A MIXED-INTEGER PROGRAMMING ANALYSIS OF THE STRUCTURE OF A FLORIDA-BASED CATTLE FEEDING INDUSTRY

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Abstract

Florida is typical of many southeastern states in that it exports feeder cattle and imports carcass and boxed beef. The objective of this paper is to estimate the cost of retaining feeder cattle in Florida, feeding these cattle to slaughter weights, slaughtering them, and distributing the meat to retail outlets. A mixed integer programming model is developed. The optimal number and location of feedlots and slaughter plants are determined. The results indicate that at production levels exceeding 600,000 head, the cost of producing carcass beef in the State is comparable to the average for the United States.

Key words: beef cattle, plant location, mixed integer programming, economic-engineering.

Development of cross-bred cattle during the early part of the 20th Century changed the Florida beef industry from scrub cattle production to cow-calf production units with limited stocker and feedlot production capacity (Shonkwiler). In 1980, Florida led all other southeastern states in the number of beef cows and ranked ninth relative to all other states (Florida Department of Agriculture).

Florida cattlemen produce an excess supply of lightweight feeder cattle and, thus, export feeder cattle which are eventually slaughtered out-of-state. In Florida, stocker calf outshipments as a percentage of calves marketed increased from 4.1 percent in 1955 to 82.3 percent in 1980 (Shonkwiler and Spreen).

At the same time that feeder calves are being exported from Florida, large quanitities of carcass and boxed beef are imported into the State because the Florida cattle industry does not produce enough slaughter beef for Florida consumers (Shonkwiler and Spreen). There has been concern expressed by those within the Florida cattle industry that because of increases in transportation rates (due to a threefold increase in petroleum prices since 1972) producers in Florida have been receiving considerably lower prices for feeder calves than do those producing and marketing calves closer to the major feeder cattle demand points. If transport rates continue to increase, Florida producers will continue to accept lower prices for feeder calves relative to producers nearer to the major feeding areas (Shonkwiler and Spreen). It also follows that consumers must pay higher prices for beef imported from other states due to transportation costs which must be included in the retail price.

Given that Florida exports feeder cattle and imports carcass and boxed beef, it is reasonable for Florida cattle producers to consider increasing feedlot production. In a recent study of the United States cattle feeding industry, Clary et al. estimated that the least cost configuration of feedlot locations included Florida producing over 500,000 head of fed cattle annually, or more than four times the present level of annual fed marketings in the State. Since Florida would still be a net importer of beef, even if all feeder calves produced in the State were finished, slaughtered, and consumed in Florida, it is reasonable to assume that Florida finished beef will be consumed in the State (Spreen).

The overall objective of this study is to determine the optimal locations for backgrounding Florida weaned calves and deter-

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mine the optimal size, number, and location of feedlots and slaughter plants within the State. The optimal timing and location of each activity (backgrounding, feeding, and slaughtering/processing) are determined. Results of this analysis provide an estimate of the cost of backgrounding (forage-based growing period between weaning and placement on a high concentrate ration in a feedlot), finishing, and slaughtering cattle in Florida.

The methodology used integrates a standard plant location model with a scheduling model. The study thereby characterizes a spatio–temporal optimization problem. The temporal dimension provides varying lengths of time a calf can be backgrounded and fed in a feedlot. Although there is a seasonal supply of calves, the temporal aspect of the model provides a means for maintaining continual availability of processed beef.

PLANT LOCATIONAL MODELS

Plant location studies have been an important part of the research conducted by agricultural economists. Research dealing with efficiency of marketing areas has focused mainly on determination of the optimal size, number, and location of marketing facilities. Two classes of models have emerged, the continuous space and discrete space approaches (French). French showed that the discrete space approach is a special case of the continuous space method. The discrete space approach groups supply sources and market territories into finite numbers of locations and considers some predetermined set of feasible potential plant locations. In order to construct the model, the researcher needs to know the transportation cost function (or all point-to-point rates) and the long-run processing and handling cost function. One of the first models for solving this type of problem was developed by Stollsteimer as a basis for determining the optimum number, size, and location of pear-packing plants in California.

The Stollsteimer model minimized total cost of pear production with respect to plant numbers and locations subject to constraints placed on availability with respect to raw materials and the finished product. In his original application of the model, Stollsteimer introduced the strategic assumption, supported by empirical analysis, that the long-run total cost function for pear packing could be approximated by a linear equation with a positive intercept (French).

The Stollsteimer model is useful in determining optimal plant location, size, and numbers with respect to either assembly or distribution systems but is not applicable to situations encompassing both systems. The solution procedure proposed by Stollsteimer frequently leads to an excessive computational burden for large problems (Faminow and Sarhan). A transshipment model, a modification of the basic linear programming transportation model, classifies each production or consumption area as a possible shipment or transshipment point. This model gains considerable computational advantage over the original Stollsteimer approach (French).

Plant location studies during the 1960s and 1970s included a variety of agricultural commodities and market locations. The Stollsteimer model was extended to include multiple products (Polopolus). The basic transportation model was used to determine warehouse location for a multi-plant meat packing firm (Pherson and Firch), in a study of country elevators (Lytle and Hill), and in a study of retail farm machinery dealerships in Virginia (Clay and Martin). Among the first applications of linear programming to the livestock-meat sector was a series of bulletins (Judge and Wallace, 1959 and 1960; Wallace and Judge) which developed annual and quarterly models of the beef and pork marketing sectors. Subsequent studies developed similar spatial livestock models for the United States (Hertsgaard and Phillipi; Judge et al.; Williams and Dietrich). Hertsgarrd and Phillipi published a bulletin which discussed a standard transportation model for 18 regions and considered projections for 1975. Judge et al. considered 26-region standard transportation models for beef, pork, veal, lamb, and mutton. Williams and Dietrich used a 20-region transportation model for beef. Another study in the mid-1960s developed a profit maximization model that integrated all cattle production costs in addition to the costs of shipping fed cattle to slaughter (Buchholz and Judge).

Other contributions to plant location modeling included the development of more realistic problem formulations and post optimal analysis. Procedures for sensitivity and parametric analysis were developed (Ladd and Halvorson) and the solution procedure was modified to two steps, allowing for discontinuous cost functions (Chern and Polopolus).

A limitation of these earlier studies is that they do not consider fixed charges associated with plant establishment and operation. One of the first models including fixed charges dealt with optimal spatial configurations for cotton-ginning plants (Fuller et al.). In this study, a plant location model was developed to determine the least cost adjustment to regional decreases in raw product output and new storage technology. The location problem was formulated as a network flow problem and solved with the use of a special primal simplex code in combination with implicit enumeration. Subsequent to this study, two other plant location studies emerged, each solving the mixed-integer programming model via a different technique. An analysis of a grain subterminal location problem within northwestern Indiana solved the problem with mixed-integer programming, using Benders Decomposition (Hilger et al.). Faminow and Sarhan studied the location of feedlots, slaughtering, and processing in the United States; they formulated a mixed-integer programming model which was solved via a branch-and-bound algorithm.

THE MIXED-INTEGER PROGRAMMING MODEL

The model used in this study is an extension of a mixed-integer plant location model which includes a temporal as well as a spatial dimension. Since supplies of weaned calves vary seasonally, it is possible that utilization of feedlot and slaughter plant capacity will also vary seasonally. In order to determine the least-cost configuration of backgrounding points, feedlots, and slaughter plants, it is necessary to consider scheduling of animals through the system so as to minimize periods of slack capacity. This is accomplished by defining activities in the programming model which differ not only in location, but also in the time at which they begin and the length of time required to feed the animal to slaughter weight.

The model includes three intermediate points: backgrounding, finishing in a feedlot, and slaughtering. A non-temporal route in the model would start at one of four supply points, pass through one of four backgrounding points, then through one of three feedlot/slaughter plant points which includes two possible slaughter plant sizes, and end at one of five demand points. Thus, without considering the temporal dimension, there are 480 (4 x 4 x 3 x 2 x 5) possible routes through the model.

The scheduling portion of the model includes paths of three different lengths: (1) two quarters of backgrounding plus two quarters in a feedlot totaling to a four quarter path, (2) four quarters of backgrounding plus one quarter in a feedlot totaling five quarters, and (3) five quarters of backgrounding plus one quarter in a feedlot totaling six quarters.[1,2] Each of these paths can begin in any one of the four quarters of the year. Thus, the static model with 480 paths is expanded to include 12 possible timing paths totaling 5,760 possible paths through the model. The model also includes placing one slaughterhouse per location with two different size options and placing multiple feedlots per location but only one size feedlot is possible. Three feedlot locations and two possible slaughter plant sizes at three locations yield nine integer variables.

In order for the model to reflect the seasonal supply of weaned calves, it is necessary to use quarterly rather than annual data. The year was divided into quarters rather than months in order to reflect seasonal supplies without involving an excessively large model. If each of the three weight-gain paths began in any of the 12 months, the model would be expanded from 5,760 paths to 17,280 paths (480 x 12 x 3). It would require extensive computer time to solve a mixed-integer programming problem with 17,280 continuous variables and nine integer variables.

The Florida beef cattle industry and marketing network are complex. Therefore, several assumptions were necessary to reduce

[1] The 4-, 5-, and 6-quarter combinations of backgrounding and feedlot finishing were selected after numerous trials of the simulation models for backgrounding feeder cattle and feedlot finishing. For example, in order to produce a five quarter gain from 400 pounds to 1,031.5 pounds, only four quarters of backgrounding and one quarter of feeding were feasible. Three quarters of backgrounding and two quarters of feeding produced fed cattle in excess of the target weight of 1,031.5 pounds. Thus, these 4-, 5-, and 6-quarter combinations of backgrounding and feeding were selected because they produced the desired weight-gain results.

[2] One quarter of feeding in a feedlot translates to 90 days on feed. This is less than the widely accepted minimum of 100 days on feed to assure that a high proportion of the cattle will grade USDA Choice. Imposing feedlot utilization periods which are not multiples of 90 days (1 quarter) complicates the temporal aspect of the model. The gains from model simplification were believed to outweigh the potential bias introduced into the cost estimates by considering only 90 and 180 day feedlot feeding periods.

the size and scope of the mathematical programming model. Regional calf supplies and beef demand are known and fixed. There is no storage of slaughtered beef, however, the potential exists for "storage" on-the-hoof via different lengths of time for backgrounding and feedlot finishing. All animals in the system are of the same quality. All are fed to the same slaughter weight; meat yields are known and constant. Feedlots and slaughter plants are located in tandem; for example, if a slaughter plant is built at location two, then at least one feedlot (and no more than ten) will also be constructed at the same location. Thus, no transport of slaughter weight cattle is permitted between different feedlot/slaughter plant locations. Total slaughtering costs are a linear function of plant volume and have a positive intercept. There is no constraint associated with acreage availability for backgrounding weaned calves. Corn is the primary ingredient of the feedlot ration. It has a fixed price and is unlimited in availability. The price of corn is higher in South Florida compared to North and Central Florida due to transportation costs.

The mathematical formulation of the spatio–temporal model is:

(1) $$\text{Minimize} \sum_i \sum_j \sum_k \sum_\iota \sum_m \sum_s \sum_{p=4}^{6} C_{ijk\iota msp} X_{ijk\iota msp} + \sum_k F_k Y_k + \sum_k \sum_\iota G_{k\iota} Z_{k\iota},$$

(2) $$\text{subject to} \sum_j \sum_k \sum_\iota \sum_m \sum_p X_{ijk\iota mksp} = S_{is}, \quad i = 1, \ldots, 4, \; s = 1, \ldots, 4,$$

(3) $$\sum_i \sum_j \sum_\iota \sum_m (X_{ijk\iota m24} + X_{ijk\iota m34} + X_{ijk\iota m15} + X_{ijk\iota m46}) < CAP_{k,1}\, Y_k,$$

(4) $$\sum_i \sum_j \sum_\iota \sum_m (X_{ijk\iota m34} + X_{ijk\iota m44} + X_{ijk\iota m25} + X_{ijk\iota m16}) < CAP_{k,2}\, Y_k,$$

(5) $$\sum_i \sum_j \sum_\iota \sum_m (X_{ijk\iota m14} + X_{ijk\iota m44} + X_{ijk\iota m35} + X_{ijk\iota m26}) < CAP_{k,3}\, Y_k,$$

(6) $$\sum_i \sum_j \sum_\iota \sum_m (X_{ijk\iota m14} + X_{ijk\iota m24} + X_{ijk\iota m45} + X_{ijk\iota m36}) < CAP_{k,4}\, Y_k, \quad k = 1, 2, 3,$$

(7) $$\sum_i \sum_j \sum_k \sum_m \sum_p \sum_s X_{ijk\iota msp} < CAP_{k\iota,t}\, Z_{k\iota}, \quad k = 1, 2, 3, \; \iota = 1, 2, \; t = 1,\ldots,4,$$

(8) $$\sum_i \sum_j \sum_k \sum_\iota \sum_p \sum_s X_{ijk\iota msp} = D_{mt}, \quad m = 1,\ldots,5, \; t = 1,\ldots,4,$$

(9) $$Z_{11} + Z_{12} < Y_1,$$

(10) $$Z_{21} + Z_{22} < Y_2,$$

(11) $$Z_{31} + Z_{32} < Y_3,$$

(12) $$X_{ijk\iota msp} > 0,$$

(13) $$0 < Y_k < 10,$$

(14) $$0 < Z_{k\iota} < 1,$$

and

(15) $$Y_k, Z_{k\iota} \text{ integer.}$$

where:

- S_{is} = weaned-calf supply at location i in quarter s (i = 1,...,4; s = 1,...,4);
- j = denotes backgrounding locations (j = 1,...,4);
- D_{mt} = final demand at point m in quarter t (m = 1,...,5; t = 1,...,4);
- s = quarter when weaned calves begin backgrounding (s = 1,...,4);
- p = length of path used for fattening weaned calves to slaughter weight (p = 4, 5, or 6 quarters);
- t = quarter when animals are slaughtered and processed beef is subsequently available at final demand points, $\mathrm{mod}_4(s+p) = t$;[3]
- $C_{ijk\iota msp}$ = cost of entire route beginning with a calf at supply point i, transported to and backgrounded at point j, transported to and fattened in a feedlot at point k, slaughtered and processed in slaughter plant size ι, and transported to demand point m. The calf begins in quarter s and follows time path p;

[3] For example, if an animal begins backgrounding in quarter 1 (s=1) and follows a 5-quarter path (p=5), it will be ready for slaughter in quarter 6 which is the second quarter of the year.

$X_{ijk\iota msp}$ = the number of animals following route $ijk\iota msp$;

F_k = the fixed cost of establishing a feedlot at location k;

$G_{k\iota}$ = the fixed cost of establishing a slaughter plant of size ι at location k;

Y_k = number of feedlots built at location k, $0 < Y_k < 10$;

$Z_{k\iota}$ = 1 when a slaughter plant of size ι is built at location k;
= 0 otherwise;

$CAP_{k,s}$ = capacity of feedlot at location k during quarter s; and

$CAP_{k\iota,t}$ = capacity of slaughter plant of size ι at location k during quarter t.

The spatio–temporal model minimizes the total cost of weaned calf assembly in region i during quarter s, backgrounding calves at location j, feeding calves at location k, slaughtering the animals in slaughter plant size ι, meeting total demand at location m during quarter t, beginning in quarter s, and following one of three weight-gain programs (p = 4, 5, or 6). Total cost also includes the annualized fixed cost of establishing a feedlot at point k and establishing a slaughter plant of size ι at location k. Since feedlots and slaughter plants are located in tandem, point k indicates the location of both type of facilities and ι indicates the size of the slaughter plant. The constraints ensure that total shipments from point i during quarter s do not exceed availability (equation (2)); utilization of feedlots at point k during the first quarter (equation (3)), second quarter (equation (4)), third quarter (equation (5)), and fourth quarter (equation (6)) is less than or equal to capacity of feedlots at that location during that particular quarter; utilization of a slaughter plant of size ι at location k during time period t is less than or equal to capacity of that size plant at that location during that particular quarter (equation (7)); the amount of boxed beef sent to final demand point m during quarter t satisfies the amount required at that location and time period (equation (8)); and a slaughter plant is built at a particular location only if a feedlot is built at that location (equations (9), (10), and (11)).

There are four feedlot capacity constraints which correspond to the capacity required during any given quarter. An animal following a four quarter weight-gain program requires two quarters of feedlot capacity while an animal on a five-or-six quarter program only requires one quarter of feedlot capacity. In order to allow for this difference in feedlot utilization, each feedlot capacity constraint specifically identifies a beginning quarter and weight-gain program which would require feedlot capacity during a specific quarter.

EMPIRICAL SPECIFICATION

Weaned-calf supply and backgrounding points fall into four major areas, based upon general forage conditions and geography of the State. The four regions included North, Central, Southeast, and Southwest Florida. Forage or pasture conditions are specified as a combination of available dry matter and quality of dry matter. Geographic and seasonal differences in forage production were reflected by varying the quality and quantity of forage assumed to be available by region and month.

Feedlot/slaughter plant locations were selected based upon centralized locations within the State. The three locations are: (1) Tallahassee, in North Florida, (2) Ocala, in Central Florida, and (3) Okeechobee, in South Florida.

Demand regions were selected according to major metropolitan areas. (These regions were not necessarily of equal population density.) The State was divided into five demand regions: two for North Florida and three for Central and South Florida.

In the spatiotemporal model, the cost of feeding a weaned calf to slaughter weight and subsequently slaughtering and delivering boxed beef to the supermarket has been formulated as a continuous path with cost components calculated at each stage of production. There were five stages: (1) supplying a weaned calf, (2) backgrounding the calf, (3) fattening in a feedlot, (4) slaughtering and processing which yielded boxed beef, and (5) transporting boxed beef to the final destination. At each stage, transportation charges were incurred if the animal (or boxed beef) was transported between locations.

Supply

In 1982, the Florida cattle industry produced 1,150,000 calves (Florida Crop and Livestock Reporting Service, 1983). To determine the number of available feeder calves, the number of heifer calves used as beef and dairy cow replacements must be subtracted from the total calf crop. Beef and dairy cow replacements for 1982 totaled 188,000 and 45,000, respectively (Florida Crop and Live-

TABLE 1. ESTIMATED QUARTERLY FEEDER CALF AVAILABILITY BY REGION, FLORIDA, 1982

Region	Quarter				Yearly total
	1	2	3	4	
North	27,176[a]	32,004	43,728	35,039	137,947[b]
	(19.7)[c]	(23.2)	(31.7)	(25.4)	(15.0)[d]
Central	39,926	41,799	70,373	58,454	210,552
	(19.0)	(19.9)	(33.4)	(27.7)	(23.0)
Southwest	62,623	77,592	91,949	73,315	305,479
	(20.5)	(25.4)	(30.1)	(24.0)	(33.3)
Southeast	49,711	75,224	79,959	58,128	263,022
	(18.9)	(28.6)	(30.4)	(22.1)	(28.7)

[a]Estimated number of feeder calves available by region and quarter.
[b]Estimated annual potential regional supply of feeder calves.
[c]Percentage of feeder calves marketed during a specific quarter in a particular region.
[d]Percentage of total state supply from a particular region.

stock Reporting Service, 1983). Thus, in 1982, 917,000 feeder calves were available.

Feeder calf availability by quarters was estimated using average quarterly marketings from several local Florida auction markets (Florida Crop and Livestock Reporting Service, unpublished). Auction markets were grouped by supply region. Total cattle inventory for 1982 for all counties in each supply region was divided by total cattle inventory in Florida, giving a percentage of calves marketed in each region for the year. The auction market data were used to distribute regional calf supplies among the four quarters of the year, Table 1. Inspection of Table 1 reveals that 62 percent of the potential supply of feeder cattle were found in Southwest and Southeast Florida. There are seasonal variations in marketings with the third quarter having the highest volume.

Backgrounding and Finishing

Florida calf prices have exhibited wider seasonal fluctuations than average national prices (Shonkwiler and Spreen). Presence of a large-scale cattle feeding industry would reduce seasonal price changes. The initial specification of the model does not reflect seasonal calf prices. All animals were assumed to enter the system weighing 400 pounds and being priced at $60 per hundredweight (United States Department of Agriculture, 1982). A $2.00 per animal intraregional transport cost was added to all animals regardless of origin.

Steers and heifers, confronted with the same diet, gained weight at differing rates. One approach to deal with this phenomenon is to specify separate paths for steers and heifers. Experimentation with growth simulation models revealed that steers could be grown to 1,050 pounds at approximately the same cost required to grow heifers to 1000 pounds (Spreen et al.; Fox and Black). Thus, to keep the size of the model manageable, a composite animal was defined. After adjusting for replacements, approximately 63 percent of the available feeder calf supply were steers and 37 percent were heifers. The ending weight of a composite animal was assumed to be a weighted average of 1,050 and 1,000 pounds, which equals 1,031.5 pounds.

The costs of backgrounding and finishing feeder cattle were estimated, using two bioeconomic simulation models. A growth simulation model for stocker cattle (Spreen et al.) provided the means to estimate backgrounding costs. A similar model based upon the work of Fox and Black was used to simulate the growth of cattle on high energy diets.

Numerous combinations of forages can be used for backgrounding weaned calves. However, in executing the growth simulation model for stocker cattle, three forage combinations were utilized. First, in North Florida, rye-ryegrass is a winter forage which can be grazed from October through March and Pensacola bahia is a summer forage which can be grazed from April through September. Second, in Central Florida, rye-ryegrass is a winter forage which can be grazed from December through March and Pensacola bahia is a summer forage which can be grazed from April through November. Third, in South Florida, digitgrass (pangola) can be grazed from February through November and hay is used as a supplemental feed during the months of December and January.

Per acre pasture costs were $127.04 for rye-ryegrass, $88.50 for Pensacola bahia, and $95.90 for digitgrass which included fertilization, seed, lime, and a charge for land rent. Supplemental corn was priced at $4.48 per bushel. Hay fed in South Florida cost $40.00 per ton. Other backgrounding costs included charges for mineral supplements, medication, growth implants, labor, interest on operating capital, and overhead. These charges varied depending on the length of the backgrounding program but averaged approximately $80.00 per head.

The ending weight and total cost estimates from the backgrounding simulation model were used as input to the feedlot simulation model. Other input to the feedlot simulation model included feed costs, ration composition, nutritional values for each component of the feedlot ration, and feedlot yardage cost.

The feedlot ration consisted of corn, sorghum silage, and sufficient quantities of protein supplement, vitamins, and minerals to meet all nutritional requirements of the animal. Corn was priced at midwest prices plus transport to Florida. In 1983, North Florida corn prices averaged $4.31 per bushel and South Florida corn prices averaged $4.54 per bushel. The cost of sorghum silage in 1983 was $.013 per pound ($26 per ton) (Hewitt). Feedlot yardage was charged at 20 cents per day.[4]

Animals that entered the system in a particular quarter followed one of three path lengths: 4, 5, or 6 quarters. An animal on a 4-quarter path must gain weight more quickly than an animal on a 5- or 6-quarter path. Animals on a 4-quarter path were given supplemental corn during the backgrounding phase and are fed a "hot" ration during the feedlot phase (which contained a high proportion of corn relative to roughage, in this case, sorghum silage). Backgrounding diets for animals on 5- or 6-quarter paths consisted almost exclusively of forage and their feedlot rations contained less corn and more roughage.

In making weight-gain projections, both the backgrounding and feedlot simulation models accounted for net energy of the ration and the influence of heat stress. The net energy an animal can obtain from a particular ration influenced weight-gain potential. Net energy has two components. Net energy for maintenance is the minimum amount of feed intake necessary for an animal to maintain current weight. Net energy for gain is the amount of intake, over and above minimum maintenance requirements, which increases current weight (Fox and Black). Different diets provide different proportions of net energy. Animals subject to heat stress have limited weight-gain potential because heat stress restricts the appetite of the animal. The effect of heat stress was incorporated into both the backgrounding growth simulation and feedlot simulation models. Heat stress was assumed to be present from June to August in North and Central Florida and from May to September in South Florida.

Transportation of live cattle results in weight loss. Furthermore, cattle usually require time to adjust to a new environment, reducing the rate of weight gain. In order to account for these factors, two adjustments were made. First, the weight of all calves entering the backgrounding phase was reduced by 1 percent. Second, since cattle are transported again between the backgrounding and feedlot phases, the number of days required to regain weight loss was varied according to the distance the animal was transported. This number was 5 days for animals remaining in the same region for backgrounding and feeding, 10 days for animals moved to an adjacent region, and 15 days for animals moved from North Florida to South Florida (or vice versa).[5] A 2 percent shrink was applied to all animals between the feedlot and slaughter plant.

Death loss was treated as a cost instead of reducing animal numbers. A 2 percent death loss was applied to all animals in the backgrounding phase. Since feedlots and slaughter plants in the same region were assumed to be located nearby, no shrink was applied to slaughter weight cattle.

The fixed cost of establishing a feedlot with an annual capacity of 50,000 head was calculated at an investment cost of $155.15 per

[4] Feedlot yardage cost included the cost of labor, machinery, repairs, facilities use, and bedding.

[5] Days to regain inshrink, expressed as a percentage weight loss, varied depending on animal weight and the feedlot ration. For example, in the case of a 725 pound animal on a 2.5 lb./day ration, 5 days to regain inshrink implies a 1.7 percent weight shrink, 10 days implies a 3.4 percent shrink, and 15 days implies a 5.1 percent shrink.

head of capacity or $7,757,500 in total (Gee). The facility was assumed to have an average investment life of 10 years, since different equipment and facilities have varying years of investment life. Thus, in a given year, the fixed cost of a feedlot with 50,000 head annual capacity was $775,750. An interest rate of 13.0 percent was calculated on all operating costs in both the backgrounding and feedlot simulation models.

Slaughtering Fed Cattle

A slaughter plant cost analyzer (Nelson) was used to determine the fixed and variable costs for two sizes of slaughter plant facilities. Fixed costs are costs associated with establishing the facility. Variable costs are costs incurred with respect to slaughtering the animals and processing the meat. The small slaughter plant can process 120 head of cattle per hour or 225,000 head annually at a fixed cost of $5,930,550 per year. The variable costs for a small plant was $53.05 per head. The large slaughter plant can process 300 head of cattle per hour, operating two shifts daily. Thus, annual capacity was 1,125,000 head at a fixed cost of $13,029,300 per year. The variable costs for a large slaughter plant were $49.38 per head.

Slaughtering costs included fabrication of each carcass into boxed beef. Carcass weight, approximately 614 pounds, was assumed to be 60.8 percent of shrunk live weight (1,010.7 pounds). Fat and bone (carcass byproducts) per carcass unit were 80 pounds for regular boxed beef (Duewer), giving 534 pounds of boxed beef. The estimated byproduct allowance was $5.96 per hundredweight of live weight (1,010.7 pounds) or $60.24 per animal (United States Department of Agriculture, 1983).

Demand

In order to determine the quantity of beef consumed in each region, the percentage of population relative to state population was estimated for each region using county population statistics (U. S. Department of Commerce). All population estimates were 1982 full-time annual equivalents which included calculations for tourist fluctuations. The model assumed that consumption was directly proportional to the population. Fed cattle consumption in Florida in 1980 has been estimated to be 1.1 million head (Spreen); this means that the available feeder calf supply (917,000) could not meet total demand requirements. The deficit was assumed to be met by importing beef from both domestic and foreign suppliers.

Transportation

Transportation costs are incurred between: (1) supply and backgrounding locations if these two stages of production occur in different regions, (2) backgrounding and feedlot locations if these occur in different regions, and (3) slaughterplant facilities and demand locations. L. T. Manning Trucking Company charges $1.70 per mile for any size truckload for all trips out of the Ocala, Florida area. Each truck can carry 49,000 pounds of live animals. A full truckload of 400-pound calves would contain 123 animals. At $1.70 per mile, this would cost $.014 per animal per mile for transporting between supply and backgrounding regions. A full truckload of 725 pound calves (the average weight of an animal after backgrounding) would contain 68 animals. At $1.70 per mile, the cost of transporting an animal between backgrounding and supply locations would be $.025 per mile. The cost of shipping 534 pounds of boxed beef was estimated at $.01 per hundred weight per mile (Duewer).

EMPIRICAL RESULTS

Since the mathematical programming model includes 5,760 possible paths (continuous variables), there is insufficient space to fully summarize the estimated cost of alternative paths. Selected information for a sample of the paths is shown in Table 2. More detailed information is given in Moseley.

Path costs ranged from approximately $669 to $944. The lowest cost paths tended to be 5-quarter paths with backgrounding and feedlot feeding in North Florida, while some of the highest cost paths were 5- and 6-quarter paths with backgrounding in Central Florida and feedlot finishing in another region. Stocking rates during the backgrounding phase varied widely. More acres per head were required for summer grazing and in Central and South Florida. Feedlot entry weights

TABLE 2. STOCKING RATES AND TOTAL PATH COSTS ESTIMATED FROM THE GROWTH SIMULATION ANALYSIS, FLORIDA, 1982-83

S[d]	B[e]	FL[f]	Sp[g]	D[h]	B[i]	E[j]	Stocking rate[a] RRG[k]	PB[l]	Feedlot entry weight (lb.)	Backgrounding & feedlot[b] Cost per pound of gain	Total cost	Total path cost[c]
2	1	1	2	5	1	2[m]	.53	.79	857	$.63	$635.91	$712.70
2	1	1	2	5	2	3[m]	.61	.66	849	.61	625.45	702.24
1	1	1	2	5	3	3[m]	.59	.54	598	.70	692.07	756.48
4	1	1	2	3	4	2[m]	.47	.75	850	.66	659.41	727.64
1	2	3	1	1	4	2	.69	1.98	847	.98	859.86	943.62
1	1	1	2	3	3	4	.50	.59	872	.58	606.46	669.27

[a]Stocking rate-acres per head.
[b]Backgrounding, feedlot, and initial animal costs.
[c]Backgrounding, feedlot, slaughter, and transportation costs.
[d]S = supply region.
[e]B = backgrounding region.
[f]FL = feedlot/slaughterplant location.
[g]SP = slaughter plant size (1=small; 2=large).
[h]D = demand region.
[i]B = Beginning quarter.
[j]E = ending quarter.
[k]RRG = rye-ryegrass.
[l]PB = Pensacola bahiagrass.
[m]Paths included in the optimal solution.

ranged from 550 to 650 pounds for 4-quarter paths and from 830 to 875 pounds for 5- and 6-quarter paths.

After deducting the revenue received from the sale of hide and offal by-products, the optimal solution of the mixed-integer programming model for 917,000 animals resulted in a total minimum cost of $604,135,885. When this total was divided by the total number of feeder calves, the cost per animal was $658.82. The cost per animal divided by the carcass weight of 614 pounds resulted in a carcass price of $1.074 per pound. In 1983, boxed beef cutout, equivalent to carcass price (Omaha, Nebraska basis), averaged $1.022 per pound (United States Department of Agriculture, 1983).

The optimal solution involved building one large slaughter plant and five feedlots in North Florida. The slaughter plant was operated at an annual capacity of 81.5 percent. Feedlots were operated at 91.7 percent capacity during the second, third, and fourth quarters and 92.7 percent capacity during the first quarter.

All animals were backgrounded in North Florida. These calves were backgrounded and fed primarily using 5-quarter weight-gain programs. Five-quarter paths constituted 77 percent of the optimal solution. Four-quarter paths were 5.8 percent and 6-quarter paths were 17.2 percent.

In the optimal solution with 917,000 calves, the average cost per animal was $658.82 or $1.074 per pound (carcass weight basis). The model was executed for different levels of supply to generate an average cost curve for the industry. Four levels of supply less than 917,000 calves (200,000; 400,000; 600,000; and 800,000) and three levels of supply greater than 917,000 (1,100,000; 1,300,000; and 1,500,000) were analyzed. Supply of less than 917,000 calves was distributed by region and quarter for supply and demand by the same methods used for the optimal solution. When the analysis was conducted for greater than 917,000 calves, it was assumed that weaned cattle were drawn from South Georgia and South Alabama, and all animals in excess of 917,000 were available for supply from the North Florida region. Furthermore, for demand levels exceeding 1.1 million head, surplus beef was assumed to be exported to nearby areas. Additional transportation costs for shipping animals and/or beef to and from out-of-state locations were not calculated. Table 3 shows the results of the eight computer executions. The level of supply; and number, size, and location of facilities, total cost, net of hide and offal value; average cost per head; and average cost per pound of boxed beef (carcass cutout price or average cost per head divided by 614 pounds carcass weight) are presented.

Results obtained from assuming availability of different levels of feeder calf supply indicate the respective average cost associated with each level. Minimum average cost occurred when 1.1 million calves were available for slaughter. Given that the large slaughter plant can process 1.125 million head annually, quantities above maximum slaughter plant capacity would cost more on the average than quantities just below max-

SUPPLY, FLORIDA, 1983

Level of supply (head)	Number, size, and location of facilities	Total cost[a]	Average cost per head	Average cost per pound of carcass beef
200,000	1 F1[b] – NFL[c]	$135,539,254	$677.70	$1.1037
	1 SSP[d] – NFL			
400,000	1 F1 – NFL	$270,434,490	$676.09	$1.1011
	2 F1 – SFL[e]			
	1 SSP – NFL			
	1 SSP – NFL			
600,000	3 F1 – NFL	$399,653,618	$666.09	$1.0848
	1 LSP[f] – NFL			
800,000	4 F1 – NFL	$528,528,391	$660.66	$1.0760
	1 LSP – NFL			
917,000	5 LSP – NFL	$604,135,885	$658.82	$1.0740
	1 LSP – NFL			
1,100,00	6 F1 – NFL	$720,763,093	$655.24	$1.0671
	1 LSP – NFL			
1,300,000	6 F1 – NFL	$853,583,187	$656.60	$1.0694
	2 F1 – SFL			
	1 LSP – NFL			
	1 SSP – SFL			
1,500,000	6 Fl – NFL	$985,283,126	$656.855	$1.0698
	6 F1 – SFL			
	1 LSP – NFL			
	1 LSP – SFL			

[a]Total cost adjusted for the value of hide and offal. [b]F1 = feedlot. [c]NFL = North Florida. [f]LSP = large slaughter plant. [d]SSP = small slaughter plant. [e]SFL = South Florida. [f]LSP = large slaughter plant.

imum capacity because quantities above maximum capacity required another slaughter plant facility. Average costs increased when a facility was not utilized at maximum capacity. Therefore, as feeder calf supply increased, the average costs decreased to a minimum when slaughter plant capacity was almost fully utilized and began to increase when another facility was required but was not operated near maximum capacity. The average cost per pound of boxed beef is plotted for each level of feeder calf supply in Figure 1.

MODEL SENSITIVITY

Sensitivity analysis was conducted on the model by varying the price of weaned calves and the price of corn. Calf prices were varied from $55 to $80 per hundredweight (cwt.). Seasonal calf prices were also considered in which calf prices ranged from $64/cwt. in quarter two to $57/cwt. in quarter four. Both seasonal calf prices and the level of calf prices had little effect on the model other than changing total system cost. All cattle were backgrounded and fed in North Florida, using primarily 5-quarter paths.

The price of corn was varied from $5 to $10 per hundredweight ($2.80/bu. to $5.60/bu.). At corn prices of $6/cwt. ($3.36/bu.) and lower, the optimal location of backgrounding and feedlot feeding switched to South Florida. Furthermore, 4-quarter paths predominated so that the number of feedlots increased from five to nine. This result is not surprising as the effect of decreasing the price of corn is to make feedlot feeding less expensive than growing cattle on forage. As the importance of backgrounding diminishes, the advantage that North Florida possesses in forage production diminishes.

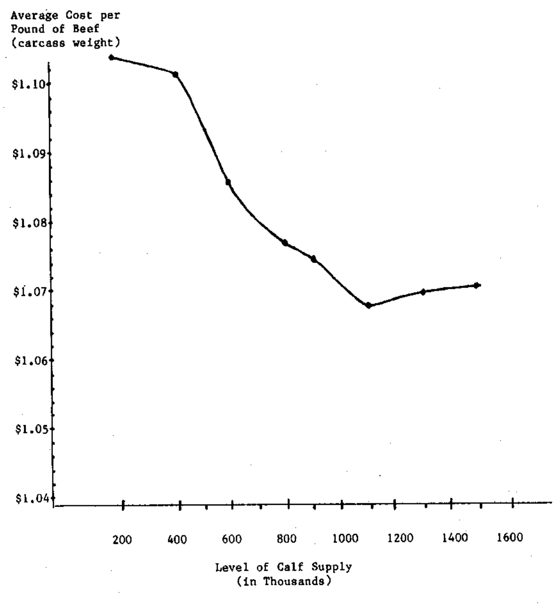

Figure 1. Projected Average Costs for Backgrounding, Feeding, and Slaughtering Cattle in Florida, 1983

CONCLUDING REMARKS

Results from the spatiotemporal model indicate that: (1) seasonal calf supplies can be redistributed to provide a continual supply of boxed beef; (2) considering feedlot and slaughter plant location possibilities, North Florida has a slight advantage over other regions of the State; and (3) the average cost of producing boxed beef in Florida is a U-shaped curve, with production levels at 1.1 million animals showing lowest average costs.

The results indicate that the Florida feeding and slaughtering industry can be competitive with the Midwest industry. The per pound price for carcass beef for the Midwest (Omaha) was $1.022 in 1983 (United States Department of Agriculture, 1983). In order to provide this beef to Florida consumers, additional transportation charges are incurred for transportation from the Midwest into Florida. Adding approximately 5.5 cents per pound for transportation back to Florida gives $1.077 as carcass weight price for beef transported to Florida. Thus, a Florida cattle feeding industry, producing more than 800,000 head annually, has an estimated cost structure which is comparable with the Midwest. With the Florida feedlot industry presently operating at levels below 200,000 head annually, the results indicate that costs of production are higher than national average costs.

In a study completed in 1976, Jordan concluded that calves could have been fed to slaughter weights within Florida and receive positive net returns in all quarters. This paper, analyzing 1982-83 data, concluded that the Florida cattle feeding and slaughtering industry can be competitive. The question arises as to why there has been little expansion in the Florida cattle feeding industry given these results. One possible explanation is that the fixed investment to construct the facilities required in the optimal solution of the model with 917,000 head is nearly $300 million.[6] Furthermore, the variable costs of the optimal solution are approximately $665 million. Considering the capital required to finance the system, other investment opportunities may exist which can produce greater returns. In addition, this study has assumed an idealized system where all stages of production fully cooperate so as to minimize overall system cost. In reality, the industry is comprised of several individual units, which may not choose to cooperate to the degree assumed.

A next step in the analysis would be extending the scope of the study to include the coastal plains area of Mississippi, Alabama, Georgia, and South Carolina. The methodology utilized in this study could be easily extended to consider more feeder calf supply points; backgrounding, feedlot, and slaughterplant locations; and demand points. Such a study would determine the optimal location for backgrounding and the optimal number and size of feedlots and slaughter plants for a southeastern cattle feeding industry and determine if it could viably compete with the existing cattle feeding and slaughtering industry.

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