INTEGRATION, RISK, AND SUPPLY RESPONSE: A SIMULATION AND LINEAR PROGRAMMING ANALYSIS OF AN EAST TEXAS COW-CALF PRODUCER

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The beef cattle industry in the Southeast is dominated by the cow-calf enterprise. Considerable discussion and research has addressed the economic potential of producers in the Southeast carrying calves longer on pasture rather than shipping them to other regions for stockering and backgrounding. Some have suggested that the region has a comparative advantage for increased grain and grass finishing of animals (Farris and Dietrich). At the firm level, the decision to retain calves must be based, among other things, on the availability of forage and on current and expected prices. The longer calves are kept, the greater the competition between cows and calves for available forage.

Prior economic analysis has focused on the beef-forage enterprise, but much of it has been based on imprecise physical modeling. Using a process-oriented approach that is concerned typically with understanding some process and not with the system of which the process is a part, most studies assume an exogenously-determined fertility level, death loss, and rates of gain in simulating the feed required to meet animal performance of a static herd (e.g., Shumway and Bentley; Gebremeskel and Shumway; Nix). A few have accounted for differences in steer and heifer growth rates (e.g., Whitson; Saez) and the impact of forage quality on voluntary intake (e.g., Whitson; Gebremeskel and Shumway; Saez). But the important effects of forage quality and availability on animal growth rate, condition, fertility level, and death loss have generally been overlooked (Sullivan; Stokes, Farris, and Cartwright are exceptions). Therefore, a systems approach that permits study of various components of the system, their simultaneous interactions and combined effects should present reality more accurately.

In addition, inadequate attention has been given to the effects of risk and length of the adjustment period on producers' decisions to modify enterprises and to change product supplies and input demands.

OBJECTIVES

This study addresses the above problems for cow-calf producers in East Texas. Economic models combining forage and cattle data are developed in a way that accurately describes biological growth and production efficiency. The specific objectives of the study are:

1. To simulate reliable input-output coefficients for beef calves, stockers, and slaughter cattle for a model farm in East Texas.
2. To determine the effects on beef production of (a) simultaneous changes in quality and quantity of forages and supplements, (b) different calving seasons, and (c) different marketing plans.
3. To analyze the effects of changes in product prices on the firm's supply of beef for alternative lengths of run.
4. To develop expected profit-risk efficient sets.

UNIT OF ANALYSIS AND ALTERNATIVES EXAMINED

A model farm consisting of 500 acres of cleared land suitable for tame forage production is analyzed. This farm, larger than average for the region, is selected for modeling purposes so that high-level management and available technology can be utilized efficiently. The farm is assumed to be self-sufficient in forage production under normal grazing conditions. No field crop alternatives are considered. Three tame forage alternatives common to the area (Coastal bermudagrass, Coastal bermudagrass overseeded with rye-ryegrass, and common bermudagrass overseeded with crimson clover-ryegrass); with four marketing plans (sell weaned calves, feeder calves,

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grain-finished slaughter cattle, or forage-finished slaughter cattle) are analyzed. In addition, two alternative calving seasons (spring and fall) and four levels of winter feed availability, varying from *ad lib.* feed supplies to heavy stress, are considered.[1] All beef enterprises are limited to those calves born on the farm. No calves are purchased. The firm is assumed to produce only Hereford-type cattle.

MODELS USED TO GENERATE INPUT-OUTPUT COEFFICIENTS

Biological Simulation Model

The first two objectives of the study concern development of reliable input-output coefficients for beef production under alternative physical and managerial conditions. Because not all required data are available from physical experiments, a very detailed biological herd simulation model (TAMU) is used to achieve these objectives. The TAMU model,[2] described in detail by Sanders, and Sanders and Cartwright (1979a, b), simulates beef cattle production for given (1) cattle genotypes for mature size, growth and maturing rate, and milk production; (2) feed conditions represented by quantity, quality, and monthly distribution of feedstuffs; and (3) management practices, including breeding age and season, weaning, replacement, culling, and sale policies. Animal performance is not prespecified, but is determined as the product of simultaneous interactions among these physical and managerial conditions. The model computes animal growth, weight, structural size and condition, cow fertility, milk production, and death loss by month of the year and animal age. Validation of the model has been undertaken over a wide range of variables (see Notter; Sullivan; Stokes, Farris, and Cartwright).

Acreage Model

Since the simulation model focuses on animal performance from a prespecified daily availability and quality of feed, several alternative feeding systems could produce the same animal performance. Thus, a second model (the acreage model) is used to select alternative forage and supplemental feed systems that provide comparable quantity and quality of feed for the simulated beef enterprise options. A linear programming model is used to determine for a given herd size the least cost combination of a single forage and supplemental feeds at alternative grain sorghum prices. It matches monthly forage production and supplementation with monthly requirements of the herd, given the simulated monthly intake requirements, forage production, and supplemental feed prices. Hay can be made from surplus forage in any of the four peak production months and is transferred to the deficit months of November, December, January, February (and March in case of Coastal bermudagrass). The option of purchasing supplements is included to account for the possibility that grown forages may not produce enough quantity or quality of forages to meet total requirements of the herd in a given month. A parametric routine that reduces grain sorghum prices from current to 60 percent of current prices in 10 percent increments is used to determine the optimal levels of supplementation at alternative grain prices. Grain sorghum prices above recent actual levels were not considered because no least cost ration included grain at actual prices.

DATA

Feed

Forage yield and quality data are based on experiments conducted at the Texas A&M University Agricultural Research and Extension Center at Overton (McCartor and Rouquette). High fertility levels were maintained, that is, annual fertilization rates in pounds of nitrogen, phosphorous, and potassium were 200-100-100 per acre for Coastal bermudagrass and for common bermudagrass overseeded with crimson clover-ryegrass, and 350-100-100 for Coastal bermudagrass overseeded with ryegrass. The forage dry matter yield data were collected frequently and generally over a period of four consecutive years (1970–73), using the cage-difference technique (Lineban). Quality data are based on laboratory analyses of leaf clippings during the years 1969–71. These average data are summarized in Table 1.

To allow for waste due to trampling and rejection, effective consumption is assumed to be 70 percent of the total dry matter available for grazing or 65 percent for hay feeding. Hay quality is also discounted by 10 percent for loss during storage and feeding.[3]

Forage production costs are based on Texas Agricultural Extension Service crop budgets and were adjusted to reflect the cost of high-level management associated with the experimental production levels (Angirasa, pp. 59–61). All costs reflect 1977 prices. Estimated total annual cost/acre is \$93.66, \$163.89, and \$118.18 for Coastal bermudagrass, Coastal bermudagrass overseeded with rye-ryegrass, and common bermudagrass overseeded with crimson clover-

[1] Availability is used in the sense that an animal has access to the amount of feed specified. *Ad lib.* means that the animal has unrestricted access to the feed at all times.
[2] This is the same biological simulation model used by Stokes, Farris, and Cartwright in their analysis of vertical integration and beef genotype.
[3] Forage utilization estimates were obtained from Texas agricultural extension specialists at Overton involved with evaluating production and use of forages in East Texas.

TABLE 1. Estimated Dry Matter (DM) Production, Digestibility (DIG) and Crude Protein (CP) Content of Various Forages

Period	Coastal Bermudagrass			Coastal Bermudagrass and Rye-Ryegrass			Common Bermudagrass and Crimson Clover-Ryegrass		
	DM	DIG	CP	DM	DIG	CP	DM	DIG	CP
	kg/acre	%	%	kg/acre	%	%	kg/acre	%	%
January	0	-	-	176	.750	.250	0	-	-
February	0	-	-	177	.750	.250	492	.807	.223
March	0	-	-	633	.700	.180	900	.750	.226
April	807	.723	.236	634	.650	.150	900	.731	.228
May	1913	.636	.159	1833	.630	.140	675	.655	.174
June	1913	.545	.122	1834	.545	.122	676	.546	.131
July	2057	.529	.109	2003	.529	.109	1115	.562	.133
August	2056	.545	.134	2003	.545	.149	1114	.628	.173
September	1008	.567	.149	1057	.567	.149	578	.628	.173
October	1007	.551	.130	1056	.551	.130	577	.632	.168
November	103	.446	.083	182	.750	.250	95	.396	.095
December	0	-	-	181	.750	.250	0	-	-

Source: M. M. McCartor and F. M. Rouquette, Texas A&M University Agricultural Research and Extension Center, Overton.

ryegrass, respectively. Costs treated as variable in the short-run models exclude labor and investment capital. Total variable cost/acre is $85.82, $149.51, and $111.35, respectively, for the same forages (Angirasa, pp. 154–58). Prices for purchased baled hay, grain sorghum, and cottonseed meal are $61.50/ton, $3.90/cwt., and $10.88/cwt., respectively (Texas Department of Agriculture, 1978). The cost of making hay on the farm is $23.28 per ton (TAES, 1977). A charge of $5.00/ton is added to the price of hay for feeding (Garner and Halbrook). A cost of $2.50/ton for feeding grain sorghum and cottonseed meal is assumed. An additional cost of $6.00/ton for flaking grain sorghum is added to its price. Waste of supplemental feed is assumed to be 15 percent for grain sorghum and 10 percent for cottonseed meal.

Livestock

Hereford-type cattle with mature structural size and peak milk potential of 480 kg. and 10 kg. per day, respectively, are analyzed in this study. The initial herd consists of 500 breeding cows. The two alternative calving seasons are January-March for spring calving and September-November for fall calving. For purposes of the biological simulation, 50 weaned heifers are kept annually to replace culled cows. Cows are culled after reaching 11 years of age or after remaining open for two years. In addition, a fraction of each age class is culled for injuries, sickness, and so on each year. The replacement heifers are first bred at 15 months of age. They are culled if they do not calve before they are 39 months old.

In this simulation, spring-born calves are weaned at seven months of age and fall-born calves are weaned when they are nine months old or on July 1, whichever is earlier. In the cow-calf enterprise, weaned calves and cull cows are sold at weaning. If not sold, weaned calves are retained as stockers on pasture and/or hay. The stocker phase terminates when stocker steers and stocker heifers reach 350 and 315 kg., respectively, and are either sold as good grade feeder calves or kept for on-farm finishing. Drylot-finishing and forage-finishing are alternative continuations of the stocker program. In drylot, cattle are fed a ration composed of 30 percent hay, 60 percent grain sorghum, and 10 percent cottonseed meal. Cattle in the forage-finishing program are kept on pasture and/or on hay and are not given any supplements. Both of these programs are terminated when finished steers reach a weight of 475 kg. and finished heifers, 430 kg. Drylot-finished steers and heifers are graded, respectively, as 50 percent choice and 50 percent good, and 100 percent good; whereas, forage-finished steers are graded 100 percent good and forage-finished heifers, 50 percent good and 50 percent standard.

Four levels of winter feed availability are analyzed. They range from *ad lib.* feeding to 40 percent of *ad lib.* feed requirements. The latter represents severe nutritional stress and weight loss.

A 15-year biological simulation is carried out on the initial herd of 500 cows to attain a stable base herd.[4] Only the fifteenth-year simulation is relevant to this study since the data used in the economic models are based on the presumption that we begin with a stable biological system. For every change made in the forage system and management practice, five additional years are simulated (except that Coastal bermudagrass, with 40 percent of *ad lib.* winter feed, requires a 10-year simulation) to restabilize the herd under new conditions. Since forages and their quantities and qualities vary, the number of cows in a stable herd also varies from one system to another.

Data Generated from the Biological Simulation Model

Table 2 reports the breeding herd size, calving rate, and percent of heifers kept as replacements in the simulated stable herd under alternative forage systems, levels of winter feed, and calving seasons. Total number of cows is greater with spring-calving than with fall-calving and is positively correlated with the amount of winter feed

[4] A stable herd is defined as a herd whose composition does not change from one year to another, given a particular management practice. Also, it produces the same amount of liveweight sold per breeding cow every year.

TABLE 2. Total Number of Breeding Cows, Calving Percent and Percent of Heifers Kept as Replacements in the Simulated Stable Herd Under Alternative Production Systems with 50 Replacement Heifers Annually

Forage	Hay Fed	Calving Season					
		Spring			Fall		
		Number of Breeding Cows	Calving Percentage	Percent of Heifers Retained	Number of Breeding Cows	Calving Percentage	Percent of Heifers Retained
Coastal Bermudagrass	(ad lib.)	275	92	42	229	87	53
	.8(ad lib.)	276	88	43	229	84	55
	.6(ad lib.)	274	74	53	221	73	65
	.4(ad lib.)	254	58	84	212	64	79
Coastal Bermudagrass	(ad lib.)	276	90	43	229	86	54
Overseeded With	.8(ad lib.)	277	87	44	229	82	56
Rye-Ryegrass	.6(ad lib.)	275	75	51	221	74	64
	.4(ad lib.)	258	61	74	210	66	76
Common Bermudagrass	(ad lib.)	272	97	40	226	97	48
Overseeded With	.8(ad lib.)	272	97	40	227	96	48
Crimson Clover-	.6(ad lib.)	274	95	41	229	90	51
Ryegrass	.4(ad lib.)	276	83	46	226	79	59

provided. Since the number of replacement heifers kept is constant for all production alternatives, the proportionate replacement rate and calving percentage are inversely correlated.

Calves are weaned by age and in different months of the year. Their average weights vary with calving season, forage system, and winter hay feeding level (see Table 3). Under all management practices, calves born in the fall are heavier at weaning than those born in the spring: this difference results primarily from the older age of fall calves at weaning.

Livestock Budgets

Average monthly prices for the period 1958–77 were obtained from the Fort Worth market for individual cattle classes and grades. All price series are inflated to 1977, using the annual index of prices paid for factors of production (USDA, 1975, 1977). As there was no significant trend, the average of each inflated monthly price series is used as the 1977 "normal" price. Estimated cattle production costs, exclusive of forage production costs, are adapted from the Texas Agricultural Extension Service livestock budgets for the region and from Dean and Long (Angirasa, pp. 159–62). Forage and feed costs are determined separately by the acreage model for each forage and livestock activity considered. These costs are entered separately into the economic models because they vary with each livestock production activity.

Adjustments in marketing costs are made as follows: a commission of 2.5 percent of gross value plus $0.20/cwt. yardage is charged for each animal sold (Hernandez and Jose). Costs of salt and minerals, labor, and interest on operating capital are adjusted for actual length of the period required to complete a particular livestock activity. If the producer carries calves through the stocker program or further, an interest charge on the value of weaned calves not sold is added as an opportunity cost on deferred income. Estimated cost per cow unit of the cow-calf, cow stocker, cow-drylot-finished, and cow-forage-finished options are, respectively, $106.16, $177.50, $241.40, and $269.05.

TABLE 3. Average Weaning Weights of Steers and Heifers Under Alternative Production Systems

Calving Season	Hay Fed	Forage					
		Coastal Bermudagrass		Coastal Bermuda-Rye-Ryegrass		Common Bermuda-Crimson Clover-Ryegrass	
		Steers	Heifers	Steers	Heifers	Steers	Heifers
		(kg)					
Spring	(ad lib.)	203	178	202	177	212	187
	.8(ad lib.)	200	175	200	175	211	185
	.6(ad lib.)	193	168	195	169	207	182
	.4(ad lib.)	172	153	185	161	200	174
Fall	(ad lib.)	237	205	238	205	250	218
	.8(ad lib.)	235	202	236	203	247	214
	.6(ad lib.)	222	191	230	197	241	207
	.4(ad lib.)	174	158	199	176	236	202

METHOD OF ANALYSIS

A conventional linear programming (LP) profit-maximizing model is used to analyze the firm's behavior under certainty. Both long-run and short-run situations are considered.

Long-Run LP Model

The long-run LP model maximizes total net revenue to land and management, subject only to the land restraint. Herd size is not treated as a fixed factor. The beef production alternatives include 3 forage systems, 4 alternative marketing plans, 2 calving seasons, and 4 levels of winter feed availability, a total of 96 livestock production activities. In addition, 25 more livestock production activities are included when supplemental grain is fed. The farm is assumed to be self-sufficient in production of forage and hay; therefore, no provision is made for buying or selling hay. Only grain sorghum and cottonseed meal are purchased, either as part of the ration for drylot-finished cattle or to supplement low-quality forages in selected months. All dry matter produced in a given year is assumed utilized or wasted. Transfer of dry matter from one year to the next is not allowed.

Short-Run LP Model

The short-run LP model differs from the long-run model in specification of the objective function, constraints on resource vectors, and treatment of fixed costs. In the long-run LP model, all resources except land are variable, and thus there are no fixed costs involved. In the short-run, some additional resources cannot be varied; therefore, the cost of those fixed resources is treated separately from variable costs. The objective in the short-run is to maximize net returns to land, labor, fixed capital, and management; thus, costs of labor and fixed capital are excluded. Constraints on the amount of labor and capital available for establishment of perennial forages and machinery and livestock investment are imposed at long-run optimal solution levels. It is further assumed that the producer has no flexibility in the production of alternative forage systems in the short-run. The only forage system included in this model is the one that entered the optimal solution of the long-run model. Choices assumed available in the short-run include calving season, beef enterprise (i.e., cow-calf, cow-stocker, cow drylot-finished, and cow forage-finished beef production alternatives), and level of hay feeding during winter without outside purchase of hay. In all, the model has 40 alternative livestock production activities. Eight of these include supplemental grain feeding.

MOTAD Model

To analyze the firm's short-run behavior under uncertainty, risk is incorporated into the LP model through an approximated E-V utility formulation (Hazell and Scandizzo). In this formulation, farmers are assumed to base their production decisions on expected income, less the subjective cost of risk associated with the income-producing activity. Hazell and Scandizzo have shown that LP can be used instead of quadratic programming (QP) for this problem, if risk is defined in terms of total absolute deviations (A), rather then variance (V) in expected profits. Thompson and Hazell have further shown that the efficient set of farm plans generated using the "minimization of total absolute deviations" (MOTAD) model not only corresponds closely with the E-V efficient set, but may be superior for skewed distributions. Since hay is often purchased (sold) when feed requirements exceed (fall short of) supplies, and since there are significant differences in net sale and purchase prices of harvested forages, the net return distribution for a calf producer may tend to be skewed (Gebremeskel and Shumway). Since all other assumptions of the QP and MOTAD models are comparable, risk-constrained LP (MOTAD) is used in this economic analysis under risk. In order to surmount the problem of inadequate historical pasture price data, the form of the model follows Gebremeskel and Shumway by measuring forage yield deviations in two-month periods, and by permitting purchase and sale of hay to produce a constant quantity of beef each year. This MOTAD model is developed by adding the risk component to the short-run LP model. Additional columns and rows are required to measure risks associated with forage yield, beef price, and supplemental feed price variability. The objective function is also modified to account for the skewed nature of the net returns distribution. Thus, the profit-maximizing solution from this model will give a lower expected profit than the profit implied by the certainty model. This model reports the mean net returns, while the certainty model reports the median. The approximated E-V efficient set is derived by parameterizing the restraint on total absolute deviations in net returns, while maximizing net returns. The firm is assumed to be self-sufficient both in pasture and hay production during the mean period.

RESULTS OF ANALYSIS

Long-Run LP Model

Table 4 presents the optimal solution of the long-run economic model. The optimal livestock enterprise includes fall calving and selling weaned calves. Although computed gross returns/acre are higher for some other activities, for example, the stocker enterprise, these enterprises are not as profitable as the cow-calf enterprise because of higher non-land costs and labor requirements.

Ad lib. feeding of hay during the winter is most profitable. Feed stress lowers not only the fertility rate of the cows, but also weaning weights of the calves. Consequently, gross revenue per head decreases proportionally more than total cost because of feeding less hay.

The optimal forage system is common bermudagrass overseeded with crimson clover-ryegrass. Although it produces less dry matter, digestibility of common bermudagrass overseeded with crimson clover-ryegrass is higher than that of the other two forages in most months. This higher-quality forage increases the biological performance of the herd, more than offsets the effects of lower yields, and thus makes this forage economically more efficient than the other two with higher dry matter yields.

The fall calving season is preferred economically, even though the spring calving season has advantages such as higher stocking rates and lower hay requirements. Fall calves are much heavier on average at weaning than spring calves. The difference in net revenue from selling heavier fall calves is sufficient to more than offset the advantages of spring calving.

To derive the long-run beef supply response, proportionate parametric changes in sale prices of all beef components were made and solutions obtained at 10 percent increments from 70 to 170 percent of the 1977 "normal" prices. Table 5 reports the corresponding total beef supply and livestock and forage activities for the various levels of beef prices. At 20-percent higher prices, the stocker program with spring calving replaces the fall calving cow-calf enterprise. These production options continue to be optimal until prices are increased by 70 percent, at which level, drylot-finishing becomes the most profitable. This shift from the stocker program to drylot-finishing occurs because proportionate increases in all product prices increase net revenue from heavier cattle proportionately more than from lighter cattle. At modest price increases, the cow herd is increased by 9 percent, and calves are retained through the stocker phase without altering the forage system by shifting to spring calving and putting substantial winter feed stress on cows. At 40 percent higher beef prices,

TABLE 4. Optimal Solution, Long-run Economic Model

Activity	Unit	Level
Net returns to land and management	$	2,631
Cow-calf (fall calving and ad lib. feeding of hay during winter)	head	517
Common bermudagrass overseeded with crimson clover-ryegrass	acres	500
Labor	hours	7,711
Land	acres	500
Hay	tons	954
Gasoline	gallons	8,451
Diesel	gallons	5,529
Natural gas	cubic feet	3,727,176
Annual non-land expenses	$	117,253

TABLE 5. Effects of Simultaneous Changes in all Beef Prices on Long-run Beef Supply and Optimum Production Systems

Price Level (% of 1977 Prices)	Total Beef Supply	Beef Supply Per Acre	Total Revenue	Livestock Activity	Calving Season	Number of Cows	Forage Activity[a]	Hay Fed
	(kg)	(kg)	($)			(head)		
90	0	0	0			0		
100	136,568	273	2,631	Cow-calf	Fall	517	CM	(ad lib.)
110	136,568	273	16,817	Cow-calf	Fall	517	CM	(ad lib.)
120	177,382	355	32,599	Cow-stocker	Spring	562	CM	.6(ad lib.)
130	179,930	360	50,860	Cow-stocker	Spring	571	CM[b]	.6(ad lib.)
140	223,104	446	71,427	Cow-stocker	Spring	748	CB	(ad lib.)
150	223,104	446	94,231	Cow-stocker	Spring	748	CB	(ad lib.)
160	228,050	456	117,132	Cow-stocker	Spring	765	CB[b]	(ad lib.)
170	282,160	564	141,525	Cow-drylot-finished	Spring	765	CB[b]	(ad lib.)

[a] CM = Common bermudagrass overseeded with crimson clover-ryegrass, CB = Coastal bermudagrass.
[b] Supplemented.

Coastal bermudagrass becomes the optimal forage. Its lower quality and higher fertilizer costs are more than offset by its very high yields when beef prices are high. Supplementation is economical at selected higher prices. The long-run beef supply elasticity for this simulated firm, estimated by linear regression on these price and quantity data in logarithms, is 1.32. Increases of at least 10 and 20 percent in relative feeder calf or finished cattle prices, respectively, make the stocker or finishing enterprises competitive with calf production. Selection of the drylot-finishing activity decreases the number of cows slightly, despite a decrease in winter feed from *ad lib.* to 80 percent of *ad lib.* and changing the calving season from fall to spring. This decrease in the number of cows results from increased hay requirements per cow. But total quantity of liveweight sold increases substantially from 136,568 kg. to 209,218 kg. because of the heavier weight of the drylot-finished cattle. Similar shifts occur in the forage-finishing case.

Short-Run LP Model

Since all restrictions on land, labor, annual charges on non-land investment and forage system in the short-run economic model are at the level of the initial optimal solution of the long-run economic model, the initial optimal solutions of both models are exactly the same, except for the value of the objective function. These values differ because in the short-run model, net returns to labor and fixed capital in addition to land and management are computed. Total net returns are $50,253 versus $2,631 in the long-run model.

To evaluate short-run beef supply response, prices of all beef components are simultaneously varied in 10-percent increments from 60 percent to 150 percent of the current prices. At prices below 80 percent of the 1977 "normal" prices, the optimal solution includes the cow-stocker enterprise with 298 cows calving in the spring, common bermudagrass overseeded with crimson clover-ryegrass, and 60 percent of *ad lib.* hay feeding. At prices 80 percent and above, the solution changes to the short-run initial optimal solution. This change results in a 45-percent increase in the total supply of beef, from 93,846 kg. to 136,568 kg. The short-run arc elasticity of beef supply for this firm is estimated to be 0.43 (almost ⅓ the estimated long-run elasticity). This elasticity is about three times as great as the short-run U.S. beef supply elasticity estimated by Ospina and Shumway (p. 53). Although elasticity magnitudes are not easily comparable because of modeling differences, firm-level supply elasticity is expected to be higher than industry-level supply elasticity because changes in output by a competitive firm have no impact on prices.

The beef price-marketing plan relationships in the short-run economic model are opposite to those of the long-run model, thus the firm-level higher short-run elasticity is not the result of keeping calves longer on the farm. In the long-run model, as the price increases, marketing plans change from cow-calf to stocker and then to drylot-finishing. In this model, the stocker option is profitable at lower prices and the cow-calf at higher prices. The reasons for this difference are: (1) the objective function in the short-run model is not proportional to that in the long-run model; (2) there are more constraints in the short-run model; and (3) the binding constraints differ. Consequently, when all prices are decreased to 60 percent, stocker activities are the only ones with positive short-run net returns. But at 80 percent of the "normal" prices, the cow-calf activities become more profitable. Even though net returns per head from these activities are less than cow-stocker activities, their increased stocking rates make them more profitable on a per-acre basis.

With all other prices at 1977 "normal" levels, a 20-percent increase in feeder calf prices causes a complete change from the cow-calf to the cow-stocker enterprise. Since the fixed cost of raising a stocker is considerably more than raising a calf, fewer cow units are carried and less total beef is produced because of limited capital when the stocker enterprise becomes profitable. Consequently, total beef supply decreases by 28 percent. Similarly, at 30-percent higher relative slaughter cattle prices, on-farm finishing programs become profitable. Beef supply decreases more than a third when the marketing plan switches from selling weaned calves to selling either drylot-finished or forage-finished slaughter cattle.

Short-Run MOTAD Model

In the long-run analysis under certainty, all labor, including operator's labor, was charged at the same rate. But given this assumption, non-positive expected returns to land and management were obtained in the risk analysis. The reason for this non-positive solution lies in the inclusion of hay purchase and sale activities in the MOTAD model. To produce the same amount of beef in each of the observation years, hay must be purchased and/or sold. Because hay purchase and sale prices are not equal, the net return distribution is skewed. Although the median net return for each activity is the same as in the certainty model, mean net return is lower. This skewness results in lower expected VMP of the resources. Because the VMP of labor was lower than the hired wage rate, no labor was used, and, thus, non-positive expected net returns were realized.

Consequently, the risk analysis is limited to the short-run only. To find the appropriate constraints on land, labor, and capital to cover non-land investment annual charges, an intermediate-run MOTAD model with 2,000 hours of given operator labor was run. Levels of activities in its optimal solution were used as constraints in the short-run model (land, labor, and capital are restricted at 102 acres, 2,000 hours, and $6,367, respectively). Choice of forages is also restricted. Since Coastal bermudagrass overseeded with rye-ryegrass does not enter any of the farm plans of the intermediate-run risk model, it is not considered an option in the short-run model.

Table 6 represents selected farm organizations in the approximated E-V efficient set. There are 9 farm plans representing a wide range in expected net returns and mean absolute deviations. The most profitable plan gives almost twice the expected net returns of the least profitable plan. But higher expected net returns are obtainable only with considerably higher levels of risk.

The level of uncertainty decreases as the proportion of stockers produced increases, suggesting that limited vertical integration of livestock production may decrease risk. Higher proportions of overseeded bermudagrass accompany the higher proportions of stockers in order to provide some winter pasture and higher-quality feed in most other seasons.

CONCLUSIONS

This economic analysis of a hypothetical cow-calf producer in East Texas was based on a unique linkage of three basic (sets of) models, one biological and two economic. A biological simulation of beef herd performance generated a large number of input-output coefficients for various management options. A linear programming acreage model was used to determine, at alternative feed prices, the least-cost sources of feed to provide the quantity and quality of feed assumed in the biological simulation. Finally, a set of economic models was applied to determine profit-maximizing management choices in the short- and long-run under certainty, and in the short-run when uncertainties were considered. The certainty models were also used to examine firm-level beef supply response, and the uncertainty model was used to examine expected net return and risk tradeoffs.

A few general conclusions based on this study's empirical findings are noteworthy. The cow-calf enterprise that is so common in the Southeast dominates the profit-maximizing solutions, but only within a narrow price band. Small relative increases in feeder calf or slaughter cattle prices make the stocker or finishing enterprises profitable. Producers who are moderately averse to risk also tend to partially integrate through the stocker phase.

The fall calving season is always preferred when calves are marketed at weaning. The value of the extra weight gain of fall-born calves more than offsets the extra cost of winter feed. Spring calving is preferred economically when calves are retained past weaning.

TABLE 6. Selected Farm Organizations in the Approximated E-V Efficient Set

Farm Plan	Livestock Activity	Calving Season	Expected Net Returns	Mean Absolute Deviation in Net Returns	Forages: Coastal Bermudagrass	Forages: Common Bermudagrass Overseeded With Crimson Clover-Ryegrass	Total Land Used	Number of Cows	Beef Prod. /Acre
			($)	($)	(Acres)	(Acres)	(Acres)	(Head)	(kg.)
1	Cow-Calf	Fall	9,124	5,681	31	71	102	127	307
2	Cow-Calf	Fall	8,789	4,845	31	53	84	87	334
	Cow-Stocker	Spring						23	
3	Cow-Calf	Fall	8,411	4,084	31	38	69	53	367
	Cow-Stocker	Spring						42	
4	Cow-Calf	Fall	8,172	3,800	31	38	69	54	369
	Cow-Stocker	Spring						42	
5	Cow-Calf	Fall	7,615	3,156	31	27	58	10	398
	Cow-Stocker	Spring						67	
6	Cow-Stocker	Spring	7,398	2,911	27	29	56	73	399
7	Cow-Stocker	Spring	6,878	2,649	18	41	59	73	383
8	Cow-Stocker	Spring	6,330	2,308	11	51	62	73	370
9	Cow-Stocker	Spring	5,472	1,784	0	66	66	74	355

Winter annuals overseeded on bermudagrass are important in the optimal forage systems over most of the range of prices, behavioral objectives, and lengths of run considered. They increase not only dry matter yield, but quality, also. The single species forage becomes economical only at high product prices, when the very high yield of Coastal bermudagrass more than offsets its lower quality.

At "normal" beef prices, stressing cattle during winter is not economically profitable. Total gross revenue for any given livestock enterprise-forage system is inversely related to level of winter feed stress. This relationship occurs primarily because of two reasons. First, fertility rate decreases with an increase in nutritional stress, resulting in a reduced total number of calves born and increasing the number of heifers that must be kept for replacement; therefore, fewer calves are sold. Secondly, more cows remain open and, thus, more must be culled. Therefore, the proportion of cull cows in the total liveweight sale increases and the average price received is reduced.

A word of caution is also warranted concerning the empirical findings of this study. These results are based on the analysis of a large farm, high-level management, and Hereford-type cattle at one location only. Given its limited resources, a small farm may or may not find these management practices equally profitable. Since performance levels and nutrient requirements vary with different breeds, analysis of exotic breeds or of different locations may give different results. Therefore, any extrapolation from the results of this study warrants consideration of the model and its assumptions.

Because profit-maximizing LP models of beef production typically ignore the likelihood of a skewed net returns distribution, LP results tend to overestimate mean net returns. These results may provide estimates of the median net returns possible, but the more highly skewed the distribution, the further that estimate is from the mean. Consequently, recommendations to beef producers based on conventional LP analyses should include specification of these additional limitations.

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