FUTURE STRUCTURE OF THE TEXAS CATTLE FEEDING INDUSTRY AS PROJECTED BY TRANSITION PROBABILITIES UTILIZING A CONVEX PROGRAM

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Cattle feeding in Texas has been characterized in the last decade by large increases in cattle marketings and rapid expansion of the number of feedlots with capacities[1] greater than 1,000 head [3]. To illustrate this dynamic growth, Texas fed cattle marketings increased by 1,950,000 head from 1962 to 1969 and more than doubled its relative proportion of the total marketed cattle from the twenty-two major feeding states [13]. During the same seven-year period, Texas cattle feedlots with capacities over 1,000 head increased from 120 to 300 [13, 14].

A recent study by Dietrich [2] indicates that the large commercial feedlots should continue to increase in capacity size and number during the next decade. The expected increase of larger feedlots is due to realized advantages from existing economies of size found in feedlots with one-time capacities of 10,000 head and over. The economies of size evidenced in the study [2] were total annual fixed-cost per pound gain, total feeding cost per pound gain, and feedlot utilization rates.

OBJECTIVES

Dual objectives are set forth in this article. First, it is intended to project the future structure of the Texas cattle feeding industry so that decisionmakers may have founded expectations of the future competitive nature and structure of their industry. The second objective is to provide an example showing how aggregate data may be used in a Markov Chain model which will make data, now available, useful for market structure projections.

MODELS

A primary objective of economics is to predict the future trends or time paths of variables having an effect on our economy. Much of the data employed in economic research are historic time series occurrences. Inherent in the economic data are properties that have been described as stochastic, dynamic, and simultaneous [8]. The finite Markov Chain model has been used to estimate such time trends and tendencies of economic variables. Such a dynamic model is needed in this study to estimate the changing structure of the Texas cattle feeding industry.

Model Assumptions of the Study

In this study, as previously stated, one objective is to predict the future structure of the Texas cattle feeding industry. To accomplish this, it is necessary to estimate the percent and number of feedlots in each feedlot capacity size group. An estimate of the percentage of marketed cattle from each feedlot capacity size group is also needed. Therefore, the estimation of two separate Markov Chain probabilistic matrices will be required.

The basic assumptions of the Markov Chain model for estimating percent and numbers of feedlots in the various feedlot capacity size groups are (1) the feedlot firms can be grouped into classes according to some size criterion, and (2) the movements of these feedlot firms through the classes can be regarded as a stochastic process, with probabilities of movement constant in time and the probability of transferring from one class to another a function of only the two classes involved [5, p. 6]. These same assumptions (those made for the feedlot Markov Chain model) are also necessary for the marketed cattle Markov Chain model. In both models, the classes (or states), i.e., feedlot capacity size groups, are stratified by the same criterion.

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[1]Feedlot capacity in this report is defined to be the one-time feeding capacity of the feedlot(s).

DATA

To estimate the transition probabilities, p_{ij}'s, of a Markov Chain matrix, it is necessary to have data from time periods of equal length and constant intervals between time periods. In each time period the data must reflect the movements of the specified units from one state or class to another. In this particular study, the only data available are the annual number of feeding firms within each feedlot capacity size group and the annual number of marketed cattle from each feedlot capacity size group. These are aggregated data and there is no way to trace the movement of each feeding firm over time.

Fortunately, a procedure has been developed that will allow transition probability estimates from aggregated data. The data must be stratified into states or classes. The proportion of observations in each state or class is calculated and these proportions are then used as the data inputs. The method of estimating the transition probabilities is by least squares. Papers by Telser [12] and Lee et al. [8] describe the procedure by which transition probabilities may be estimated. The least squares estimates of transition probabilities are discussed later.

The number of cattle marketed annually and the number of feeding firms for each year are reported by feedlot size capacity groups in the *Cattle on Feed* and the *Texas Cattle on Feed* reports [13, 14]. The data are grouped as follows:

Size Code	One-Time Feedlot Capacity Class
F_1	Under 1,000 head
F_2	1,000 to 1,999 head
F_3	2,000 to 3,999 head
F_4	4,000 to 7,999 head
F_5	8,000 to 15,999 head
F_6	16,000 head-and-over.

The data for the number of feeding firms and for the number of marketed cattle are listed in Tables 1 and 2, respectively.

PROCEDURE

Consistent with the definition of a Markov Chain stochastic process, where the outcome in time period t (t=1,2,. . .,T) depends on the outcome of the preceding period t-1, let:

F_i represent the feedlot capacity size groups (states) as defined in the preceding section with i = 1, 2, . . . ,r,

m_{it} represent the proportion of feeding firms and the proportion of marketed cattle in each F_i for each time period or the probability of being in a particular state during a particular time period, i.e., $P(F_{it})$,

P_{ij} represent a transition probability, an individual row-column value in the Markov Chain matrix, and designate the probability of the process at time t moving from state F_i to state F_j in time t+1, i.e., $P(F_{j,t+1} / F_{i,t}) = p_{ij}$, and

P represent the Markov Chain or transition probability matrix; where p_{ij} $(i \neq j)$ denotes the probability of moving from F_i to F_j for each time period and p_{ij} (i=j) represents the diagonal probabilities of remaining in the same state, F_i, for each time period.

Derivation of the Least Squares Equation

The transition probability matrix has properties

$$P_{ij} \geq 0 \qquad (1)$$

TABLE 1. NUMBER OF CATTLE FEEDLOTS BY FEEDLOT CAPACITY SIZE, 1962-1969, TEXAS

Year	Under 1,000	1,000–1,999	2,000–3,999	4,000–7,999	8,000–15,999	16,000 and over	Total
1962	1,600	98	60	31	14	–	1,803
1963	1,550	91	65	32	12	3	1,753
1964	1,500	101	73	43	12	5	1,734
1965	1,500	100	77	47	15	6	1,745
1966	1,500	118	79	53	20	8	1,778
1967	1,397	120	76	51	31	16	1,691
1968	1,300	121	68	52	30	23	1,594
1969	1,300	108	67	53	32	40	1,600

Source: *Cattle on Feed* and *Texas Cattle on Feed* reports, selected issues.

TABLE 2. NUMBER OF FED CATTLE MARKETED BY FEEDLOT CAPACITY SIZE, TEXAS 1,000 HEAD, 1962-1969

Year	Under 1,000	1,000–1,999	2,000–3,999	4,000–7,999	8,000–15,999	16,000 and over	Total
1962	105	87	109	194	261	–	756
1963	120	111	144	205	185	131	896
1964	118	100	174	223	177	179	971
1965	104	108	205	324	107	246	1,094
1966	163	127	268	359	205	290	1,412
1967	138	126	194	372	343	481	1,654
1968	112	91	138	321	439	869	1,970
1969	111	78	133	303	514	1,567	2,706

Source: *Cattle on Feed* and *Texas Cattle on Feed* reports, selected issues.

and

$$\sum_{j=1}^{r} P_{ij} = 1. \qquad (2)$$

The notation for the first order Markov Chain is depicted as

$$P(F_{i,t}, F_{j,t+1}) = m_{it}p_{ij} \qquad (3)$$

with the probability of being in F_j in time t+1 represented by

$$P(F_{j,t+1}) = \sum_{i=1}^{r} m_{it}p_{ij} = m_{j,t+1}. \qquad (4)$$

With equation (4), a linear function has been derived. To allow for random sampling errors in the data an error term (v_{jt}) must be added to the equation. The statistical equation is then

$$m_{jt} = \sum_{i=1}^{r} m_{i,t-1}\, p_{ij} + v_{jt} \qquad (5)$$

or

$$v_{jt} = m_{jt} - \sum_{i=1}^{r} m_{i,t-1}\, p_{ij} \qquad (6)$$

Estimating the Transition Probabilities

To estimate the p_{ij}'s by least squares, subject to the restrictions of equations (1) and (2), it is first necessary to calculate the uncorrected X'Y and X'X matrices.[2] The problem is to minimize the error sum of squares

$$v_{jt}^2 = Y_i'Y_i - 2\beta_i'X'Y_i + \beta_i'(X'X)\beta_i \qquad (7)$$

where i=1, . . . ,6.

A restricted least squares technique[3] is needed to calculate this quadratic problem.[4] The solution of the quadratic problem in this study is derived from a convex program. The convex program allows the restraints to be placed on the least squares problem.

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[2] In order to make the text easier to follow and to put the notation in a more familiar form, let Y = m_{jt}, and X = $m_{i,t-1}$ when matrix notation is being used. Also let

$\beta 1$ = (P11 P21 P31 P41 P51 P61)
$\beta 2$ = (P12 P22 P32 P42 P52 P62)
$\beta 3$ = (P13 P23 P33 P43 P53 P63)
$\beta 4$ = (P14 P24 P34 P44 P54 P64)
$\beta 5$ = (P15 P25 P35 P45 P55 P65) and
$\beta 6$ = (P16 P26 P36 P46 P56 P66).

[3] An excellent paper by Lee et al. [8] discusses alternative methods of estimating the transition probabilities and the relative precision of each method.

[4] The function is quadratic because the problem is to minimize the error sum of squares, a quadratic identity.

Projections Made From the Transition Probability Matrices

Two other procedural steps remain to be discussed. These two steps are as follows:

1. The method of projecting the proportion of marketed cattle and feeding firms in each state (F_i) and

2. The method of projecting number of firms in each state (F_i).

First, with the first order Markov Chain matrix and an initial starting state, the outcome of the n^{th} year can be estimated. The initial starting state used in this study is the row vector of the proportion of feeding firms in 1969. For example, let w^o represent the 1969 starting vector. Then

$$w(^o)\hat{P} = w(^1)$$
$$w(^1)\hat{P} = w(^2)$$
$$\vdots \quad \vdots$$
$$w(^{n-1})\hat{P} = w(^n) = w(^o)\,\hat{P}^n \qquad (8)$$

This procedure is used to estimate the annual outcomes of marketed cattle.

A simple linear regression model is used to estimate the total number of feeding firms over time. In this model, the total number of feeding firms is hypothesized to be a function of time. The equation is

$$\hat{y} = b_o + b_1x_1 + e \qquad (9)$$

where $\hat{y}$ is the predicted total number of feeding firms, b_o is the y – intercept point, b_1 is the slope of the curve that represents the change in number of the total feeding firms over time, x_1 is the time period, and e is the random error term.

The simple regression model, total number of cattle feeding firms regressed on time, merely shows the decreasing trend in numbers of firms over time. This particular equation does not show the effect of specific variables on the dependent variable. This is more consistent with the first order Markov Chain model which measures trends caused by stochastic processes rather than the effects of specific variables causing the change.

Finally, to estimate the number of feeding firms in each feedlot capacity size group, the predicted total number of feeding firms for a given year ($\hat{y}_t$) is multiplied by the projected annual proportion of firms in each state (w^{n-1}).

RESULTS

The change this study projects in the physical structure of the Texas cattle feeding industry is not surprising, but it is very interesting. These results parallel very closely the results of Dietrich's study discussed previously in this report [2]. The results projected by the first order Markov Chain model used in this study indicate that the number of feedlots with capacity sizes greater than 8,000 head will continue to increase and the number of feedlots with capacity sizes less than 8,000 head will decrease.

The Transition Probability Matrices

The transition probability matrices of this study illustrate the movement from one state to another. The majority of the movements, common to both matrices, are from a smaller one-time feedlot capacity size group to a larger one. The transition probability matrix $\hat{P}$*, depicting the probability estimates of marketed cattle by the feedlot size capacity groups, is as follows:

$$\hat{P}^* = \begin{array}{c} \\ F_1 \\ F_2 \\ F_3 \\ F_4 \\ F_5 \\ F_6 \end{array} \begin{array}{c} \begin{array}{cccccc} F_1 & F_2 & F_3 & F_4 & F_5 & F_6 \end{array} \\ \begin{bmatrix} .20262 & .46270 & 0 & .33468 & 0 & 0 \\ .13309 & 0 & .86691 & 0 & 0 & 0 \\ 0 & 0 & .28909 & .71091 & 0 & 0 \\ .20563 & .09813 & .05353 & .27403 & .36868 & 0 \\ .05143 & .04393 & 0 & .03711 & .40286 & .46467 \\ 0 & 0 & 0 & 0 & .03772 & .96228 \end{bmatrix} \end{array} \qquad (10)$$

The convex program estimates for the feedlots' transition probability matrix, $\hat{P}$**, is as follows:

$$\hat{P}^{**} = \begin{array}{c} \\ F_1 \\ F_2 \\ F_3 \\ F_4 \\ F_5 \\ F_6 \end{array} \begin{array}{c} \begin{array}{cccccc} F_1 & F_2 & F_3 & F_4 & F_5 & F_6 \end{array} \\ \begin{bmatrix} .97224 & 0 & .02776 & 0 & 0 & 0 \\ .19977 & .46821 & 0 & .33202 & 0 & 0 \\ 0 & .86685 & .13315 & 0 & 0 & 0 \\ 0 & 0 & .52718 & .24662 & .22620 & 0 \\ 0 & 0 & 0 & 0 & .72207 & .27793 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \end{array} \qquad (11)$$

An interesting property of Markov Chain matrices yet to be discussed is the "absorbing state." This occurs when a transition probability of state i is the diagonal of the matrix and has a value of one. An example of an "absorbing state" occurs in the transition probability matrix $\hat{P}^{**}$, diagonal observation p_{66}. This value interprets that the probability of a feedlot remaining in the one-time capacity size of 16,000 head and over, once it has entered the category, is one. If it is possible for the firms to go from every state to the "absorbing state," then through a period of time all the firms will enter the absorbing state and the entire industry will be composed of firms of the specifications of the absorbing state.

Structural Projections for the Texas Cattle Feeding Industry

The projected annual proportions of marketed cattle and feeding firms for each feedlot capacity size group are listed in Tables 3 and 4, respectively. The 1969 capacity class proportions for marketed cattle and for feedlots were used as the base vectors for Tables 3 and 4, respectively.

The simple regression model projected a decrease of Texas cattle feeding firms at a rate of 27.5 per year since 1962. The projection from the simple regression model is not meant to be a once and for all projection, but to be used to predict over a short number of years. The result of the total annual numbers of Texas feedlots regressed on time is

$$\hat{y} = 1{,}836.11 - 27.52\, x_1.$$

The projected number of Texas feeding firms by feedlot size capacity groups are calculated by multiplying the projected total number of feeding firms for a given year by the projected proportion of feeding firms (Table 4) for the same years. The results are shown in Table 5.

Projections beyond 1976, or a seven-year period, were not made for several reasons. First, cattle marketings from Texas feedlots have been increasing at an exorbitant rate the past ten years. The number of feedlots of one-time capacities of 16,000 head and over have increased eightfold in only five years. This rapid expansion cannot be expected to continue

TABLE 3. PROJECTED PROPORTIONS OF MARKETED CATTLE FROM TEXAS FEEDLOTS BY ONE-TIME CAPACITY SIZES, 1970-1976

Year	F_1	F_2	F_3	F_4	F_5	F_6
1970	.04494	.03830	.04518	.08644	.13964	.64550
1971	.03916	.03541	.05089	.07603	.11247	.68604
1972	.03407	.03052	.04948	.07429	.09922	.71242
1973	.03135	.02741	.04474	.07062	.09423	.73165
1974	.02937	.02557	.04048	.06515	.09159	.74784
1975	.02746	.02401	.03736	.05986	.08912	.76219
1976	.02565	.02250	.03482	.05546	.08672	.77485

TABLE 4. PROJECTED PROPORTIONS OF TEXAS FEEDING FIRMS BY ONE-TIME CAPACITY SIZES, 1970-1976

Year	F_1	F_2	F_3	F_4	F_5	F_6
1970	.80343	.06793	.04558	.03057	.02193	.03056
1971	.79470	.07132	.04449	.03009	.02275	.03665
1972	.78689	.07196	.04385	.03110	.02323	.04297
1973	.77943	.07170	.04408	.03156	.02381	.04942
1974	.77212	.07178	.04414	.03159	.02433	.05604
1975	.76503	.07187	.04397	.03162	.02471	.06280
1976	.75815	.07177	.04376	.03166	.02499	.06967

TABLE 5. PROJECTED NUMBER OF TEXAS FEEDLOTS IN EACH FEEDING CAPACITY SIZE GROUP, 1970-1976

Year	Under 1,000	1,000–1,999	2,000–3,999	4,000–7,999	8,000–15,999	16,000 and over
1970	1254	106	71	48	34	48
1971	1219	109	68	46	35	56
1972	1185	108	66	47	35	65
1973	1152	106	65	47	35	73
1974	1121	104	64	46	35	81
1975	1089	102	63	45	35	89
1976	1059	100	61	44	35	97

indefinitely. Second, the data are limited to only an eight-year period. Lastly, long extensions beyond the years of data observed begin to quickly amplify any errors in the sampled data [10, p. 154]. Forecasts for the distant future could be very misleading.

In comparing the actual situation in 1969 to the projected structure of 1976, it is noted that most of the change in number of feeding firms in each capacity size group occurs only in the very small group (F_1) and the very large group (F_6). The feedlot numbers in the under 1,000 head capacity size group show a substantial decrease, from 1,300 in 1969 to 1,059 in 1976. The next four categories of feedlot capacity sizes show essentially no change. The most dynamic growth of feeding firms occurs in the largest category, i.e., feedlots with one-time capacities of 16,000 head and over. These feedlots have a projected increase from 40 feedlots in 1969 to 97 feedlots in 1976 or a 117.5 percent increase over the seven years.

In 1969, seventy-two firms were responsible for 77 percent of the cattle marketed from Texas feedlots. In 1976, it is estimated that 97 feeding firms will handle 77.5 percent of the cattle marketed from Texas feedlots. However, if this analysis is carried a step further, 300 feedlots handled approximately 95 percent of the cattle marketed from Texas feedlots in 1969. In 1976, it is projected that 237 feedlots will handle 95 percent of the cattle marketed from Texas feedlots. Therefore, when the entire structure of the Texas cattle feeding industry is included, there is a trend to higher concentration.

SOME IMPLICATIONS

Management activities, decisions, and responsibilities are amplified by the expanding size of the firm. The task of increasing the one-time capacity of a feedlot is no exception. Obtaining operating capital for a larger feedlot is perhaps the most difficult task. Large operating capital requirements per head fed make large outlays of operating capital necessary. For example, one budget study [15] estimates the operating capital requirement for a 20,000 head capacity feedlot to be $247 per head for choice steers entering the feedlot at 600 pounds and leaving it at 1,050 pounds. The operating capital necessary to fill this lot to capacity and feed the steers to market weight is then $4,940,000.

Managers have several alternatives for facing the larger operating capital requirements. First, the manager may choose to continue to operate a smaller feedlot. This decision will not allow him to take advantage of the economies of size related to the larger capacity (10,000 head or over) feedlots. Unless his cattle feeding activities are a supplement to farming and/or ranching enterprises, he may be forced out of the industry because of his relatively higher average cost of production. Second, he may overcome the large operating capital requirement by custom feeding cattle. Under this method, the feedlot manager reduces his operating capital requirement because he does not have to purchase the cattle. With custom feeding, his primary activities are selling feed to the custom feeder and feeding the cattle for him. This trend is verified by another study [3, p. 30] which indicated 57.5 percent of the cattle fed in feedlots of 10,000 head or more capacity were not owned by the feedlot but were custom fed. Another alternative the manager has available is to increase his operating capital outlay. Dietrich's study [2, p. 9] pointed out that 70.9 percent of the Texas feedlots were proprietorships, while 20.6 percent were partnerships and 8.5 percent were corporations. This indicates that different types of ownership could allow for larger capital outlays. By taking in partners or incorporating, the proprietorship feedlots may increase their equity and, thus, increase their credit position or capital assets. Where possible, some of the feedlots are becoming public corporations.

Other major obstacles which feedlot managers must overcome include uncertain feeder cattle supplies, feed supplies, and market outlets for their cattle. The multitude of daily problems and decisions are going to demand that the manager delegate more of the buying and selling activities to contracted or salaried buyers and salesmen.

To conclude, it has been shown that the structure of the Texas cattle feeding industry is expected to continue to change. It has also been shown that if a small feedlot is to stay in business, it must expand to remain in a competitive position. Certain firm structural changes needed, if smaller feedlots want to increase their capacity sizes, have also been discussed.

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