7)	60	57.61	70.63	(70.53, 70.74)
8)	65	57.61	75.63	(75.53, 75.74)
9)	70	57.61	80.63	(80.53, 80.74)

Horned Calves, All Frame Sizes

M_1 Schedule 2.1

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$25.63	$59.43	(58.51, 60.38)
2)	65	25.63	64.02	(63.03, 65.04)
3)	70	25.63	68.61	(67.54, 69.69)
4)	60	30.38	60.24	(59.31, 61.20)
5)	65	30.38	64.83	(63.83, 65.86)
6)	70	30.38	69.42	(68.34, 70.52)
7)	60	35.13	61.05	(60.12, 62.03)
8)	65	35.13	65.64	(64.63, 66.69)
9)	70	35.13	70.23	(69.15, 71.35)

M_2 Schedule 2.2

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$55.22	$67.78	(66.71, 68.89)
2)	65	55.22	72.60	(71.45, 73.82)
3)	70	55.22	77.42	(76.20, 78.68)
4)	60	67.71	70.03	(68.96, 71.17)
5)	65	67.71	74.85	(73.67, 76.07)
6)	70	67.71	79.67	(78.41, 80.97)
7)	60	83.69	72.91	(71.77, 74.10)
8)	65	83.69	77.73	(76.51, 79.00)
9)	70	83.69	82.55	(81.25, 83.89)

M_3 Schedule 2.3

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$30.88	$63.29	(61.98, 64.66)
2)	65	30.88	68.11	(66.69, 69.58)
3)	70	30.88	72.93	(71.40, 74.50)
4)	60	37.88	64.55	(63.22, 65.94)
5)	65	37.88	69.37	(67.93, 70.86)
6)	70	37.88	74.19	(72.64, 75.78)
7)	60	48.38	66.44	(65.08, 67.86)
8)	65	48.38	71.26	(69.79, 72.78)
9)	70	48.38	76.08	(74.50, 77.70)

M_4 Schedule 2.4

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$55.22	$67.30	(65.89, 68.72)
2)	65	55.22	72.08	(70.58, 73.61)
3)	70	55.22	76.86	(75.26, 78.51)
4)	60	67.71	69.53	(68.09, 71.00)
5)	65	67.71	74.31	(72.78, 75.89)
6)	70	67.71	79.09	(77.46, 80.78)
7)	60	83.69	72.39	(70.91, 73.90)
8)	65	83.69	77.17	(75.60, 78.79)
9)	70	83.69	81.95	(80.27, 83.68)

M_5 Schedule 2.5

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$ 5.25	$64.27	(63.08, 65.49)
2)	65	5.25	69.54	(68.25, 70.86)
3)	70	5.25	74.81	(73.42, 76.23)
4)	60	7.50	64.71	(63.51, 65.94)
5)	65	7.50	69.98	(68.69, 71.31)
6)	70	7.50	75.25	(73.86, 76.68)
7)	60	13.25	65.84	(64.63, 67.09)
8)	65	13.25	71.11	(69.80, 72.46)
9)	70	13.25	76.38	(74.97, 77.83)

M_6 Schedule 2.6

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$38.25	$66.65	(65.52, 67.80)
2)	65	38.25	71.61	(70.39, 72.85)
3)	70	38.25	76.57	(75.27, 77.90)
4)	60	47.68	68.40	(67.25, 69.57)
5)	65	47.68	73.36	(72.12, 74.62)
6)	70	47.68	78.32	(77.00, 79.67)
7)	60	60.61	70.80	(69.62, 72.00)
8)	65	60.61	75.76	(74.49, 77.05)
9)	70	60.61	80.72	(79.37, 82.10)

M_7 Schedule 2.7

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$38.25	$67.16	(67.06, 67.25)
2)	65	38.25	72.16	(72.06, 72.25)
3)	70	38.25	77.16	(77.06, 77.25)
4)	60	47.68	68.92	(68.81, 69.03)
5)	65	47.68	73.92	(73.81, 74.03)
6)	70	47.68	78.92	(78.81, 79.03)
7)	60	60.61	71.34	(71.19, 71.48)
8)	65	60.61	76.34	(76.19, 76.48)
9)	70	60.61	81.34	(81.19, 81.48)

<u>Polled</u>, <u>Large</u> <u>Frame</u> <u>Size</u> <u>Calves</u>

M_1 Schedule 3.1

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$25.63	$59.48	(58.63, 60.35)
2)	65	25.63	64.10	(63.18, 65.03)
3)	70	25.63	68.72	(67.74, 69.72)
4)	60	30.38	60.23	(59.37, 61.10)
5)	65	30.38	64.85	(63.92, 65.79)
6)	70	30.38	69.47	(68.48, 70.48)
7)	60	35.13	60.97	(60.11, 61.86)
8)	65	35.13	65.59	(64.66, 66.55)
9)	70	35.13	70.21	(69.22, 71.24)

M_2 Schedule 3.2

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$54.22	$66.96	(65.98, 67.96)
2)	65	54.22	71.79	(70.75, 72.86)
3)	70	54.22	76.63	(75.51, 77.77)
4)	60	66.21	68.93	(67.93, 69.96)
5)	65	66.21	73.77	(72.70, 74.87)
6)	70	66.21	78.60	(77.46, 79.78)
7)	60	80.69	71.32	(70.29, 72.38)
8)	65	80.69	76.16	(75.05, 77.29)
9)	70	80.69	80.99	(79.82, 82.20)

M_3 Schedule 3.3

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt.	CI
1)	$60	$29.88	$62.86	(61.65, 64.09)
2)	65	29.88	67.68	(66.38, 69.02)
3)	70	29.88	72.51	(71.12, 73.94)
4)	60	36.38	63.93	(62.71, 65.18)
5)	65	36.38	68.75	(67.44, 70.11)
6)	70	36.38	73.58	(72.17, 75.03)
7)	60	45.38	65.41	(64.17, 66.69)
8)	65	45.38	70.24	(68.90, 71.61)
9)	70	45.38	75.06	(73.63, 76.54)

M_4 Schedule 3.4

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$54.22	$66.51	(65.24, 67.81)
2)	65	54.22	71.31	(69.95, 72.71)
3)	70	54.22	76.11	(74.66, 77.61)
4)	60	66.21	68.47	(67.18, 69.81)
5)	65	66.21	73.27	(71.88, 74.71)
6)	70	66.21	78.08	(76.59, 79.61)
7)	60	80.69	70.85	(69.51, 72.22)
8)	65	80.69	75.65	(74.22, 77.12)
9)	70	80.69	80.45	(78.93, 82.02)

M_5 Schedule 3.5

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$ 4.25	$63.69	(62.62, 64.80)
2)	65	4.25	68.94	(67.78, 70.13)
3)	70	4.25	74.18	(72.93, 75.47)
4)	60	6.00	64.01	(62.93, 65.11)
5)	65	6.00	69.25	(68.09, 70.45)
6)	70	6.00	74.50	(73.24, 75.78)
7)	60	10.25	64.77	(63.68, 65.88)
8)	65	10.25	70.01	(68.84, 71.22)
9)	70	10.25	75.26	(73.99, 76.55)

M_6 Schedule 3.6

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$37.25	$65.89	(64.87, 66.94)
2)	65	37.25	70.86	(69.76, 71.98)
3)	70	37.25	75.82	(74.64, 77.03)
4)	60	46.18	67.40	(66.37, 68.47)
5)	65	46.18	72.37	(71.25, 73.51)
6)	70	46.18	77.33	(76.14, 78.56)
7)	60	57.61	69.34	(68.28, 70.43)
8)	65	57.61	74.31	(73.17, 75.47)
9)	70	57.61	79.27	(78.05, 80.52)

M_7 Schedule 3.7

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$37.25	$66.35	(66.28, 66.43)
2)	65	37.25	71.35	(71.28, 71.43)
3)	70	37.25	76.35	(76.28, 76.43)
4)	60	46.18	67.88	(67.79, 67.97)
5)	65	46.18	72.88	(72.79, 72.97)
6)	70	46.18	77.88	(77.79, 77.97)
7)	60	57.61	69.83	(69.72, 69.94)
8)	65	57.61	74.83	(74.72, 74.94)
9)	70	57.61	79.83	(79.72, 79.94)

Polled, Small-Medium Frame Size Calves

M_1 Schedule 4.1

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$25.63	$59.42	(58.48, 60.39)
2)	65	25.63	64.00	(62.98, 65.04)
3)	70	25.63	68.57	(67.48, 69.69)
4)	60	30.38	60.25	(59.30, 61.23)
5)	65	30.38	64.83	(63.80, 65.88)
6)	70	30.38	69.41	(68.31, 70.54)
7)	60	35.13	61.09	(60.12, 62.08)
8)	65	35.13	65.66	(64.62, 66.73)
9)	70	35.13	70.24	(69.13, 71.38)

M_2 Schedule 4.2

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$54.22	$67.79	(66.69, 68.91)
2)	65	54.22	72.60	(71.43, 73.81)
3)	70	54.22	77.41	(76.16, 78.71)
4)	60	66.21	70.00	(68.87, 71.16)
5)	65	66.21	74.81	(73.61, 76.06)
6)	70	66.21	79.63	(78.34, 80.95)
7)	60	80.69	72.67	(71.50, 73.88)
8)	65	80.69	77.49	(76.24, 78.77)
9)	70	80.69	82.30	(80.98, 83.67)

M_3 Schedule 4.3

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$29.88	$63.20	(61.84, 64.59)
2)	65	29.88	68.00	(66.55, 69.50)
3)	70	29.88	72.81	(71.25, 74.42)
4)	60	36.38	64.39	(63.02, 65.81)
5)	65	36.38	69.20	(67.73, 70.72)
6)	70	36.38	74.01	(72.43, 75.64)
7)	60	45.38	66.05	(64.66, 67.49)
8)	65	45.38	70.86	(69.36, 72.41)
9)	70	45.38	75.67	(74.06, 77.32)

M_4 Schedule 4.4

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$54.22	$67.28	(65.86, 68.75)
2)	65	54.22	72.06	(70.53, 73.63)
3)	70	54.22	76.84	(75.20, 78.51)
4)	60	66.21	69.48	(68.02, 70.98)
5)	65	66.21	74.25	(72.69, 75.87)
6)	70	66.21	79.03	(77.37, 80.75)
7)	60	80.69	72.13	(70.63, 73.67)
8)	65	80.69	76.91	(75.30, 78.56)
9)	70	80.69	81.69	(79.98, 83.45)

M_5 Schedule 4.5

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	\$60	\$ 4.25	\$64.18	(62.96, 65.43)
2)	65	4.25	69.45	(68.14, 70.81)
3)	70	4.25	74.73	(73.31, 76.19)
4)	60	6.00	64.53	(63.31, 65.79)
5)	65	6.00	69.81	(68.49, 71.17)
6)	70	6.00	75.08	(73.66, 76.55)
7)	60	10.25	65.39	(64.16, 66.66)
8)	65	10.25	70.67	(69.33, 72.04)
9)	70	10.25	75.94	(74.51, 77.42)

M_6 Schedule 4.6

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	\$60	\$37.25	\$66.62	(65.47, 67.80)
2)	65	37.25	71.58	(70.34, 72.85)
3)	70	37.25	76.54	(75.21, 77.90)
4)	60	46.18	68.32	(67.15, 69.52)
5)	65	46.18	73.28	(72.02, 74.57)
6)	70	46.18	78.24	(76.89, 79.62)
7)	60	57.61	70.49	(69.30, 71.72)
8)	65	57.61	75.45	(74.17, 76.77)
9)	70	57.61	80.42	(79.04, 81.82)

M_7 Schedule 4.7

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$37.25	$67.14	(67.06, 67.22)
2)	65	37.25	72.14	(72.06, 72.22)
3)	70	37.25	77.14	(77.06, 77.22)
4)	60	46.18	68.85	(68.76, 68.95)
5)	65	46.18	73.85	(73.76, 73.95)
6)	70	46.18	78.85	(78.76, 78.95)
7)	60	57.61	71.04	(70.92, 71.17)
8)	65	57.61	76.04	(75.92, 76.17)
9)	70	57.61	81.04	(80.92, 81.17)

Horned, Small-Medium Frame Size Calves

M_1 Schedule 5.1

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$25.63	$59.41	(58.46, 60.39)
2)	65	25.63	63.98	(62.95, 65.04)
3)	70	25.63	68.55	(67.45, 69.69)
4)	60	30.38	60.26	(59.29, 61.25)
5)	65	30.38	64.83	(63.79, 65.90)
6)	70	30.38	69.40	(68.28, 70.54)
7)	60	35.13	61.10	(60.12, 62.10)
8)	65	35.13	65.67	(64.62, 66.75)
9)	70	35.13	70.24	(69.12, 71.40)

M_2 Schedule 5.2

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$55.22	$68.08	(66.96, 69.23)
2)	65	55.22	72.89	(71.69, 74.12)
3)	70	55.22	77.70	(76.43, 79.02)
4)	60	67.71	70.41	(69.26, 71.60)
5)	65	67.71	75.23	(74.00, 76.50)
6)	70	67.71	80.04	(78.73, 81.39)
7)	60	83.69	73.40	(72.21, 74.64)
8)	65	83.69	78.22	(76.94, 79.54)
9)	70	83.69	83.03	(81.67, 84.43)

M_3 Schedule 5.3

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$30.88	$63.42	(62.05, 64.84)
2)	65	30.88	68.23	(66.75, 69.76)
3)	70	30.88	73.03	(71.49, 74.67)
4)	60	37.88	64.73	(63.34, 66.17)
5)	65	37.88	69.54	(68.04, 71.09)
6)	70	37.88	74.34	(72.74, 76.00)
7)	60	48.38	66.69	(65.27, 68.17)
8)	65	48.38	71.50	(69.97, 73.08)
9)	70	48.38	76.30	(74.67, 78.00)

M_4 Schedule 5.4

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$55.22	$67.56	(66.11, 69.06)
2)	65	55.22	72.34	(70.78, 73.94)
3)	70	55.22	77.11	(75.45, 78.83)
4)	60	67.71	69.88	(68.40, 71.42)
5)	65	67.71	74.66	(73.07, 76.30)
6)	70	67.71	79.43	(77.73, 81.19)
7)	60	83.69	72.85	(71.32, 74.43)
8)	65	83.69	77.62	(75.98, 79.32)
9)	70	83.69	82.40	(80.65, 84.20)

M_5 Schedule 5.5

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$ 5.25	$64.44	(63.20, 65.72)
2)	65	5.25	69.73	(68.38, 71.11)
3)	70	5.25	75.01	(73.56, 76.49)
4)	60	7.50	64.91	(63.66, 66.19)
5)	65	7.50	70.19	(68.84, 71.58)
6)	70	7.50	75.47	(74.02, 76.96)
7)	60	13.25	66.09	(64.82, 67.39)
8)	65	13.25	71.37	(70.00, 72.77)
9)	70	13.25	76.65	(75.18, 78.16)

M_6 Schedule 5.6

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$38.25	$66.90	(65.73, 68.11)
2)	65	38.25	71.87	(70.60, 73.16)
3)	70	38.25	76.83	(75.47, 78.21)
4)	60	47.68	68.72	(67.53, 69.95)
5)	65	47.68	73.68	(72.40, 75.00)
6)	70	47.68	78.64	(77.27, 80.05)
7)	60	60.61	71.22	(69.99, 72.48)
8)	65	60.61	76.18	(74.86, 77.53)
9)	70	60.61	81.14	(79.73, 82.58)

M_7 Schedule 5.7

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$38.25	$67.44	(67.33, 67.54)
2)	65	38.25	72.44	(72.33, 72.54)
3)	70	38.25	77.44	(77.33, 77.54)
4)	60	47.68	69.27	(69.14, 69.40)
5)	65	47.68	74.27	(74.14, 74.40)
6)	70	47.68	79.27	(79.14, 79.40)
7)	60	60.61	71.78	(71.62, 71.95)
8)	65	60.61	76.78	(76.62, 76.95)
9)	70	60.61	81.78	(81.62, 81.95)

Horned, Large Frame Size Calves

M_1 Schedule 6.1

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$25.63	$59.47	(58.61, 60.35)
2)	65	25.63	64.09	(63.16, 65.03)
3)	70	25.63	68.70	(67.71, 69.72)
4)	60	30.38	60.23	(59.36, 61.12)
5)	65	30.38	64.84	(63.91, 65.80)
6)	70	30.38	69.46	(68.46, 70.49)
7)	60	35.13	60.99	(60.11, 61.88)
8)	65	35.13	65.60	(64.66, 66.57)
9)	70	35.13	70.22	(69.21, 71.25)

M_2 Schedule 6.2

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$55.22	$67.21	(66.22, 68.22)
2)	65	55.22	72.04	(70.98, 73.13)
3)	70	55.22	76.87	(75.74, 78.03)
4)	60	67.71	69.29	(68.28, 70.34)
5)	65	67.71	74.12	(73.04, 75.24)
6)	70	67.71	78.96	(77.80, 80.15)
7)	60	83.69	71.96	(70.90, 73.05)
8)	65	83.69	76.79	(75.67, 77.95)
9)	70	83.69	81.62	(80.43, 82.86)

M_3 Schedule 6.3

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	\$60	\$30.88	\$63.06	(61.83, 64.31)
2)	65	30.88	67.88	(66.56, 69.24)
3)	70	30.88	72.71	(71.29, 74.16)
4)	60	37.88	64.22	(62.98, 65.50)
5)	65	37.88	69.05	(67.71, 70.42)
6)	70	37.88	73.87	(72.44, 75.35)
7)	60	48.38	65.97	(64.71, 67.28)
8)	65	48.38	70.80	(69.44, 72.20)
9)	70	48.38	75.62	(74.17, 77.12)

M_4 Schedule 6.4

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	\$60	\$55.22	\$66.75	(65.46, 68.08)
2)	65	55.22	71.55	(70.17, 72.98)
3)	70	55.22	76.35	(74.87, 77.88)
4)	60	67.71	68.82	(67.50, 70.18)
5)	65	67.71	73.62	(72.21, 75.08)
6)	70	67.71	78.42	(76.91, 79.98)
7)	60	83.69	71.47	(70.11, 72.88)
8)	65	83.69	76.27	(74.82, 77.77)
9)	70	83.69	81.07	(79.52, 82.67)

M_5 Schedule 6.5

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$ 5.25	$63.92	(62.83, 65.05)
2)	65	5.25	69.17	(67.99, 70.39)
3)	70	5.25	74.42	(73.15, 75.73)
4)	60	7.50	64.33	(63.23, 65.46)
5)	65	7.50	69.58	(68.39, 70.80)
6)	70	7.50	74.83	(73.55, 76.14)
7)	60	13.25	65.37	(64.26, 66.52)
8)	65	13.25	70.62	(69.42, 71.86)
9)	70	13.25	75.87	(74.58, 77.20)

M_6 Schedule 6.6

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$38.25	$66.14	(65.10, 67.20)
2)	65	38.25	71.11	(69.99, 72.25)
3)	70	38.25	76.07	(74.87, 77.30)
4)	60	47.68	67.76	(66.70, 68.84)
5)	65	47.68	72.72	(71.58, 73.89)
6)	70	47.68	77.69	(76.47, 78.94)
7)	60	60.61	69.98	(68.89, 71.09)
8)	65	60.61	74.94	(73.78, 76.13)
9)	70	60.61	79.91	(78.66, 81.18)

M_7 Schedule 6.7

	$P_1(j)$/cwt	CM(j)	$p_2(j)$/cwt	CI
1)	$60	$38.25	$66.61	(66.52, 66.70)
2)	65	38.25	71.61	(71.52, 71.70)
3)	70	38.25	76.61	(76.52, 76.70)
4)	60	47.68	68.24	(68.13, 68.35)
5)	65	47.68	73.24	(73.13, 73.35)
6)	70	47.68	78.24	(78.13, 78.35)
7)	60	60.61	70.47	(70.33, 70.61)
8)	65	60.61	75.47	(75.33, 75.61)
9)	70	60.61	80.47	(80.33, 80.61)

BIBLIOGRAPHY

Agresti, Alan; and Agresti, Barbara Finlay. Statistical Methods for the Social Sciences. San Francisco: Dellen Publishing Co., 1979.

Fieller, E. C. "The Distribution of the Index in a Normal Bivariate Population." Biometrika 24 (1932):428-40.

Fuller, Wayne A. "Estimating the Reliability of Quantities Derived from Empirical Production Functions." Journal of Farm Economics 44 No. 1 (February 1962): 82-99.

Johnston, J. Econometric Methods, 2nd Ed. New York: McGraw-Hill Book Company, 1972.

Judge, George G.; Hill, R. Carter; Griffiths, William E.; Lutkepohl, Helmut; and Lee, Tsoung-Chao. Introduction to the Theory and Practice of Econometrics. New York: John Wiley & Sons, 1982.

Larsen, Harold J. Introduction to Probability Theory and Statistical Inference. New York: John Wiley & Sons, 1974.

Rao, C. Radhakrishna. Linear Statistical Inference and Its Applications, 2nd Ed. New York: John Wiley & Sons, 1973.

Strohbehn, Daryl R.; and Willham, R. L. "A.S. Leaflet R329." Iowa State University Agricultural and Home Economics Experiment Station, Cooperative Extension Service, Ames, December, 1981.

U.S. Department of Agriculture. Agricultural Prices, April 1983. Washington, D.C.: Government Printing Office, 1983.

Theil, Henri. Principles of Econometrics. New York: John Wiley & Sons, 1971.